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DEVELOPMENT OF A DYNAMIC SIMULATION MODEL FOR PLANNING PHYSICAL DISTRIBUTION SYSTEMS: THE FINANCIAL IMPLICATIONS OF WAREHOUSING DECISIONS

Thesis for the Degree of Ph. D.

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MICHAEL LANCE LAWRENCE

This is to certify that the

thesis entitled

Development of a Dynamic Simulation Model for Planning Physical Distribution Systems: The Financial Implications of Warehousing Decisions

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ABSTRACT

DEVELOPMENT OF A DYNAMIC SIMULATION MODEL FOR PLANNING PHYSICAL DISTRIBUTION SYSTEMS: THE FINANCIAL IMPLICATIONS OF WAREHOUSING DECISIONS

By

Michael Lance Lawrence

This thesis is based on a dynamic computer simulation of a large scale physical distribution system developed by a faculty and doctoral student research team under a Michigan State University industrial research grant. The project and model name is Long-Range Environmental Planning Simulator (LREPS) and the model was built to experimentally study the behavior of physical distribution systems.

The specific purpose of this thesis was to use the LREPS model to study the effects of distribution warehousing decisions on financial variables.

To accomplish this purpose, four steps were taken:

1. The researcher participated on the LREPS research team to build the computer simulation model upon which experimentation and sensitivity analysis could be performed to study the total impact of five alternative warehousing decisions on

financial variables in modeled companies from the health cares products and appliances wholesale industries.

2. The experimentation and sensitivity analysis were performed, with only one variable exogenously changed per experiment and the resultant changes in financial variables were observed.
3. Those financial variables which were "significantly" affected under varying economic conditions in each of the two industries by the alternative warehousing decisions were identified from the results of the experimentation.
4. The results were studied for general relationships which would help explain the interaction between warehousing decisions and changes in financial variables.

There were several results which should help financial management to better anticipate the effects of warehousing decisions and aid distribution managers in making correct warehousing decisions. Further, experimental analysis yielded several by-products of interest to finance. The findings of primary interest are the effects on financial variables of the addition of a warehouse and of the shift from private to public warehousing.

Every experiment which involved adding a second warehouse resulted in a drop in the average level of accounts payable of 13 to 21 percent. The drop in accounts payable in every case resulted in a decline in the average cash balance; an increase in short term debt; and a drop in the debt service coverage ratio and net earnings, which reflected the fact that interest bearing debt replaced a cost free source of financing. The major implication of this finding is that managers contemplating an additional warehouse should consider the adverse effects which such a decision will have on the financial structure and liquidity position of the firm and include these considerations in the decision-making framework.

The addition of a second warehouse caused a substantial rise in inventories in the health cares company but only a small increase in the appliances company. However, the change in accounts payable was relatively the same between the two industries. Resultantly, the strain on the financial structure and liquidity position caused by the drop in accounts payable is aggravated in the health cares company by the substantial rise in the level of inventories. That this rise in inventories was not financed by a rise in accounts payable led to the following analysis of the relationship between warehousing additions, inventories, and accounts payable:

1. Increases in safety inventories are financed from cash or some other source, not from accounts payable.
2. Increases in re-order inventories which occur because of the addition of a second warehouse result in an increase in accounts payable at the beginning of each re-order cycle and an increase in the

length of the re-order cycle. The net result of the two effects is that the average level of accounts payable is left unchanged, meaning that the increased inventories are not financed through accounts payable.

3. The average cost of carrying inventories shifts as the result of the addition of a warehouse if the addition causes re-order inventories to increase.

Each experiment involving a change from private to public warehousing resulted in a drop in the level of sales required to break even on net income, a drop in the variability of earnings and cash flows, and an improvement in the liquidity and debt service coverage ratios. These changes individually and in total reflect a much improved defensive posture against market and economic reversals if the firm uses public warehousing.

Furthermore, replacing a private with a public warehouse resulted in an increase in accounts payable because the expenses incurred through the use of a public warehouse all give rise to payables. Many private warehousing expenses do not. These increased payables are a small but permanent source of financing and are another reason that public warehousing puts less strain on the liquidity position of the firm than private warehousing.

The research by-products of interest to finance center on the experimental verification that short term loans have a strong tendency to decline when sales turn downward and to build up when sales rise. The specific observations are:

1. The inclusion of short term loans in the $\frac{\text{Debt}}{\text{Equity}}$ ratio will cause the ratio to give false danger signals during upturns.
2. The debt service coverage ratio may cause undue alarm if interest or re-payments on short term loans are included in its construction.
3. The acid test ratio is a signal of a poor liquid position if sales turn up, not a danger signal of the succeptibility of the firms liquidity position to sales reversals.

A major limitation of this research is that the model firms are small, based on two industries, and limited to one or two warehouse systems. Another is that the research is based on wholesale companies and generalization of some of the findings to manufacturing firms would be dangerous. The need for more sophisticated output monitoring - model adjustment feedback mechanisms is a third major limitation. Of necessity, the range of possible future economic and market conditions under which the decision alternatives were tested was also quite limited. Future research to rectify each of these limitations and test the consistency of the findings is in order.

DEVELOPMENT OF A DYNAMIC SIMULATION MODEL FOR PLANNING PHYSICAL DISTRIBUTION SYSTEMS: THE FINANCIAL IMPLICATIONS OF WAREHOUSING DECISIONS

By

Michael Lance Lawrence

A THESIS

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DOCTOR OF PHILOSOPHY

Department of Accounting and Finance

To my loving wife, Janis

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CHAPTER I

INTRODUCTION

Correct business decisions require explicit consideration of the effect which the decision will have on all of the activity centers (functions) of the organization. Traditionally, this has not been possible because of the poor quality of information concerning the interaction of functional areas and because of the limitations of quantitative decision techniques. Thus, firms typically have been divided into "manageable" functions with the implicit understanding that each functional manager should subjectively consider the effects of his decisions on the other functional areas of the firm.

The advent of electronic data processing, improvements in computer technology, and advances in the management sciences have substantially increased the number of variables which can be included in quantitative decision analysis.[1] Recently, interest in the interaction of the functional areas within the firm has grown rapidly. The application of systems analysis as a tool of decision making is a logical outgrowth of these recent developments.

Systems analysis can be considered an extension of the role of management decision making.[2] In a general sense, the systems concept involves viewing a united system of objects as a hierarchy of ranked sub-systems integrated into a single system.[3] Johnson, Katz, and Rosenzweig define the concept of the business firm as a system in this way:[4]

> A business firm is an integrated whole where each system, sub-system and supporting sub-system is associated with the total operation. Its structure therefore is created by hundreds of systems arranged in hierarchical order. The output of the smallest system becomes input for the next larger system which in turn furnishes input for a higher level.

The systems concept contends that optimum decisions cannot be made on the basis of individual functions because of the complex inter-relationships between the functions. Decisions in the firm should be concerned with the final outcome, not with individual phenomena along the way.[5] Optimization of the objective of the firm is often frustrated by optimizing individual functions.

Computer simulation is an operations research tool which facilitates systems analysis. The word simulation has been used in many different contexts to mean many different things. For the purposes of this research, it is defined as follows:

> Simulation is an iterative operations research tool which involves building a model to imitate the operation of a business system and then performing experiments with that model in order to generate answers to specific questions, provide information, and study the behavior of the system. The model itself is usually written in mathematical form and may contain either stochastic or deterministic variables, or both.

The ultimate tool for management decision making from the systems perspective would be a simulator of the total firm and simulating the major sub-systems of the firm is a logical first step toward reaching this ultimate goal.

A major sub-system of the firm which lends itself most readily to systems analysis is physical distribution, which has been defined by the National Council of Physical Distribution Management as follows:[6]

> A term employed in manufacturing and commerce to describe the broad range of activities concerned with efficient movement of finished products from the end of the production line to the consumer, and in some cases includes the movement of raw materials from the source of supply to the beginning of the production line. These activities include freight transportation, warehousing, material handling, protective packaging, inventory control, plant and warehouse site selection, order processing, market forecasting and customer service.

The performance of the physical distribution system (and its management) is measured by two standards: (1) level of customer service and (2) the total cost required to attain that level.[7] Typically, service and cost move directly but non-proportionately with each other. A firm might find that the cost of achieving a service level of 95% of the "optimal" level is double the cost of a 90% service level. The design and management of physical distribution systems involves striking the best overall balance between service and total cost. The best overall system will seldom if ever be service maximizing or cost minimizing. Rather, it will attain reasonable service levels at a realistic total cost.[8]

Determining this optimum balance is complicated by inverse cost relationships between the activity centers of the system (transportation, inventory, warehousing, communications, and unitization.) Cost savings adjustments in one of these centers often causes cost increases in one or more of the other activity centers. Thus, finding the total cost to compare to the potential service level of a system design alternative is an involved process. The design process is further complicated by ever-changing environmental conditions. The optimum system for any given time period will likely not be optimum in successive time periods. Thus, the flexibility of alternative systems to adjust to future change is a third objective which complicates the problem of designing physical distribution systems.

In its proper perspective, then, physical distribution system design must primarily be concerned with the centralized and integrated management of the movements system in such a way that decisions are based not on individual objectives and functions but rather on the total performance of the system over a prescribed planning period. Prior to the development of systems simulation, planning from such a viewpoint was largely a discussional art rather than a quantitative decision science.

A dynamic computer simulation of a large scale physical distribution system which will be used for planning and designing purposes from a systems perspective has been developed by a team of faculty and doctoral candidates under a Michigan State University industrial research grant. The project and model name is Long-Range Environmental Planning Simulator (LREPS) and the research has two major objectives:

1. To conceptualize, construct, and computerize a dynamic simulation of a large scale physical distribution system.

2. To use the computerized model in experimentation to examine questions about and study the behavior of physical distribution systems.

The first objective has been achieved, as LREPS is operational and performing according to specification. The research monograph Dynamic Simulation of Physical Distribution Systems explains the conceptualization of LREPS and offers a general overview of the project.[9] The development of the mathematical model is explained in a doctoral dissertation entitled Development of a Dynamic Simulation Model for Planning Physical Distribution Systems: Formulation of the Mathematical Model.[10] The computerization of the math model is reported in a doctoral dissertation entitled Development of a Dynamic Simulation Model for Planning Physical Distribution Systems: Formulation of the Computer Model.[11]

The second goal of the project has been partially achieved. A recently completed doctoral dissertation entitled Development of a Dynamic Simulation Model for Planning Physical Distribution Systems: Validation of the Operational Model has validated the design and output of the model for scientific experimentation.[12] A dissertation currently in progress considers the statistical design ramifications of experimentation with the model.[13] This dissertation involves modifying the basic model in order to study the effect which distribution warehousing desicions have on another major sub-system of the firm: the finance sub-system.

The Basic LREPS Model

The development and conceptualization of the basic LREPS model are presented in detail in the above mentioned monograph[14] and in the first two dissertations from the project.[15,16] The following summary comments concerning the basic model are presented to lend continuity to this volume.

General Framework

The basic LREPS model imitates the operations of the modeled physical distribution system from the end of the manufacturing activity to the transfer of product to customers. The five major components of the physical distribution system which are included are as follows:

1. The fixed facility system, which is concerned with when, where, and in what size and form warehouses should be included in the total distribution system.

2. Inventory, which is concerned with where, when, and in what volumes finished goods should be held in the system.

3. Transportation, which is concerned with the movement, and the form and timing of movement, into and out of the fixed facilities.

4. Throughput (or unitization), which is concerned with movement of goods within the fixed facility and with the physical picking and preparation of customer orders. As such, it is also concerned with the internal management of fixed facilities.

5. Communication, which is concerned with the flow of orders and other information between the firm and its customers and between various stages of the firm.

There are three major stages of the modeled system at which activities occur, originate, and/or terminate. The three stages are presented in graphical form in Figure 1.1. The type of distribution system they represent is summarized in Figure 1.2. These stages are:

1. The Manufacturing Control Center (MCC) and its associated Replenishment Center (RC) at which products are manufactured and stored. Each MCC produces only a partial line of products and each product is manufactured at no more than two MCC's.

2. The Distribution Center (DC) which is an intermediate fixed facility between the RC and the marketplace.

3. The demand unit (DU) which can by design be either an individual customer or a group of geographically agglomerated customers.

The second (DC) stage requires further discussion, as there are four different possible forms of distribution centers. A primary distribution center (PDC) is one which handles all products and possesses a design capability of serving all DU's within a defined region of the total market area. It differs from the second type, the Remote Distribution Center - Full Line (RDC-F), in that the RDC-F

PHYSICAL DISTRIBUTION SYSTEM

MANUFACTURING CONTROL CENTERS (MCC)
MULTI-LOCATION
EACH PRODUCES LESS THAN FULL LINE
EACH PRODUCT IS PRODUCED AT MORE THAN ONE MCC

REPLENISHMENT CENTERS(RC)
MULTI-LOCATION
EACH STOCKS ALL PRODUCTS MANUFACTURED AT MCC

DISTRIBUTION CENTERS (PDC) (RDC)
MULTI-LOCATION
FULL LINE - PRIMARY DC (PDC)
FULL OR PARTIAL LINE - REMOTE DC (RDC)

CONSOLIDATED SHIPPING POINT (CSP)

TRANSPORTATION
COMMON CARRIER - TRUCK, RAIL, AIR

INVENTORY
STOCKS AT RC, PDC, RDC

COMMUNICATIONS
COMPUTER, TELETYPE, MAIL, TELEPHONE

UNITIZATION
AUTOMATED OR MANUAL

PRODUCT PROFILE

MULTI-PRODUCT LINE
KEY PRODUCT GROUPS FOR EACH CUSTOMER CLASS OF TRADE

MARKET PROFILE

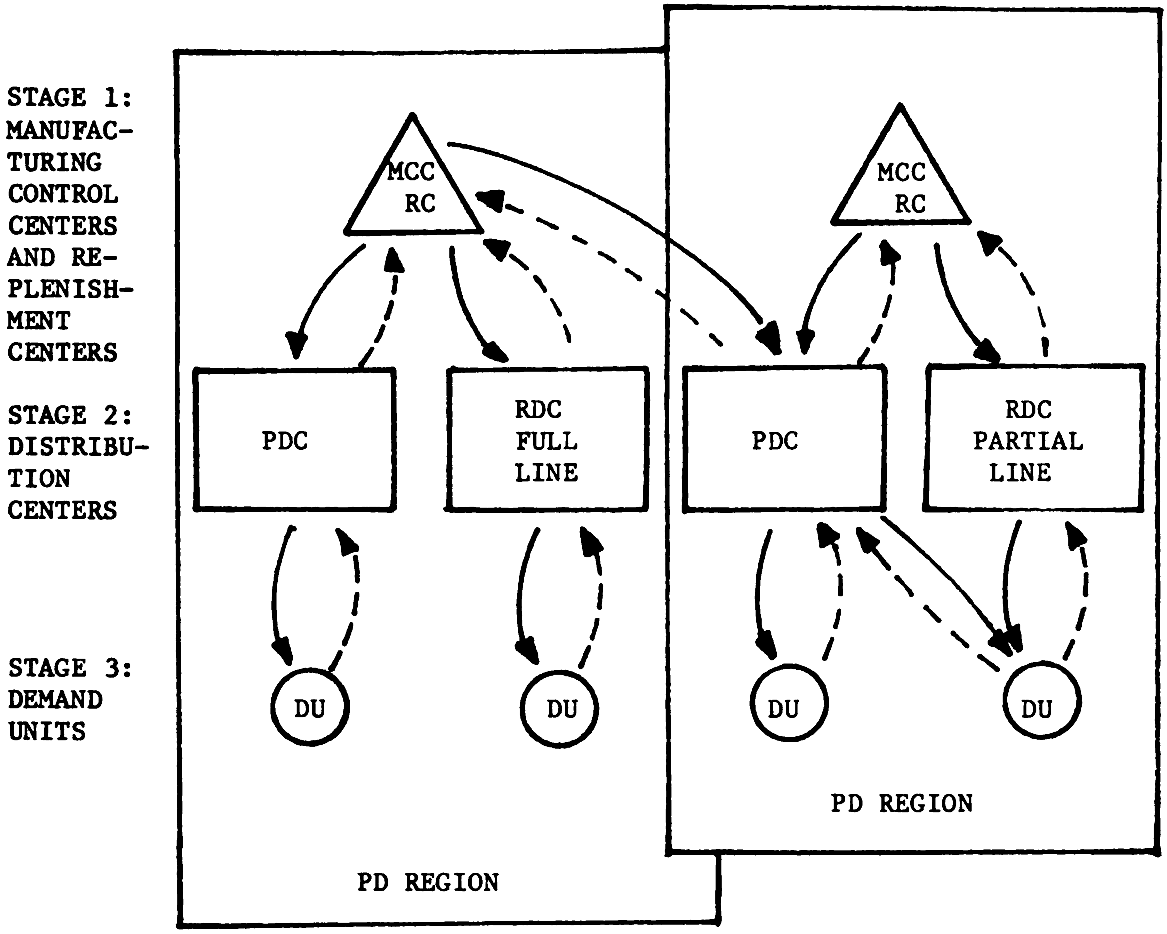
MULTI-CUSTOMER CLASSES OF TRADE
TOTAL U.S. MARKET

COMPETITIVE PROFILE

MULTI-COMPETITORS

Figure 1.1--General Description of Firm-Distribution Audit[1]

[1]D. J. Bowersox, et al., Dynamic Simulation of Physical Distribution Systems, Monograph (East Lansing, Michigan: Division of Research, Michigan State University, Forthcoming).



– – – – – 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 DEMEND UNIT CONSISTS OF ZIP SECTIONAL CENTER(S).

CSP......CONSOLIDATED SHIPPING POINT.

Figure 1.2--Stages of the Physical Distribution Network[1]

[1]D. J. Bowersox, et al., Dynamic Simulation of Physical Distribution Systems, Monograph (East Lansing, Michigan: Division of Research, Michigan State University, Forthcoming).

is designed with a full line of products but with the responsibility to serve only part of the DU's in a prescribed region. The third type, a Remote Distribution Center-Partial Line (RDC-P) supplies only a partial line of products to its assigned DU's with the other products (usually the slower moving products) being supplied from the PDC to which the RDC-P is linked. The fourth type of DC, the consolidated shipping point (CSP) is merely a break-bulk point to which the aggregate demand for several DU's can be shipped.

Model Design Criteria

The general framework discussed above described the physical distribution system of most of the larger sized manufacturing firms. Based on this general framework, the LREPS conceptual model was formed under the following design criteria:

1. The construction should be in modular form and the model should be universally applicable to industrial and consumer products firms after only minor changes in design.

2. The model should enable testing of trade-offs between cost and service and among the various cost functions.

3. The model should embody the capacity to measure the extent to which the desired physical distribution system change as the environmental conditions changes; that is, it should embody a sequential decision process.

4. The constraints of computer resources and reasonable real world validity should be met.

Conceptual Design of LREPS

The major systems and sub-systems through which LREPS was modularly constructed are summarized in Figure 1.3. The Supporting Data System (the input system) is run off-line and exists to facilitate design analysis and the preparation and reduction of data for input into the Operations System. The Operations System is the model system which imitates the real world physical distribution system described in Figures 1.1 and 1.2. The third major system, the Report Generator System is designed to print the simulation output in several optional management reports.

The LREPS model is discussed in more detail in Chapter III through description of these three systems and their sub-systems.

System Identification

The design procedure used in the development of the LREPS simulation model is summarized in Figure 1.4. The first step, "Problem Definition and Feasibility Study," was based on a collection and analysis of data to determine if the objectives of the research were attainable. The outputs of this step were a detailed problem statement, the specifications for the mathematical model, and the design criteria for the operational model. This served as input to the conceptualization of the mathematical model, which consisted of the specification of (1) system boundaries and assumptions, (2) the inputs and outputs, (3) the

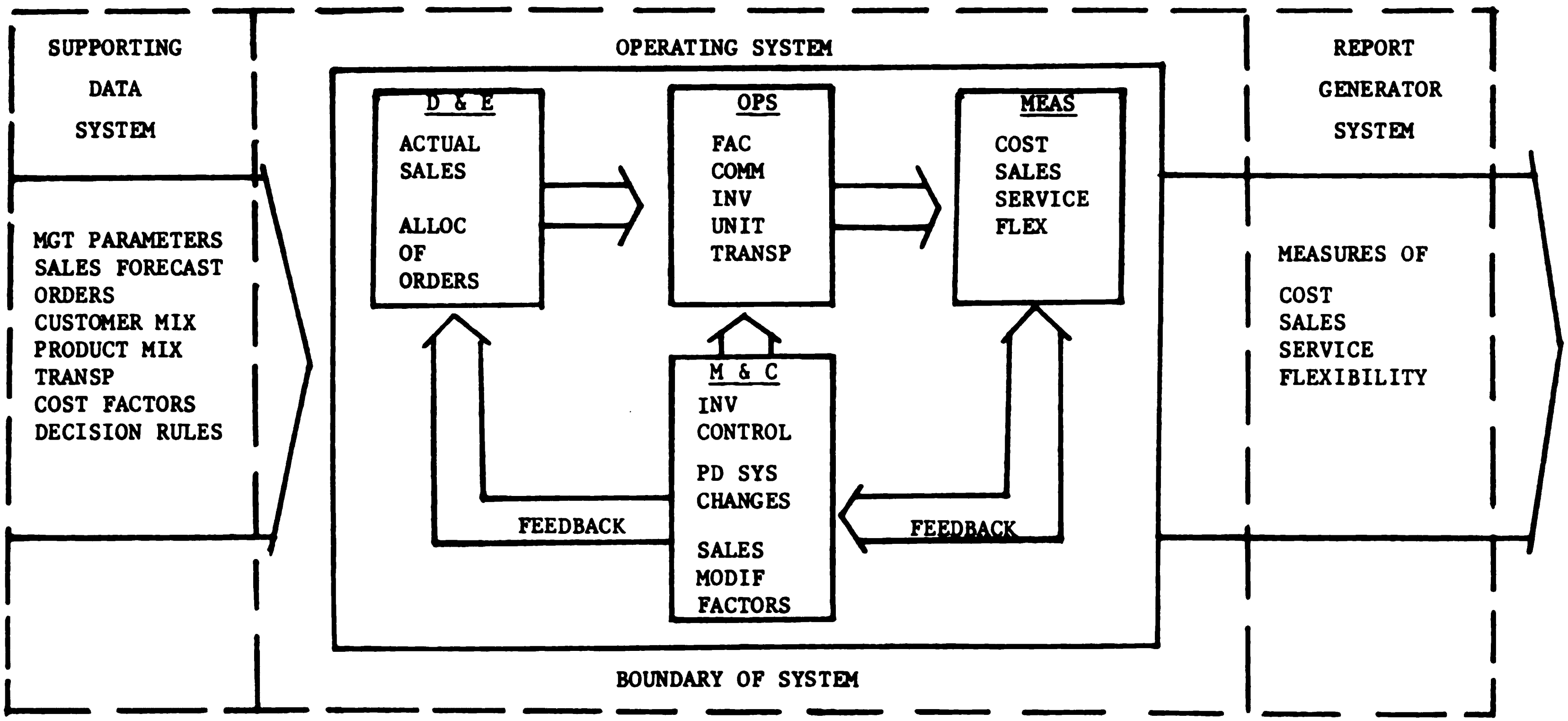


Figure 1.3--LREPS Systems Model Concept[1]

[1]D. J. Bowersox, *et al.*, *Dynamic Simulation of Physical Distribution Systems*, Monograph (East Lansing, Michigan: Division of Research, Michigan State University, Forthcoming).

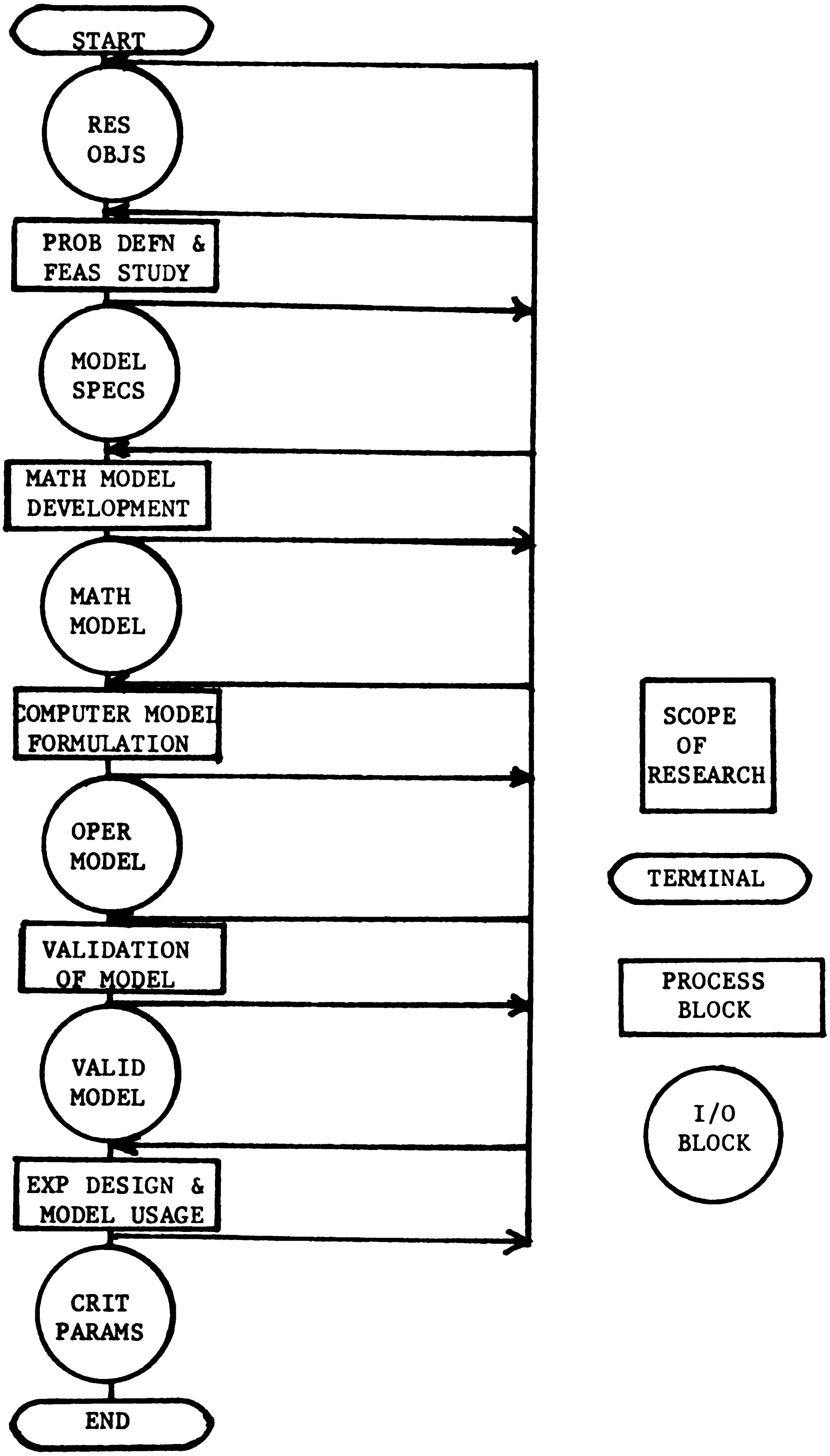


Figure 1.4--LREPS System Design Procedure[1]

[1]D. J. Bowersox, _et al._, _Dynamic Simulation of Physical Distribution Systems_, Monograph (East Lansing, Michigan: Division of Research, Michigan State University, Forthcoming).

constraints of the inputs, outputs and system configuration measurement, (4) criteria for comparing alternative systems, (5) the design parameters to be used for experimentation, (6) the estimation of parameters via further data collection and analysis, and (7) comparison to real world data as a measure of model validity.[15] The next step was the computerization of the mathematical model which involved the following:[16]

1. Specification of the computerized data base.
2. Selection of the programming language.
3. Identification of each of the computer model activities with their respective data bases and programming them.
4. Identification of activities and information flows, flowcharting and coding, and testing and debugging; for each individual sub-program associated with the LREPS procedure.
5. Combination of the subprograms and their respective inputs, outputs, and data base requirements.
6. Testing, debugging, and operationalizing the combined subsystem models and calibration to the actual system.

The following step in the system design was Model Validation, which involved demonstrating that the model is a reasonable representation of reality. The validated model was the input into the final process in the system design, Experimental Design and Model Usage. The focus of this thesis is on the last step. The model is used to experimentally study the effect of warehousing decisions on variables of the finance sub-system of the firm.

Detailed Problem Statement

Financial position of the firm refers to balance between liquid and productive assets in the asset structure, the split between long term and short term debt and equity in the financial structure, and the extent to which the asset and financial structures complement one another. In the broadest sense it encompasses all of the components (variables) of the finance sub-system of the firm. Financial position is typically managed by exception. That is, various financial ratios are compared to prescribed standards and changes are made only when the ratios deviate substantially from their standards. There has recently been much criticism of the waste inherent in financial management by exceptions and management from a preventive orientation has been encouraged. Preventive management suggests anticipating adverse changes in financial position and preventing their occurrence. Changes can only be anticipated, however, if their causes are understood and identification of the causes of change in financial position is a necessary condition for preventive management.

There are two basic premises to this research:

(1) Much of the change in financial position of the firm over time is the result of overt management decisions in other functional areas of the firm.

(2) Most operational decisions within the firm trigger changes, either directly or indirectly, in many of the variables of financial position.

It follows from these premises that a major step toward more enlightened financial management is to identify the effects which various classes of management decisions have on the components of financial position. A better understanding of the total financial effects of specific management decisions would also increase the likelihood of correct decisions.

Objectives of the Research

The objective of this research is to study the nature of the effects of decisions in the warehousing function on variables of the finance sub-system. This is accomplished by:

1. As a member of a faculty and student research team, building a dynamic computer simulation model upon which experimentation and sensitivity analysis can be performed to study the impact of alternative warehousing decisions on financial variables of modeled firms.

2. Performing the experimentation and sensitivity analysis, with only one variable exogenously changed per experiment and recording the resultant changes in financial variables.

3. Identifying those financial variables which are "significantly" affected by each warehouse decision alternative under varying sales growth rate assumptions and in different industries.

4. Studying these results for general relationships which would help describe the nature of cross functional interaction between warehousing decisions and financial variables.

Financial position (or financial health) is an area of the firm which has traditionally not been considered in distribution system decisions. A better understanding of the interaction between warehousing decisions and financial variables would enable managers to more accurately anticipate the total financial effect of decisions made in the warehousing area. Better informed decisions could be made in the warehousing area and changes resulting from warehousing decisions could be anticipated in the finance area. Management of financial position from a preventive rather than a corrective approach would be closer to reality.

Warehousing Decision Alternatives

The warehousing decision alternatives selected for study are the various possible combinations of public and private warehouses for one and two warehouse systems at two possible locations in a study region. The study region is limited to the twelve state area which includes: Missouri, Nebraska, Iowa, North Dakota, South Dakota, Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, and Kentucky.

Chicago is the single location which minimizes the total ton-mile distribution requirements for the twelve state area, assuming that sales are perfectly correlated with population. As such, Chicago will always be included as either a public or private warehouse. Given that Chicago is in solution, Detroit is the location for the second warehouse which offers the biggest reduction in total ton miles. However, problems with the directional flow of traffic significantly reduce service capability from Detroit and the next best location, Columbus, is selected as the second location for the two warehouse systems. Since the possible combination of a private warehouse at Columbus and a public warehouse at Chicago is eliminated as being unrealistic (Chicago will always handle the largest volume), the possible one and two warehousing schemes remaining to be tested experimentally are:

1. A private warehouse at Chicago.
2. A public warehouse at Chicago.
3. Private warehouses at Chicago and at Columbus.
4. Public warehouses at Chicago and at Columbus.
5. A private warehouse at Chicago and a public warehouse at Columbus.

Sales Growth Rates

The experimentation is performed assuming 5%, 15%, and -5% annual growth rates in sales to test the sensitivity of the relationship between warehousing decisions and financial variables to changes in economic and market conditions. Daily sales vary randomly within each experiment but annual sales are designed to average the assumed growth rate bias over the five year horizon of the model.

Types of Industries Involved

The LREPS model is based on a data survey of a major company in the health cares industry. Modeling the financial system of such a company would require expanding the model to include the manufacturing system. To avoid such a monumental task, it is assumed that the model represents a company in the health cares products wholesale industry. The required financial information not obtained in the basic data survey were obtained by taking the median average data for this industry from the Robert Morriss Associates and Dun and Bradstreet industrial financial statement studies. The model has been pre-tested and various parameters have been adjusted to assure that the model output, before experimentation, is a reasonable approximation of the reported financial and operating statistics for the average company in this industry with annual sales in the ten million dollar range.

To test the consistency of findings across industry lines, the experimentation is repeated for the home appliance products wholesale industry. Since the basic model has been built with universal application a prime consideration, extensive basic model changes are not required for modeling the second industry. Changes in the data input are necessary, however. The necessary data for changing distribution system cost and structure characteristics and product and market characteristics were provided by two major firms in the appliance industry. The required financial information was obtained by taking the median average data for the industry from the Robert Morriss Associates financial statement study.

Financial Variables

The financial variables included in this research consist of the following:

1. Each item in the balance sheet and income statement of the modeled firms.

2. Twelve selected financial ratios.

3. Several proxy measures of risk which are based on the regression of quarterly sales and adjusted quarterly net income. Adjusted net income is defined by net earnings, after taxes plus depreciation less annual principle repayments on long term debt. The specific statistics from this regression analysis are:

   a. The formula $X = \frac{a}{b}$, formed by transforming the linear regression equation, which is a measure of the level of quarterly sales below which adjusted net income would become negative.

   b. Total variance, which is the total dispersion of adjusted net income over the twenty quarter period and is a measure of the stability of earnings.

   c. Residual variance, which is the amount of total variance not explained by the relationship between sales and net income. It is a measure of the uncertainty of earnings beyond the instability which occurs because of sales variability.

The financial statements and the twelve ratios are included as traditional measures of financial position and performance. The special statistics are used as measures of the more academic concept of risk.

Distribution System Measurement Variables

Although the objective of the research is to study the interaction between warehousing decisions and changes in financial variables, certain financial changes may occur indirectly from warehousing decisions through the direct effects which the decisions have on distribution system variables. Therefore, measures of distribution variables are included as possible tools for explaining the observed changes in financial variables.

The two standards by which distribution systems are most commonly measured are service and costs. For this research, the service levels will be measured from two approaches: stock-out frequencies and order cycle time. The measures of stock-out frequencies used for this research are:

1. Number of stockouts.
2. Average days per stock-out.
3. Standard deviation days per stock-out.

The measures of order cycle time employed are:

1. Percent of total sales dollars delivered to customers within 5, 6, 7, and 8 days from the time the order is placed.
2. Percent of total orders delivered to customers within 5, 6, 7, and 8 days from the time the order is placed.

Costs are measured for the total physical distribution system and for each of its components which are separated for costing purposes as follows:

1. Inbound transportation
2. Outbound transportation
3. Warehouse operations expense (throughput cost)
4. Warehouse facilities expense

5. Communications expense

6. Inventory expense

Organization of the Thesis

This thesis is divided into six chapters. The first chapter has served as an introduction to the research. Chapter II explains where this research fits in the main-stream of research in the finance area and reviews the pertinent finance literature. Chapter II also identifies and defines certain significant finance variables and describes in general terms why a multitude of variables and reports are required to measure financial position of the firm.

Chapter III describes the LREPS model as it has been adjusted to perform this research and describes the additional data gathering and assimilation required for model adjustment and experimentation. Chapter IV briefly reviews pertinent general concepts of experimental design, discusses the design problems encountered in this research, and describes the experimental design adopted. Chapter V reports the results of experimentation, the analysis of those results, and the conclusions drawn from the analysis. Chapter VI summarizes the objectives and findings of the research, describes several limitations, and discusses implications for future research.

CHAPTER I--FOOTNOTE REFERENCES

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CHAPTER II

BACKGROUND TO THE RESEARCH

The financial variables considered in business decisions traditionally have been expected profits and return on investment. In recent years, the concept of risk is receiving considerable attention from the academic community as an additional financial decision variable. The total risk complexion of the firm is popularly treated in two parts: business risk and financial risk. Business risk is the variability of net operating income.[1] It is a function of the uncertainty of sales and other environmental variables; and of the operations structure through which sales and other exogenous inputs are transformed into operating cash flows.

Financial risk is often defined as the extent to which business risk is magnified or accentuated by the financial structure of the firm.[2] The addition of debt to the financial structure adds interest expense and debt principal repayment to the total fixed expense structure, which increases the probability that the gross operating margin from sales will not cover the fixed obligations of the firm under adverse economic conditions. The definition of financial risk is often broadened to include the degree of complementarity between the level of liquid assets and the maturity of the debt within the firm.[3,4] Since both business risk and financial risk are related to the nature of the firm's assets, the two are overlapping. This is one explanation of why risk has been measured in total rather than in its component parts.

Measures of risk in the finance literature are typically based on the variability of expected return.[5,6] No explicit recognition is given in these measures to the importance of the shifts which the decision in question would cause in the asset and financial structure of the firm, and these shifts are integral determinants of business and financial risk.

The most sophisticated approach used generally by practitioners to explicitly consider risk as a decision variable is the addition of a risk premium to the discount rate in calculating net present value.[7] The inadequacy of information concerning the variability of returns on projects often prohibits use of techniques of measurement suggested in the academic literature. Nevertheless, practioners do recognize the importance of risk as a decision variable, as reflected in the following statement by Tucker:[9]

> Profit planning must plan for continuous profits which are made consistent with the financial state of health of the company. The maximization of profit is no guarantee of financial health, and in fact, when profits are maximized to the exclusion of other considerations, the company can get into serious difficulty.

That risk is important as a second parameter is not disputed by practitioners; how to measure it is. In measuring the risk nature of the firm as of a given point in time, practical analysts have long depended on the concept of financial position.[10]

The Concept of Financial Position

Although authors writing on the subject of financial analysis and control agree on the importance of financial position, there is wide disagreement concerning exactly what it is. Arthur Dewing, one of the earliest of the finance authors, felt that financial position is the asset and liability structure of the firm as stated in the balance sheet.[11] Many writers feel that financial position is primarily determined by the solvency of the firm, as measured by liquid assets and the coverage those assets give to immediate obligations.[12,13] It is also often defined as the split between equities and liabilities and the maturity structure of those liabilities.[14] Others feel that financial position is the measure of a firm's ability to withstand adverse market and economic conditions.[15]

Why is there such a divergence of opinion among respected authorities on such an important element of financial management? Felix Kollaritch has succinctly characterized this problem.[16]

> Financial position is many different things to many different people. . . . .A creditor with no substantial interest in the borrower's business (a trade creditor, for example) will base his judgment on the enterprises liquidating value.....(Creditors who have a substantial interest in the debtor's business) will use two yardsticks to measure the security behind the loans extended. First, they will decide whether or not the assets in their relationship to production are sufficient to assure solvency and continuation of the enterprise. (The second yardstick) is whether or not the assets of the enterprise can be maintained.....(The owner's) primary interest lies in the financial worth of his investment and in the profits to be derived from it. As such he is interested in the company's maintaining the vitality in asset structure required to grow in the future.....To financial management, the management group primarily responsible for and interested in the financial position of a business, the term 'financial position' is synonymous with the collequial use of the term in business, namely its debt paying ability as a going concern (including asset acquisition, labor, creditors, etc.) Immediate paying ability of the firm will be judged on the basis of a continuing enterprise.

The orientation of this research is the manager's viewpoint. However, Kollaritch's description of financial position from the viewpoint of financial management is incomplete and inaccurate for at least three reasons. First, it is widely accepted among finance authorities that the ultimate financial objective of the firm is maximization of the wealth of the shareholder.[17,18] Managing financial position in a manner which investors find undesirable will penalize the market value of the company. Second, a continuing enterprise must always be concerned with obtaining future debt financing and therefore must be concerned with the appearance of the firm to outsiders.

Third, the financial performance of the firm under future conditions depends largely on the financial position of the firm today. If future sales increase significantly but the firm has a disproportionately high level of current and liquid assets, the firm will not realize the full profit potential from the upswing. If future sales turn down and the firm has a disproportionately high level of fixed assets and little borrowing capacity with suppliers of outside financing, the solvency of the firm may be endangered. In summary, the degree of flexibility with which the firm can adjust to uncertain future conditions is a function of the vitality of the asset structure, the vitality of the liability structure, and the extent to which these structures complement one another.

Wright warns that maintaining this character of vitality and complementarity should be a prime objective of financial management and refers to it as "financial balance."[19] He suggests arranging financial position so that the firm can benefit substantially from favorable future conditions while providing the required protection against future adverse conditions.

Borrowing from Wright's concept of financial balance, financial position for the purposes of this research is the vitality of the firm as a going concern to beneficially adapt to ever changing future conditions and refers to the balance within and among the asset and financial structures.

Measuring Financial Position

Just as there is no accepted single definition for "financial position," there is also wide disagreement on how to measure it.

The Balance Sheet

For the early finance writers, the balance sheet served as a measure of financial position. Dewing, for example, defines the balance sheet as "a statement of the financial position of a firm as of a point in time."[20] At even this early date, however, many of the shortcomings of the balance sheet as a measure of financial position were recognized. Graham and Dodd, for example, warn that the balance sheet is an extremely static measure and individual items mean little unless considered in relation to other items and compared to some objective standard.[21] Guthmann and Dougall are especially critical of the static nature of the balance sheet and insist that whether individual items are in an improving or decaying trend is far more important than their absolute values.[22] Today, many accountants and financial analysts are displeased that balance sheet information is on a historical rather than a reproduction basis and that wide latitude in accounting practices makes it difficult to know what the absolute values actually represent.[23]

The Sources and Uses of Funds Statement

The general purpose of this statement is to exemplify the changes in financial position which occur as the result of operations in any given time period. The most common technique of calculation is to subtract each balance sheet item in time period t-1 from the corresponding item in time period t. Guthmann and Dougall, who were among the earliest to recommend the use of the funds statement, feel it rectifies the static nature of the balance sheet.[24] Their contention that it is primarily a tool for understanding from where cash has come and to whence it has gone is shared by many prominent authors.[25,26] Bierman explains that the funds statement is preferred to the balance sheet by many analysts because accounting conventions (historical rather than reproduction cost, for example) have produced a balance sheet which is a residual of accounting procedures rather than a meaningful statement of financial position.[27]

As a measure of total financial position, however, the funds statement lacks concrete value. Financial items must be considered in relation to each other and compared against some objective standard of measure to have economic meaning.

Financial Ratios

As early as the 1890's financial analysts recognized that individual financial statement items only carry significance in relation to other items.[28] At a much later date, Tucker explains the rationale for considering financial data in the form of ratios as follows:[29]

> Primary data are defined as those data which cannot in themselves be used to predict or appraise objectively performance, progress, and profitability. Primary data are used as the ingredients for various types of ratios which do give economic meaning to events and permit objective diagnosis, decision making, and assessment of all areas of a company's economy and activity.

Early writers, notably Dewing, warn that hard and fast rules for ratios are dangerous because acceptable financial policies in one industry are not necessarily acceptable in others. In the period 1900-1920 a significant development in the art of financial analysis was the establishment of industry averages as rules of thumb against which the ratios of individual companies could be compared.[30] Alexander Wall developed average ratios for 981 companies, stratified by industry and geographical location. His measures were incomplete and were based on a very insufficient sample, but were noteworthy as a beginning.[31] Ten years later, Roy Foulke began keeping averages of twelve ratios from a wide sampling of companies which was the first form of the fourteen key ratio averages published currently by Dun & Bradstreet.[32] The use of financial ratios in conjunction with industry averages satisfies the two most commonly heard criticisms of financial statements. Through ratio analysis items are considered in relation to other items and objective standards of measure are available in the form of industry averages.

Evaluating financial position through ratio analysis has been often criticized. As early as the 1930's, Gillman expressed concern over ratio analysis for the following reasons:[33]

1. Changes in ratios can result from movement in either the numerator or denominator and the cause of ratio change is not always clear.

2. Ratios divert attention from the comprehensive view of the firm.

3. Even within the same industry, a particular ratio with a certain value might indicate safety for one firm and trouble for another because of varying management attitudes and philosophies, market characteristics, and so on.

Gillman's criticisms, however, were largely ignored for many years, probably because of several studies in the early 1930's which demonstrated the highly predictive power of certain financial ratios in anticipating bankruptcies. The results of the studies are of significant interest. Winakor and Smith conclude from their studies of firms which experienced financial difficulties from 1923-1931 that deterioration in the net working capital to total assets ratio preceded financial difficulties and often began to deteriorate ten years in advance of bankruptcy.[34] Fitzpatrick added successful companies to his sample to serve as a control group against which the unsuccessful firms could be compared, a precaution which Winakor and Smith failed to take. He concludes that the deterioration in any one of a number of ratios can predict bankruptcy, but that the most powerful are net profit to net worth, net worth to debt, and net worth to fixed assets.[35] Merwin analyzed financial reports for six prior years for a larger number of "continuing" and "discontinuing" firms. Among his findings are that net working capital to total assets; net worth to debt; and the current ratio are the most sensitive predictors of discontinuance.[36]

A noteworthy observation is that in total the three studies indentify seven ratios which are significant ex-ante predictors of financial difficulties. Of the seven, only one is a measure of profitability and return. Two ratios are concerned with balance within the capital structure, two with the balance within the asset structure, and two with the complementary relationship between the asset structure and the capital structure. This evidence strongly indicates that there are other financial variables as important to the firm as profitability.

Wide use of the traditional financial ratios to measure financial position continued into the 1950's. In their 1951 edition Graham and Dodd state:[37]

> The tangible factors affecting the quality of a company may be measured through the use of certain key ratios. .....(The security analyst) should then develop a number of key ratios which will throw light on the company's over-all performance, on the safety of its senior securities, and on the attractiveness of its common stock for investment.

In the late 50's and early 60's displeasure developed with the static nature of the traditional ratios, which are calculated from items in the balance sheet and income statement.[38,39] The following are examples of criticisms aimed at the traditional ratios:

1. Long term debt totaling one million dollars would appear the same in traditional ratios for a ten year, 8 percent loan as for a thirty year, 4 percent loan, even though the former requires over two times more outflow of cash each year.[40]

2. Lease payments, which constitute a major fixed outflow of cash each year for many companies do not appear in the traditional ratios.[41]

To alleviate these and other shortcomings, much attention is given in recent years to "coverage ratios" such as the number of times working capital covers average daily cash flows and the number of times annual earnings plus depreciation covers annual interest expense and principle re-payment. Although the more traditional ratios (liquidity, profitability, and leverage ratios) continue in wide use, the coverage ratios are significant additions to the measurement of financial position.

Despite the widespread use of the traditional and coverage ratios, many finance academicians question the value of ratio analysis. Their disenchantment is largely with the use of industry averages as objective measures.[42] Donaldson summarizes this disenchantment as follows:[43]

> Even assuming strict comparability, which is hard to establish, there is no proof that the companies concerned have arrived at their current debt proportions in a deliberate and rational manner. In view of the wide variations in debt policy within any industry group, there can be little real meaning in an industry average. And what happens if

> every other member of the group looks to the other for guidance? The most that can be said for this approach to debt policy is that the company concerned can avoid the appearance of being atypical in the investment market so far as its capital structure is concerned.

Unlike most critics of ratio analysis, Donaldson does propose an alternate measure of financial position. However, in his judgment financial position is synonymous with defensive position. His technique centers on preparing the firm for any "reasonably" possible future extended economic downturn and is not concerned with priming the company to take optimum advantage of economic and market prosperity.

Although ratio analysis is strongly criticized, no viable alternatives for measuring total financial position have been found. Resultantly, academicians are again testing empirically the utility of ratio analysis. Baruch Lev used the financial statements on COMPUSTAT and the changes in these statements over time to test the hypothesis that firms manage their financial position by periodically adjusting their financial ratios to industry averages.[44] He concludes that they do. The implication of his work is that, as many finance people suspected, firms use ratio analysis to manage their financial position from a corrective orientation.

Beaver analyzed the ability of individual ratios to accurately classify firms as "failed" and "non-failed", using a classification test.[45] The five ratios he found, in order of predictive strength are: Cash flow/ total debt, net income/total assets, total debt/total assets, working capital/total assets, and the current ratio. Beaver notes, however, that since several of these ratios are highly correlated, the predictive ability of certain ratios could be their correlation to other "strong" predictors.

Altman built a multiple discriminant analysis model based on ratios which he found to be much more accurate in predicting failure than are the individual ratios standing alone.[46] The five ratios in his most predictive model are: working capital/total assets; retained earnings/total assets; earnings, before interest and taxes/total assets; market value of equity/book value of total debt; and sales/total assets. However, while these five ratios in combination constitute the most accurate predicting model, they are not individually the five best predicting ratios. Therefore, Altman's conclusions are not necessarily inconsistent with those of Beaver. Both authors conclude that financial ratios are significant tools for analyzing financial position. Several variables in combination should offer a better prediction than any single variable.

Beaver and Altman considered financial position only as the defensive posture of the firm. Carlson recognized this shortcoming and, borrowing from Altman's conclusion that several variables are better predictors than any single variable, developed a model to predict "financial efficiency" based on several financial ratios.[47] The individual ratios in his model, which he explains are not all superior predictors in univariate analysis, are: the current ratio, the cash turnover, the inventory turnover, the debt ratio, and the dividend payout ratio. He concludes that financial ratios used in a proper research framework are valuable tools both for management planning and control and for financial analysis by outsiders such as bankers, credit managers, and investors.

In conclusion, financial ratios are not academically the ideal technique for measuring financial position. However, empirical research evidence indicates that individual ratios can do a reasonable job of evaluation and that jointly, they are extremely accurate. It is also demonstrated empirically that ratio analysis is used in managerial control and analysis and no technique is shown to do a better job in practical analysis.

Anticipating the Effect of Decision Alternatives on Financial Position

Financial statements and ratios are based on past performance and as such lack a crucial dimension as information tools for effective financial decisions. Thomas Neff alludes to this problem:[48]

> He (the financial executive) should use history as a benchmark but concentrate on the future. His most valuable contribution is not in telling management where they have been, but in telling them where they are going.

Neff is referring specifically to the use of pro-forma financial statements for planning purposes. Pro-forma financial statements are projections of how the financial statements will look in the future as the company operates over time. The importance of pro-forma statements for planning purposes is emphasized by Raymond Kent:[49]

> A projected balance sheet makes it possible to judge to what extent an enterprise's financial position will be strengthened or weakened as a result of its planned activities up to the date for which it is planned. .....Often, projected balance sheets reveal errors in planning or expectations not readily discoverable elsewhere.

This does not mean, however, that pro-forma statements are incorporated into the decision making process. They are used for planning purposes only. This literature review substantiates that financial planning, asset management decisions, and management of financial position are performed within the firm as separate functions.

Financial position is typically managed on an exceptions basis. That is, individual items are adjusted when the ratios deviate from prescribed standards. Financial management by exception is concerned with detecting areas of over - and under - investment, lack of capital, trends toward insolvency: measuring what has been and comparing it to what should be. The research by Baruch Lev reported earlier demonstrates that management by exception (corrective management) is the technique used today to manage financial position.[50]

In the past such techniques were appropriate because so much potential existed in "skimming the cream" that detailed attention to subtle, hidden relationships could hardly be justified. However, the texture of industrial life has changed. As Tucker explains:

> Industrial competition has steadily moved into the subtler areas of manufacturing structure to where the little things are important. Profit making now comes from unmasking hidden costs, from policing against insiduous creeping change, from lighting up a hitherto unknown profit area.[51]

Support is building for financial management from a preventive rather than from a corrective viewpoint. In discussing the importance of financial balance, Wright says:[52]

> Financial managers too often await results of operations before seeking to adjust financial position. This is too late in time to begin efforts to control financial position.

In writing on the future direction of financial management, Jaedicke states that in the future knowing what causes items to change and financial position to decay and taking steps to prevent such changes will become a major responsibility of financial management.[53]

Concluding Remarks

This research is concerned with understanding the causes of change in financial position. By understanding the causes, the changes can be anticipated, considered in decision analysis, and prevented if so desired. Many of the causes are exogenous. Such environmental variables as economic conditions, industry sales, and cost structures are largely out of control of the manager. However, a premise of this research is that much of the change in financial position is the result of overt decisions in functional areas of the company. Another underlying premise is that most operational decisions within a company trigger changes in many of the variables which make up the financial position of the company. A major step toward more enlightened financial management, then, is to provide management with a capability of predicting the total financial impact of various classes of decisions.

Tucker made a significant first step toward scientific specification of total financial impact.[54] Through the use of a multitude of ratios, he developed a large number of general relationships among ratios and developed composite indices by which management can predict the total financial effect of decisions made in the production and sales areas.[55]

However, he omitted a major area of the operations system of the firm - the distribution sub-system. This research studies the effect of a specific class of decisions in the distribution sector, warehousing decisions, on the financial position of modeled firms in two industries.

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CHAPTER III

LREPS: FINANCE VERSION

Introduction

The purpose of this chapter is to describe the version of the LREPS model capable of modeling the finance subsystem. Although the basic LREPS model was built based on an extensive data audit of a sponsor company, LREPS - Finance Version (LREPS-F) is not intended to imitate the operation of a "real world" company. Rather, information was drawn from several different sources and the model was pretested with the objective of building a reasonable approximation of a "typical" firm in each industry. In instances where an input to the model is not important to the results of test questions, the value of that variable was estimated.

The validity of the model was evaluated by comparing the output of test runs to industry average operations and financial statistics reported in several data sources. This chapter describes LREPS-F with the data input and model parameters for simulating the hypothetical "typical firm" within the health care products wholesale industry. The changes which are necessary to simulate a typical firm in the appliance wholesale industry are explained in Chapter V.

General Features of LREPS-F

The model is programmed in GASP II-A, an event oriented simulation language. It is divided into three overlapping sub-systems. A sub-system is a combination of model components and activities linked in a logical arrangement. Components are the functional entities of the firm (e.g. demand component and transportation component) and are formed in the firm by combining activities. An activity, the most basic element in the model, is the process of action in the firm. Activities involve the interplay among the most elementary inputs and outputs. The values of the material, monetary, or informational flows which the inputs and outputs involve are termed variables.

There are three general types of model variables: exogenous, status, and endogenous. An exogenous variable is an input variable, the value of which is not changed by the operation of the model. A status variable describes the state of a system component (or one of its attributes) for any given point in time. The values of these variables change over time as operations proceed. For example, a balance sheet item is a status variable. The balance sheet status variable "cash" describes the value of a system component, cash, as of a given point in time. An endogenous variable is a model variable whose value is dependent on the operation of the model and is considered an output of one phase of the model and an input to another phase. A given variable is often a status variable for certain purposes and an endogenous variable for other purposes.

The relationships among variables and components are modeled through algorithms. An algorithm is the quantitative or logical description of the interaction among variables, activities and/or components; and it is the functional form by which an activity processes inputs into outputs. A routine is a computer sub-program which links activities into components and/or activities, components, and variables into a sub-system. A routine is usually a logical arrangement of several algorithms. The sequencing of routines is the process by which the model is made to operate a meaningful order.

Events are the timing mechanisms which activate routines within the model. Each event usually activates several routines, which are sequentially attached in some orderly framework. The occurrence of events is controlled by the Executive Routine of the Monitor and Control Subsystem. The events which are to occur on a particular day are stored in an event file and are picked by the executive on the following basis:

1. All variable events are picked on a first in first out basis.
2. All fixed time events are picked in the order in which they are "fixed" to occur.

Fixed time events are events which occur with some prescribed regularity, such as daily, weekly, and end-of-quarter. Variable events are events which occur sporadically as the value of certain status variables reach prescribed levels.

LREPS-F includes eight fixed time events and four variable time events, which are the following:

1. The event that initializes the LREPS-F Operating System for start of LREPS-F simulation planning horizon cycle, Beginning-Of-Cycle, BOCYC.

2. The event to initiate the normal sales processing activities for the day, DAILY.

3. The event to initiate the processing of the end and beginning of week activities, WEEKLY.

4. The event to initiate the processing of beginning-of-month activities, MONTHLY.

5. The event to initiate the processing of the end and beginning-of-quarter activities required for Operating System information input/output and control of the feedback responses, QUARTERLY.

6. An event similar to the Quarterly event, but with some additional half-year activities, HALF-YEAR.

7. An event similar to the Half-Year event, but with some additional yearly activities, YEARLY.

8. The event that completes the LREPS Operating System activities of a simulation cycle and generates the required information to terminate the execution, End-Of-Cycle, (EOCYC).

9. A variable event that initiates the Operations Sub-system processing of a MCC order arrival from the DC, MCC-Order-Arrival, (MCORA).

10. A variable event that initiates the Operations Sub-system processing of a DC shipment arrival, DC-Shipment Arrival, (DCSHPAR).

11. A variable event that initiates the process

of paying trade accounts generated by the receipt of replenishment inventories, ACCPYDS.

12. An event to imitate the payment of principle on long term debt at the end of the seventh week and every thirteenth week thereafter, QTRPRP.

The clock (CLOCK) is the driving mechanism which identifies the day in process and by which the model moves from one day to the next. When all events listed in the event file for a particular day (T-NOW), have occurred, CLOCK advances to the next time and the events filed for occurrence at T-NOW + 1 are processed.

Events do not activate all of the routines in a sub-system at the same time and often routines from more than one sub-system are called by the same event. The remainder of this chapter describes the routines within each system and sub-system. The event by which each routine is activated is identified in the associated discussion.

The Supporting Data System

The Supporting Data System is the avenue by which all exogenous information is inputted to the model at the beginning of each experimental run. The specific facilities which exist in the distribution system scheme and the number and location of suppliers are identified exogenously in LREPS-F. Changing the value of exogenously inputted data and the location of fixed facilities in the system through the Supporting Data System is the manner in which experimentation is performed on the model.

To simplify the discussion, the data listed in the Supporting Data System, and a brief comment on the analysis required to prepare it, are discussed in conjunction with the particular sub-systems of the Operations system which the data supports.

Operations System

The Operations System is the system of the model in which the imitation of the firm occurs. It traces the flow of materials, money, and information (demand, operational, and financial) through the structure of the distribution system. For the health cares company, the distribution system consists of 125 customer demand units in a twelve state region; supplier's (MCC's) at Chicago, Philadelphia, and Dallas; a distribution center (DC) at Chicago; and, in eighteen experiments, a DC at Columbus, Ohio. The Operations System is described according to the sub-systems and routines of which it consists.

Operating System: Demand and Environment Sub-system

The primary purpose of this sub-system is to imitate the volume characteristics and product breakdown of orders flowing from the customers to the DC's of the modeled firm. The sub-system operates in four separate but over-lapping routines, which are:

1. Generation of daily sales for the total company.

2. Assignment of daily sales to individual DC's.

3. Determination of the volume and geographic destination of each other and the volume of each individual order sold.

4. Summaries at the end of each day of the total volume and product characteristics of sales at each DC.

Generation of Daily Sales. Daily sales (DLSLS) are generated in the model by randomly selecting a normal deviate (Z score) and plugging it into the formula

$$\text{DLSLS} = \frac{\overline{M}}{21} + \quad * \frac{\sigma}{21}$$

$\overline{M}$ and σ are the mean and standard deviation respectively of the probability distribution from which monthly sales are being sampled for the month in process. Twenty-one is the number of working days in each month. The twenty-one daily sales points selected in a month will total to M, actual monthly sales, which will be the same as $\overline{M}$ only by chance. M is a random variable of the joint probability distribution which is obtained by combining the twenty-one daily probability distributions, which are defined by $\frac{\overline{M}}{21}$ and $\frac{\sigma}{21}$.

The value of $\overline{M}$ for any given month is determined by the formula

$$\overline{M}_i = \frac{\overline{M}_1 (1+\frac{r}{12})^i}{W_i}$$

where

$\overline{M}_i$ = the mean of the probability distribution from which monthly sales will be generated for the i th month.

$\bar{M}_1$ = the mean monthly sales for the first month in any run.

r = annual growth bias in sales.

i = the month for which sales are being generated.

W_i = a weighting factor between .1 and 2.0 used for building seasonality patterns into the experimentation.

The value of σ for any given month is determined by the formula

$$\sigma_i = \frac{\sigma_1 (1 + \frac{r}{12})^i}{W_i}$$

σ_i = the standard deviation for the probability distribution from which monthly sales will be generated for the i th month.

σ_1 = the standard deviation for the first month in any run.

r, i, W_i = as defined above.

σ is allowed to grow at the same rate as $\bar{M}$ to assure a constant value for the co-efficient of variation.

The input parameters for this routine for the health cares company were determined by studying the monthly sales patterns of the sponsor company, calculating the standard deviation of monthly sales after the growth bias had been removed, and determining the standard deviation of daily sales which would be required to attain the identified monthly standard deviation. No significant seasonality characteristics were found in the monthly demand patterns.

Sales Assignments to DC's. Daily sales assignments are made to an individual distribution center based on the following formula:

$$DLSLS_p(DC_i) = DLSLS_p(TOT) * \frac{\sum_{j=1}^{n} WTIDX(DC_i DU_j)}{\sum_{j=1}^{m} WTIDX(DU_j)}$$

where

$DLSLS_p(DC_i)$ = sales for day p at DC_i.

$DLSLS_p(TOT)$ = sales for day p for total company.

$\sum_{j=1}^{n} WTIDX(DC_i DU_j)$ = the sum of the weighted indices for all DU's assigned to DC_i.

$\sum_{j=1}^{m} WTIDX(DU_j)$ = the sum of weighted indices for all DU's in the company.

The weighted index for each DU is based on the population of the DU and the relationship found in a cross section analysis between population patterns and sales for the sponsor company. Several independent variables were examined in the cross section analysis and population, with a correlation co-efficient of .95, was found to be the best predictor of sales.

Demand Unit Sales Assignment. Total DC_i sales are assigned to individual customers by randomly picking orders from an order file and randomly assigning them to a DU. The relative probability that any DU_j will have any given order assigned to it is

$$\frac{WTIDX(DU_i)}{\sum_{j=1}^{n} WTIDX(DC_i DU_j)}$$

A basic assumption is that all customer orders emanate from the center of DUj. Each postal zip code in the twelve state study region is assigned to a DU. The center of each DU is a Zip Code Section Center, (ZSC) although each ZSC is not necessarily the center of a demand unit. The demand unit is identified by the number of the ZSC which serves as its center and by the longitudinal - latitudinal bearings of that ZSC. The 1970 population of each DU is listed in the data base and the running model updates the population each running year based on Rand McNally geographical area population growth rates.

Order Picking. The order file (Supporting Data System) from which orders are picked consists of ten-order blocks of sample invoices. The sample of invoices was systematically selected from the files of the sponsor company and the sample size was determined with Type I and Type II errors set at .01. Orders are randomly selected ten at a time and 10 percent of the total sales dollars and weight in an order block are randomly assigned to DU's ten different times.

Specific sales information is summarized by the DCi level and is kept only for fifty representative or "tracked" products. Because of the cost and impracticality of keeping track of all of the products sold by the company, these fifty products were selected to be tracked from day to day for inventory management, shipment and costing purposes. Each tracked product represents a group of products and extrapolation factors are used for determining total product sales, inventory, shipment, and costing patterns based on the patterns of the tracked products. The characteristics of each tracked product (sales value, pounds, cube, and cost of goods sold per care unit) are listed in the order file of the data base.

Summary of Output. The output of the Demand and Environment sub-system serves as the input to the Operating sub-system. The information is summarized as follows:

1. Total daily sales for the company, in dollars, weight, cube, orders, and line-items.

2. Total daily sales for each DC in dollars, weight, cube, orders, and line-items.

3. The total sales for each DU in dollars and weight.

4. The sales volume for each tracked product at each DC.

Operating System: Finance Routines

Finance is not a model sub-system in LREPS-F. Rather, routines associated with cash and financial information flows are located in each of the sub-systems of the Operations system. To provide an overview of the total finance function in LREPS-F, a general outline of the routines associated with cash and financial information flows are presented in Tables 3.1, 3.2, and 3.3. Detailed description of the routines is deferred to the particular sub-system in which each routine is located.

TABLE 3.1.--Financial Statement Items and the Associated Operations System Routines

Item	Code	Associated Routines
Cash	CASH	PAYAC, ARADJ, LAMGT, CSMGT, FTXPY, CPBUD, DIVPY, INTRS, MKSCY, PRRPY, TOPRX
Marketable Securities	MKTSC	CSMGT
Accounts Receivable	ACCRC	DLSLS, ARADJ
Inventory	INVTY	IDCGS, INRPL
Fixed Assets	PLNEQ	CPBUD, TOPRX
Total Assets	TOTAS	(RESIDUAL)
Accounts Payable	ACCPY	PAYAC, INRPL
Taxes Payable	TXPAY	FTXRT, FTXPY
Deferred Taxes	DEFTX	FTXRT
Short Term Loans	STDBT	LAMGT
Current Maturities - Long Term Loans	LTDTC	PRRPY
Long Term Loans	LTDBT	PRRPY
Equity	SHEQT	EAFIT, DIVPY
Sales	SALES	DLSLS
Cost of Goods Sold	CSTGS	IDCGS
Gross Margin	GMARG	(RESIDUAL)
Administrative and Selling Expense	ADSLX	TOPRX
Outbound Transportation Expense	OTBDX	TOPRX

TABLE 3.1.--Continued

Item	Code	Associated Routines
Inbound Transportation Expense	INBTX	TOPRX
Throughput Expense	THPTX	TOPRX
Communications Expense	COMMX	TOPRX
Straight Line Depreciation	SLDPX	TOPRX, FTXRT
Interest on Debt	CSDBT	INTRS
Net Operating Income	NOINC	(RESIDUAL)
Marketable Securities Income	MSINC	MKSCY
Marketable Securities Expense	MKSCX	CSMGT
Net Income	EBFIT	(RESIDUAL)
Federal Income Taxes	FINCT	FTXRT
Net Income, after Taxes	EAFIT	NETIN

TABLE 3.2.--A Summary Overview of the Finance Associated Routines and Their Associated Variables

Routine				Associated Variables		
Name	Code	Event	Associated Routines	Input	Output	Explanation
Daily Sales	DLSLS	DAILY	IDCGS	GENRL	SALES	Generate daily sales and assign to OC's and DU's.
Inventory depletion, Cost of Goods Sold	IDCGS	DAILY	DLSLS	SALES	CSTGS INVTY	Calculate cost of units sold and subtract from inventory.
Inventory Replenishment	INRPL	DCSHPAR		GENRL	INVTY ACCPY	Record arrival of inventory, increase accounts payable.
Payment of Accounts	PAYAC	END-OF-DAY	INRPL	INVTY ADSLX OTBDX INBOX THPTX COMMX	ACCPY CASHA	Pay accounts scheduled for payment today.
Accounts Receivables Adjustments	ARADJ	END-OF-DAY	DLSLS	SALES ACCRC	CASHA ACCRC	Randomly generate receipts; add todays sales to receivables.

TABLE 3.2.--Continued

Routine		Event	Associated Routines	Associated Variables		Explanation
Name	Code			Input	Output	
Liquid Assets Management	LAMGT	END-OF-DAY		LIQUAS	STDBT CASHA	Compare LIQAS to acceptable limits. Adjust with short term loans if required.
Cash Management	CSMGT	END-OF-DAY		CASHA	CASHA MKTSC MSCTX	Compare CASHA acceptable limits, adjust with MKTSC if required.
Accumulating Variable Update	AVUPD	END-OF-DAY		MKTSC STDBT LTDBT	ADDMS ADDSD ADDLD	Add amount in each security, loan account to appropriate accumulating variable for income and costing purposes.
Operating Expense Routines	TDPRX	END-OF-WEEK		GENRL PLNEQ	ADSLX OTBDX INBTX THPTX COMMX SLDPX CASH ACCPY	Calculate all operating expenses for week. Make appropriate adjustments to cash and accounts payable.
Interest	INTRS	END-OF-MONTH	AVVPD	ADDSD ADDLD	CSDBT CASH	Multiply daily interest rates by accumulated loan dollar days.

TABLE 3.2.--Continued

Routine		Event	Associated Routines	Associated Variables		Explanation
Name	Code			Input	Output	
Marketable Securities Income	MKSCY	END-OF-MONTH	AVVPD	ADDMS	MSINC CASH	Multiply daily return by accumulated M.S. dollar days.
Accumulated Depreciation	SYDDP	END-OF-MONTH		PLNEQ	SYDDX	Sum-of-years digits depreciation for tax purposes
Net Income	NETIN	END-OF-MONTH		ALL INCOME STATEMENT ITEMS		Calculate net income, after taxes, based on straight line depreciation.
Federal Income Taxes	FTXRT	END-OF-MONTH	SYDDP		TXPAY DFTAX	Calculate taxes payable based on SYDDP. Add 1/2 of (SYDDP-SLDPX) to deferred taxes.
Tax Payment	FTXPY	END-OF-QUARTER		TXPAY	TXPAY CASH	Pay taxes; subtract from cash and taxes payable.
Principle Repayment	PRRPY	END-OF-QUARTER		LTDTC	LTDBT	Pay 1/4 of current maturities. Transfer same from LTDBT to LTDTC.
Dividend Payment	DIVPY	END-OF-QUARTER		EAFIT	CASH SHEQT	70% of net earnings, after taxes.
Capital Budgeting	CPBUD	END-OF-YEAR		SLDPX SALES	CASH PLNEQ	Replacement + net equipment.

TABLE 3.3.--Financial Variable and Routine Code Glossary

Code	Description
ACCPY	Accounts Payable
ACCRC	Accounts Receivable
ADSLX	Administration and Selling Expense
ARADJ	Accounts Receivables Adjustment Routine
AVUPD	Accumulating Variable Update Routine
CASH	Cash
COMMX	Communications Expense
CPBUD	Capital Budgeting Routine
CSDBT	Interest on Debt
CSMGT	Cash Management Routine
CSTGS	Cost of Goods Sold
DEFTX	Deferred Taxes
DIVPY	Dividend Payment Routine
DLSLS	Daily Sales
EAFIT	Net Income, after taxes
EBFIT	Net Income
FINCT	Federal Income Taxes
FTXPY	Tax Payment Routine
FTXRT	Federal Income TAXEs Routine
GMARG	Gross Margin
IDCGS	Inventory Depletion, Cost of Goods Sold Routine

TABLE 3.3. --Continued

Code	Description
INBTX	Inbound Transportation Expense
INRPL	Inventory Replenishment
INTRS	Interest Routine
INVTY	Inventory
LAMGT	Liquid Management Assets Routine
LTDBT	Long Term Loans
LTDTC	Current Maturities - Long Term Loan
MKSCY	Marketable Securities Income Routine
MKSCX	Marketable Securities Expense
MKTSC	Marketable Securities
MSINC	Marketable Securities Income
NETIN	Net Income Routine
NOINC	Net Operating Income
OTBDX	Outbound Transportation Expense Routine
PAYAC	Payment of Accounts Routine
PLNEQ	Fixed Assets
PRRPY	Principle Repayment
SALES	Sales
SHEQT	Equity
SLDPX	Straight Line Depreciation

TABLE 3.3.--Continued

Code	Description
STDBT	Short Term Loan
SYDDP	Accumulated Depreciation Routine
TDPRX	Operating Expense Routine
THPTX	Throughput Expense
TOTAS	Total Assets
TXPAY	Taxes Payable

A summary of the financial flows is presented in Tables 3.1 and 3.2. Table 3.1 lists the items in the balance sheet, and income statement, their code names, and the code name of routines in the model which directly cause change in that item.

Table 3.2 presents a schematic of the finance - associated routines, approximately in the order in which they occur in the model. The information presented in Table 3.2 includes: the code name of the routines; the event which activates the routine; the name of the routine; the code name of the finance variables and finance related variables which link to it in the model, both input and output; and a brief explanation of the routine. In Table 3.3, each code name used in this section is listed in alphabetical order along with the variable or routine which it represents. Discussion of the financial ratios and special statistics, which are calculations based on data in the financial statements, is deferred to the Report Generator System.

Operating System: Operations Sub-System

The purpose of this sub-system is to imitate the flow of orders, material, cash and information through the distribution system. The first activity is the arrival of batches of orders at the distribution center as an output of the D&E sub-system. This section described the Operations Sub-System through a discussion of the routines triggered by the arrival of orders, which are:

1. The Order Processing, Preparation, and Shipment Routine.

2. The Inventory Depletion - Cost of Goods Sold Routine.

3. The Inventory Management Routine.

4. The Inventory Replenishment Routine.

5. The Inventory Arrival - Accounts Payable Adjustment Routine.

6. The Accounts Receivable Adjustment Routine.

7. The Liquid Asset Management Routine.

8. The Cash Management Routine.

9. The Accumulating Variable Update Routine.

The Order Processing, Preparation and Shipment Routine. This routine is activated by the DAILY event. Figure 3.1 traces through the physical flow of a batch of orders from a DU from the time it arrives at a DC. The available inventory for each tracked product on the order is checked to determine if the line item can be filled. If sufficient inventory is not available for one or more of the products, stock outs are reported (see the Measurement subsystem for stock - out level reporting). Order processing and preparation are assigned a time lag of two days and shipment occurs at the end of this lag. All outbound shipments are less - than - truck - load shipments by common carriers. The elapsed transit time before the order is received by the customers is generated in the following steps:

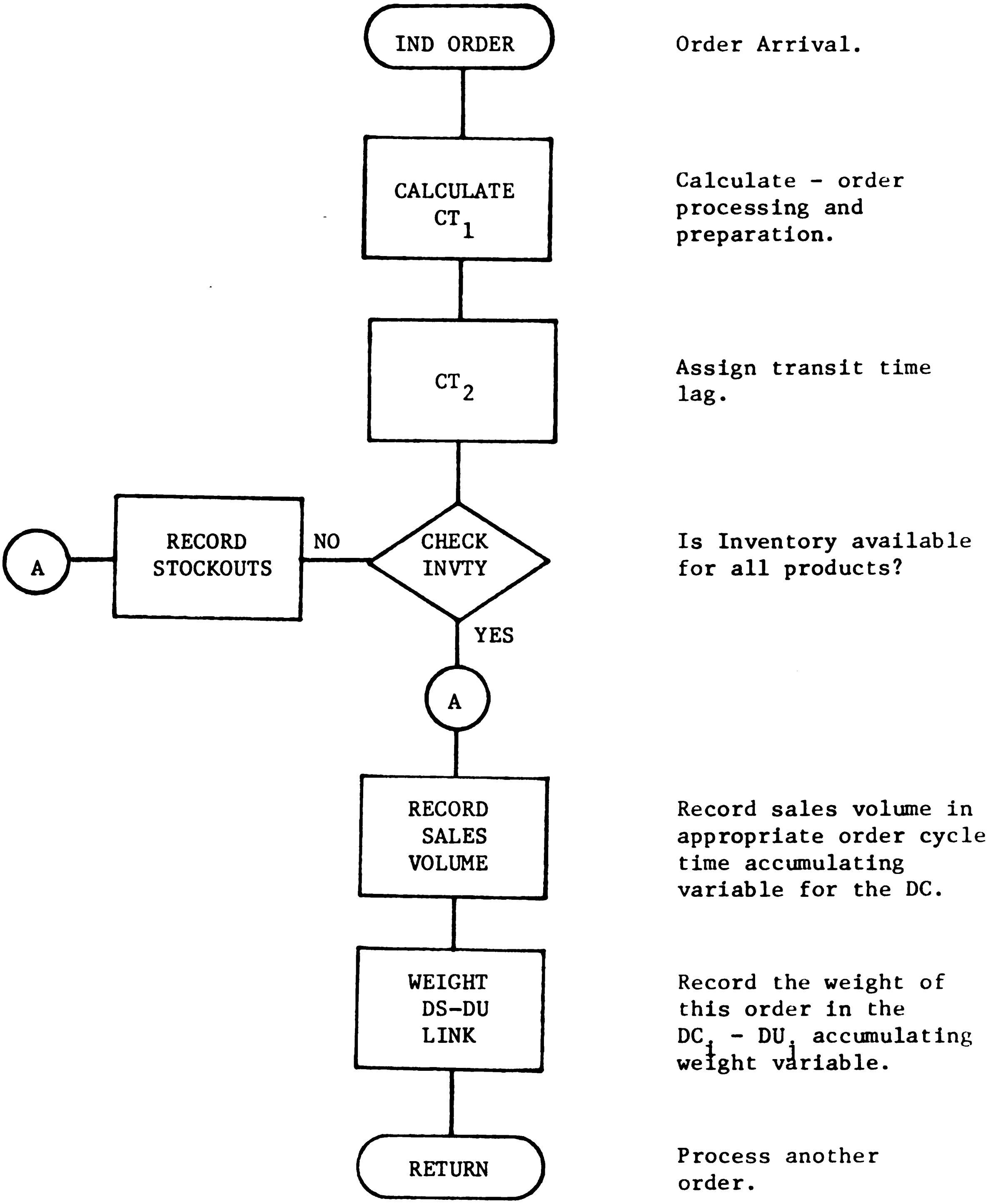


Figure 3.1.--Flowchart: Processing Preparation, and Shipment Routine

1. The distance from the DC to the destination DU is calculated by calling the distance routine, which reads longitude and latitude of the DU and DC from a list in the data base. The straight line distance between the two points is calculated based on the difference between their navigational bearings and this distance is increased by 17 percent to allow for highway circuity.

2. For each DC, three geographical radii are listed within which the expected transit times are 1, 2, and 3 days respectively. The appropriate expected transit time is selected based on the particular radii within which the DC-DU distance falls.

The transit, order processing and order preparation times are summed to obtain normal order cycle time and the total weight for these orders are added to the weight accumulating variable for this length of order cycle.

The real world times required for processing and preparing orders were determined by tracing an order through the sponsor company and obtaining estimates from the appropriate manager of the time required for each activity. The transit times over each MCC-DC link, and the maximum distances from each DC which can be reached by outbound shipments in 24, 48, and 72 hours were gathered by polling the motor common carriers serving the DC's. The survey was conducted through the sponsor company.

<u>The Inventory Depletion, Cost of Goods Sold Routine</u>. This routine (IDCGS) is activated by the event End-of-Day. It is flow charted in Figure 3.2. At the end of each day, the total sales units for each tracked product, DLSLS (IPT), are subtracted from the inventory on hand (IOH) for that product. The cost of goods sold for each product,

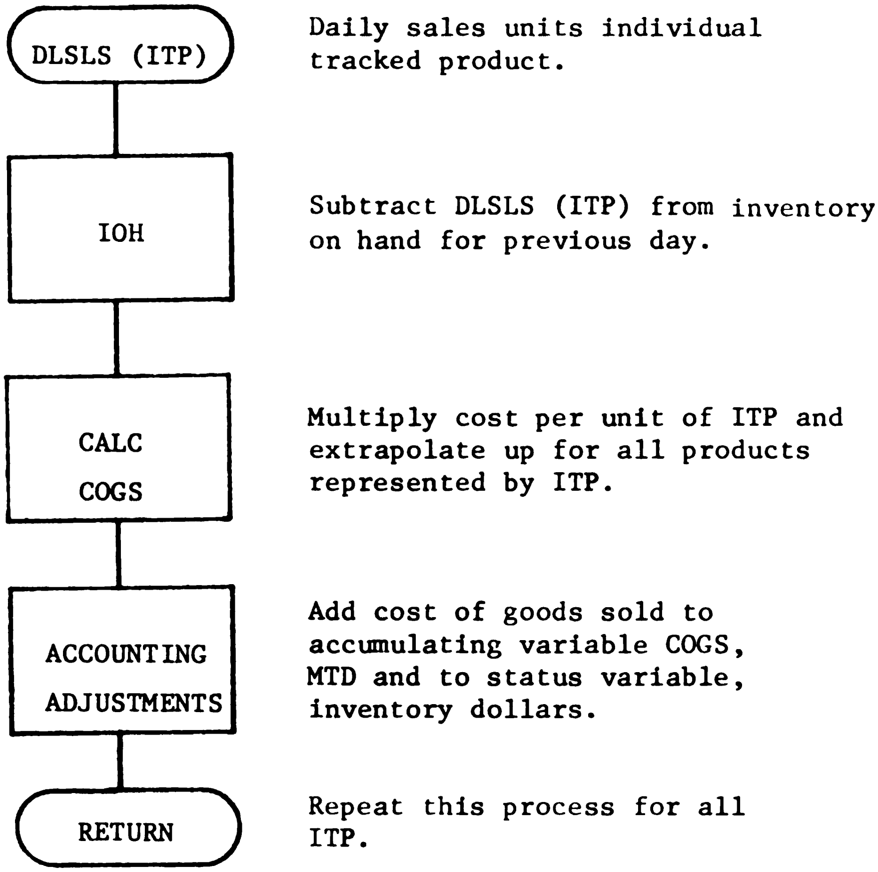


Figure 3.2.--Flowchart: Inventory Depletion - Cost of Goods Sold Routine

CSTGS (ITP), is calculated by multiplying the number of case units times the unit cost, which is listed in the data base. CSTGS (ITP) is extrapolated up to reflect the total cost of goods sold for the category of products which it represents, CSTGS (CATi). The sum of CSTGS (CATi) for all categories is added to the income statement variable "cost of goods sold" (CSTGS) and subtracted from the balance sheet variable "inventory" (INVTY).

Daily Inventory Management Routine. Subsequent to the adjustment of unit inventories by the amount of daily customer shipments, the level of inventory on hand for each tracked product, IOH (ITP) is checked to determine if replenishment is necessary. This routine is flow-charted in Figure 3.3. IOH (ITP) is compared to the re-order point ROP (ITP) to determine if a replenishment for that product should be ordered. ROP (ITP) is a variable parameter and is calculated in the Monitor and Control Sub-system Controller function.

If the answer is that IOH   ROP, the replenishment que is checked to see if replenishment has already been ordered. If not, a replenishment order is placed for the amount M - IOH (ITP), which is a variable also provided from the M&C Controller function.

The Inventory Replenishment Routine. Figure 3.4 depicts the inventory replenishment shipment routine, which is associated with the event MCORAR (MCC order arrival). The total volume in an inventory replenishment order

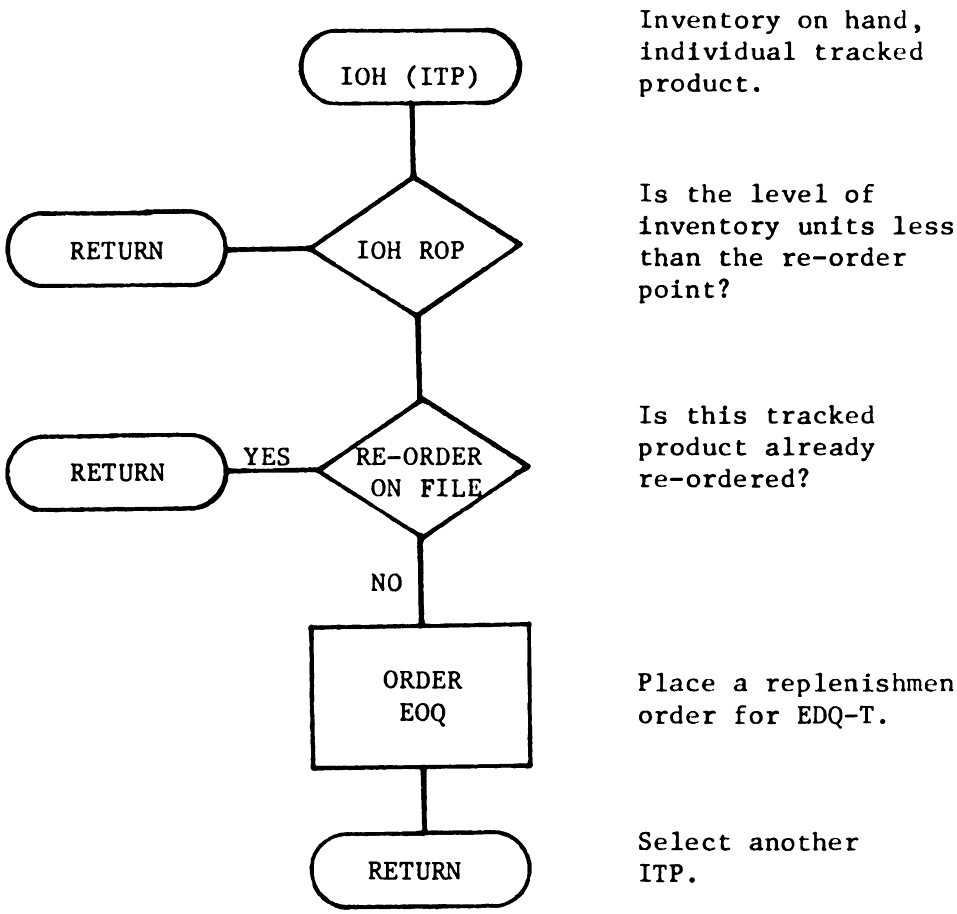
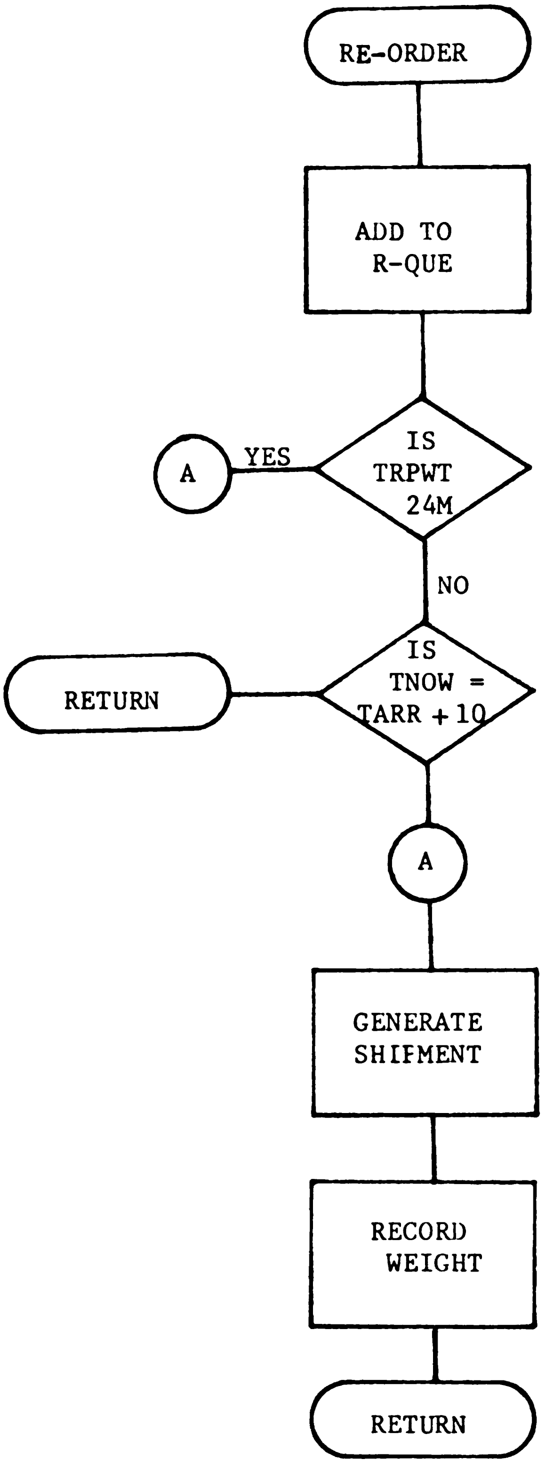


Figure 3.3.--Flowchart: Inventory Management Routine



Re-Order for EOQ-T.

Add EOQ-T to replenishment que, MCC:k-DC:i.

Have ten working days elapsed since the arrival of the first order. If not, go on to next routine.

Generate time lag to ascertain day shipment will arrive at DC.

Record the weight of the shipment in the appropriate weight category for the MCC_k - DC_i link.

Figure 3.4.--Flowchart: Inventory Replenishment Routine

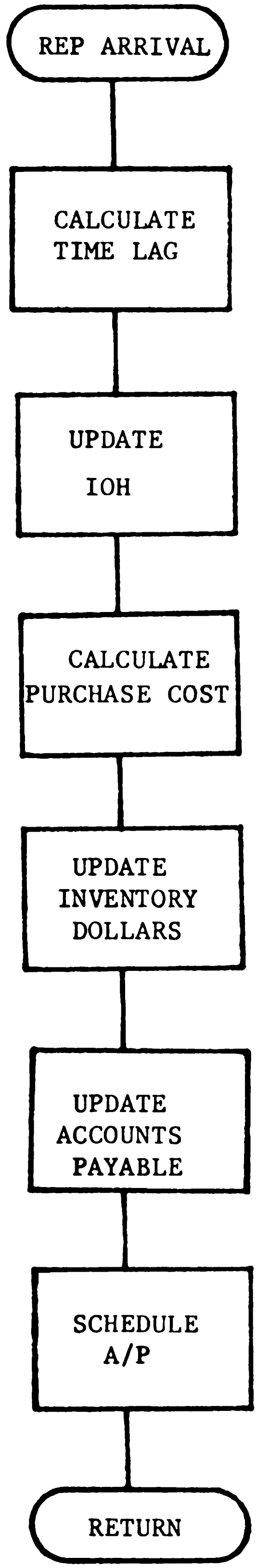
is determined by extrapolating the amount ordered of the tracked product. However, the re-order quantity for most of the products is sufficiently small in that even after extrapolation a single replenishment order will not normally justify a truck-load inbound shipment. Thus, when a replenishment order arrives at the Supplier (MCC) the total ordered volume (EOQ-T) is placed in a que, which accumulates the total weight of outstanding orders for the particular MCC-DCi link. Shipment of the orders in the que is generated when the total weight reaches 24,000 pounds or after ten working days from the day the first order is placed in the que, whichever comes first. 24,000 pounds is the minimum weight on which the truck-load rates are applicable and ten is the number of days beyond which the cost of additional buffer stock required to protect against stockouts exceeds the expected gain from truck-load freight rate savings.

When the replenishment shipment is dispatched from the supplier (MCC) to the DC, a transit time lag is generated. Each MCC-DC replenishment link is assigned a transit time in the data base. An event is scheduled for the arrival of the replenishment shipment at shipment date plus elapsed transit time. The total weight shipped is also recorded and served as input to the measurement system.

The Inventory-Accounts Payable Adjustment Routine. The purchase of inventories creates an account payable. Thus, the arrival of an inventory replenishment shipment triggers a series of adjustments in IOH (ITP), for each tracked product which is replenished; the inventory account (INVTY); and accounts payable (ACCPY). The Inventory - Accounts Payable Adjustment Routine is summarized in Figure 3.5.

Upon arrival of the replenishment shipment, a time lag for handling and processing is generated. Subsequently, the replenished units for each tracked product are added to IOH (ITP). The purchase cost for the tracked products is calculated and extrapolated up to represent purchase cost for the group of products which the tracked products represent, PRCST (CATi). PRCST (CATi) is then added to INVTY and to ACCPY. Payment of PRCST (CATi) to the supplier is scheduled for the 25th following working day, at which time this prescribed amount is subtracted from CASH and from ACCPY.

The twenty-five day lag in Accounts Payable is determined by dividing twenty-one days, the average number of days sales in accounts payable for the industry on the average, by .85. .85 is the quotient of expenses which generate accounts payable divided by sales. It is based on the estimate that all of inventory purchases and transportation expenses give rise to trade accounts; and that 50 percent of the administrative and selling expenses, throughput expenses, and communications expenses create trade accounts. In the running model, accounts payable turnover closely approximates the industry average.



Arrival of replenishment shipment @ DC.

A time lag is generated for handling and processing the delivery.

Inventory on hand is updated by the units of each ITP delivered.

The purchase cost of each ITP is calculated, extrapolated for product classes, and summed.

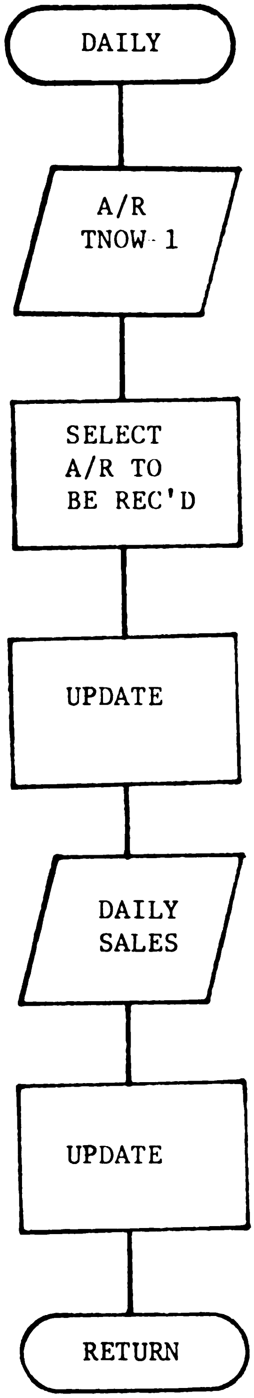
The total purchase cost of the recorder is added to inventory dollars and to accounts payable.

A time is schedules for paying the associated A/P.

Figure 3.5 --Flowchart: Inventory - Accounts Payable Update Routine

Account Receivables Adjustment Routine (ARADJ). Accounts receivable (ACCRC) are created by daily sales. They are depleted when payment is received. The amount of ACCRC paid off each day is a stochastic variate and a function of the total amount of ACCRC outstanding at the beginning of the day. Since the health cares industry average turnover of accounts receivable is thirty three days, an average of three percent of outstanding A/R is paid off each day. At the end of each day, the percentage of outstanding receivables paid-off is randomly selected from an approximately normal distribution with mean .03 and standard deviation .005. The standard deviation is estimated. Receipts for the day are subtracted from ACCRC and added to CASH. The dollar amount of sales for the day (DLSLS) are added to ACCRC. This routine is flow-charted in Figure 3.6.

The Liquid Asset Management Routine. Total liquid assets (TLQAS) are defined as cash plus marketable securities. The preservation of a prescribed amount of liquidity among the assets of the firm is necessary to support operations. In LREPS-F liquid assets fluctuate daily within a prescribed band. If the level of liquid assets at the end of a day is less than the lower boundary, T_1, liquidity is added through short term borrowings, in an amount sufficient to return the level of liquid assets to a prescribed replenishment level, M. If the level of liquid assets at the end of the day exceeds an upper



Level of accounts receivable from previous day.

Randomly generates outstanding A/R for which payment will be received.

The amount received is added to cash and A/R.

Reads in daily sales dollars, total firm.

Adds daily sales to sales, MTD, and A/R.

Figure 3.6.--Flowchart: Accounts Receivable Routine

boundary, T_u, a sufficient amount of short term loans is repaid to bring the level of liquid assets down to M.

The parameters for this routine are calculated offline and exogenously inputted. The value of M is the average level of liquid assets for a firm in the health cares industry with annual sales of $10MM. The upper and lower boundaries are calculated using a standard replenishment inventory control formula.[1] The mean and standard deviation of the distribution of daily cash flows are calculated from test runs of the model and a normal distribution is assumed. A lag of two days to transact short term borrowings and repayments is assumed. Interest charges on outstanding short term loans are assumed to be 6 percent and per transaction costs are assumed to be $100. An assumed management parameter is that the probability of running out of cash in the two day lag required to transact a loan should be less than .01.

<u>Cash Management Routine</u>. The level of cash also fluctuates daily within a prescribed band. The upper and lower boundaries and the target level of cash are prescribed with the same replenishment inventory control model used for managing liquid assets. The level of cash is adjusted by buying and selling marketable securities. Because of the absence of marketable securities from the asset structure of the industries modeled, this routine is inactive for the research currently performed.

The Accumulating Variable Update Routine. The purpose of this routine is to record the end-of-day value of several status variables in accumulating variables for costing and income reporting purposes. At the end of each day the amount in Marketable Securities is added to accumulating dollar days of marketable securities (ADDMS). The amount in short term loans and long term loans at the end of each day are also closed into accumulating dollar day variables, accumulating dollar days of short term loans (ADDSL) and accumulating dollar days of long term loans (ADDLL). In the Measurement sub-system, these accumulating variables are all multiplied by a daily interest rate or a daily rate of return to obtain weekly revenue and cost totals for the associated expense items.

The Operations System: Measurement Sub-System

The purpose of this sub-system is to measure the service levels attained by the distribution system, to measure the costs of operating the firm, and to prepare all financial items for inclusion into financial statements and reports.

Measures of Service.

The general levels of service which are measured by this research are stockout frequencies and total elapsed order cycle times.

The Stock-Out Measurement Routine. If inventory is insufficient to cover a line item on an order, a stock-out is reported to the Stock-Out Measurement Routine. The amount reported is the case units ordered on the line item, and it is added to a status variable, case units back-ordered (CUBO). At the end of each day, CUBO is added to an accumulating variable, accumulated stock out days delays (ACSODL). When a replenishment shipment is received containing a back-ordered product, all back orders for that product are removed from CUBO. At the end of each week, the following service statistics are calculated for each DC and for the total company: total number of stockouts, average delayed days per stockout, and standard deviation delayed days per stockout.

Average delayed days per stockout and standard deviation days delays per stockout are calculated based on the following formulas:

$$AVVDL = \frac{ACSODL}{WKSLS}$$

$$SDDDL = \frac{MSADD}{WKSLS} - AVVDL^2$$

where

AVVOL = average days delay per stockout

SDDDL = standard deviation days delay

ACSODL = accumulated stockout days delay

WKSLS = weekly sales, in case units

MSADD = mean of the square of accumulated stockout days delays

These service statistics are calculated for each individual DC and for the total company.

Total Elapsed Order Cycle Times. The generation of elapsed time per order for order processing and preparation and for shipment transit times are explained in the Operating Sub-system. The total sales dollars for each order are added to the appropriate accumulating variable for sales volume which is delivered to the customer in k days from order arrival date, where k = 4, 5, 6, 7 or 8 or more. The total order cycle time actually includes an allocation for the average days delayed per order because of back-orders. However, this allocation is a constant and does not affect the relative distribution. Thus, at the end of the month, the percentage of sales delivered with order cycle times of 4, 5, 6, 7, and 8 or more days is calculated for a given distribution center by simply dividing monthly DC sales into each of the appropriate accumulating variables.

Measures of Cost

The process of costing operations in the model are explained according to the function they serve. There are two cost accounts which are associated with general management. These are:

1. Administrative and Selling Expenses.
2. Cost of goods sold (purchase cost of inventories).

There are six components of total cost to the physical distribution system:

1. The outbound transportation component.
2. The inbound transportation component.
3. The throughput component.
4. The communications component.
5. The facilities component.
6. The inventory component.

Finally, there are two expense areas which are common to both functions. These are:

1. Interest expense.
2. Federal income taxes.

Cost-of-goods sold calculations are described in the Operations sub-system inventory depletion routine. Each of the other nine costing sub-routines are explained here along with the financial activities associated with each of the expenses.

Administrative and Selling Expense Routine. This routine is activated by the Weekly event. Administrative and selling expenses include all expenses incurred by the firm except those expenses associated with the actual physical distribution system and the purchase price of inventories or securities. Weekly administrative and selling expenses (ADSEX) are calculated using an equation of the functional form:

$$ADSEX = FADEX\ (1+g)^{t} + VADEX * WKSLS$$

where

FADEX = fixed weekly expenses.

VADEX = variable cost per sales dollar.

g = an annual growth rate in fixed expenses.

t = the year of operation (1,2,....5)

ADSEX is added to the income statement endogenous variable ADSLX. The amount .5 ADSEX is added to the balance sheet status variable accounts payable (ACCPY) and subtracted from cash. An event is scheduled for the twenty-fifth following day to subtract the amount .5 ADSEX from cash and from ACCPY to reflect payment of the accounts payable generated.

The values of FADEX, VADEX, and g are used in the model as residuals to aid in designing the model for the base experiment as a reasonable approximation of the modeled industry.

Outbound Transportation Expense Routine. A comprehensive survey of freight rates from each potential distribution center to a sample of destination points in the study was undertaken through the sponsor company. The rates for the various weight breaks for the class of products shipped were summarized into a weighted average freight rate for each sample DC - DU linkage and these weighted averages were regressed against the appropriate distances. The resulting equations had correlation coefficients significant at the .01 test level. Based on this survey, outbound freight rates are generated in the model from equations which are of the general form:

$$FRTRAT\ (DC_1 DU_j) = R_1 * A * (1+R_3)^t + R_2 * B\ (1+R_4) * DIST$$

where

$FRTRAT\ (DC_i DU_j)$ = the estimated weighted average freight rate for shipment from DC_i to DU_j.

R_1, R_2 = adjustment factors used for reflecting negotiated rates.

R_3, R_4 = adjustment factors used to reflect general shifts in the transportation rate structure.

t = the year (1,2,....5)

A,B = the regression co-efficients from the sample rate analysis.

DIST = the distance from DC_i to DU_j.

The adjustment factors (R_1, R_2, R_3, and R_4) are all set at 1.0 for this experimentation. The total outbound freight expense at a particular DC_i for a given week $WKOTBTC(DC_i)$ is calculated from the formula

$$WKOTBTC\ (DC_i) = \sum_{j=1}^{n} [FRTRAT\ (DC_i DU_j) * VOLWT_j]$$

where

$VOLWT_j$ = the total sales volume in pounds shipped from DC_i to each DU_j.

n = number of DU's served by DC_i.

The total weekly outbound freight expense for the company (WKOTBEX) is

$$\sum_{j=1}^{m} WKOTBTX\ (DC_i)$$

where

$$m = \text{the number of DC's in the system.}$$

WKOTBEX is added to the income statement variable OTBDX and to accounts payable (ACCPY). Payment of the appropriate trade account is scheduled for the twenty-fifth day after the expense is occurred.

Inbound Transportation Expense Routine. Each DC receives replenishment shipments from three supplier's (MCC's) which are located in Chicago, Philadelphia, and Dallas. Motor common carrier freight rates were obtained through the sponsor company for each of the six MCC - DC supply links (three MCC's to two DC's) for three different weight categories, which are: under 5,000 pounds, 5,000 to 24,000 pounds; and over 24,000 pounds.

Replenishment shipments are recorded in the operations sub-system according to the weight category in which the shipment falls. The total weekly inbound freight expense from a particular DC_i [ITCST (DC_i)] is calculated from the formula

$$\text{ITCST}\ (DC_i) = \sum_{k=1}^{3} \sum_{l=1}^{3} [\text{FRTRAT}\ (MCC_k\text{-}DC_i, CAT_e * \text{VOLWT}...$$

$$...(MCC_k\text{-}DC_i, CAT_e)]$$

where

$\text{FRTRAT}\ (MCC_k\text{-}DC_i, CAT_e)$ = the freight rate for shipments to DC_i from MCC_k for weight category e.

VOLWT (MCC_k-DC_i,CAT_e) = the total replenishment volume over the linkage which moved in shipments of weight category e.

The total weekly inbound transportation expense for the company (ITCST) is the sum of ITCST (DC_i) for all DC_i. ITCST is added to the income statement variable INBTX and to accounts payable. Payment of the associated trade credit is scheduled for the twenty-fifth day after the expense is incurred.

<u>Throughput Expense Routine</u>. Throughput (or facilities operation) expense is the cost of the physical activity of loading, unloading, handling and storing inventories. For privately owned and operated warehouses it includes the following cost activities:

1. Unloading inbound shipments.
2. Handling and moving the inventories within the warehouse, with related costs such as:
    a. Lift truck rentals, maintenance, and operating costs.
    b. Packing materials.
    c. Automated picking units.
3. Taxes and utilities.
4. Warehouse management and clerical salaries.
5. Loading outbound shipments.

The sponsor company owns and operates five warehouses of sizes ranging from three million dollars volume annually to one hundred million dollars annually and ranging in degree of automation from manual picking to 80 percent automated picking and loading. The private warehouse throughput expenses used in modeling this industry are based on a comprehensive analysis of the elements of the standard costing reports from each of these warehouses over a three year period. The analysis involved examination of changes in cost characteristics between different types and sizes of warehouses; of the upward shifts in the expense structure of the warehouse over the three year period; and of the changes in operating costs resulting from sales volume increases.

For the volume through public warehouses, throughput costs are the charges against the company by the public warehouseman. These charges consist primarily of three elements:

1. Handling charges.
2. Storage charges.
3. Accessorial charges for such things as preparing products for shipment.

The public warehouse throughput expenses are based on rates quoted by public warehousemen of the cities included in the model. The rates were gathered through the auspices of an independent trade association and were approved as being representative by the association.

The throughput cost parameters are stored in the Supporting Data System for warehouses by type and size. The two types of feasible warehouses in LREPS-F are private distribution centers and public distribution centers. The possible sizes (sales volume for the modeled company moving through the DC) are:

Size	Capacity
1	Under \$5MM
2	\$6MM - \$11.99MM
3	\$12MM - \$23.99MM
4	\$24MM - \$35.99MM
5	Over \$36MM

For the private distribution centers, a fixed cost per week plus a variable cost per pound of throughput is listed for each of the five sizes in the data base. For the public distribution centers, a variable cost per pound of throughput is listed for each of the five sizes.

The weekly throughput cost for a particular DC_i [TPCST (DC_i)] is calculated from the formula

$$TPCST\ (DC_i) = FTPEX\ (o,p) + VTPEX\ (o,p) * VOLWT\ (DC_i)$$

where

FTPEX = the fixed weekly expense for a DC of size and type p.

VTPEX = the variable cost per pound for a DC of size and type p.

VOLWT (DC_i) = the total pounds shipped out of DC_i during this week.

For public facilities, FTPEX = 0. The weekly total throughput cost for the company (TPCST) is the sum of TPCST (DC_i) for all DC_i. TPCST is added to the income statement variable THPTX. For private DC's, .5 TPCST (DC_i) is subtracted from cash and the same amount is added to accounts payable. For public DC's, TPCST (DC_i) is added to accounts payable. The trade accounts are paid by scheduling a deletion of both cash and accounts payable for twenty-five days after the expense in incurred for the amount .5 TPCST (DC_i) for all private DC's and for the amount TPCST (DC_i) for all public DC's.

Communications Expense. Communications expense is essentially the cost of processing orders within the company. The cost parameters are listed in the Supporting Data System and are computed in two parts. There is a fixed communications expense and a variable expense per order and line item for the total company. There is also a fixed communications expense and a variable expense per order and line item listed for each size and type of distribution center. The types and sizes are the same as for throughput costing.

Weekly orders and line items for the total company and for each DC are inputted from the Operations Sub-System. The weekly communications expense for each DC is calculated by multiplying the per order variable expense and per line item variable expense for the size and type of DC times the weekly DC orders and line items, and adding the results to the weekly fixed communications expense for that size and type of DC. Total weekly company communications expense (CMCST) is calculated in three steps:

1. Weekly company total orders and line items are multiplied times the company level variable expense per order and per line items and these products are added to company-wide fixed communications expense.

2. The total communications expense for each DC are summed.

3. The outputs of steps 1 and 2 are summed.

CMCST is added to the income statement variable COMMX and .5 CMCST is subtracted from cash and added to accounts payable. Payment of the appropriate trade account is scheduled for the twenty-fifth subsequent day.

Fixed Facilities Expense Routine. The fixed facilities component exists only for private distribution centers and serves the purpose of describing the expense associated with the fixed investment in facilities.

There are two components to fixed facilities expense. The first, the cost on the financing required for the investment, is an actual cash flow. The second, depreciation, is an accounting allocation. To further complicate this routine, the cost of capital has an economic meaning for measuring the cost of the physical distribution system and takes on a different value for purposes of composing an income statement. Further, depreciation is based on the streight line method for financial reporting purposes and on the sum-of-the years-digits method for tax purposes. This gives rise to deferred taxes.

As input into the physical distribution system cost report, fixed facilities expense includes (1) straight line depreciation, and (2) a financing charge equal to the weighted average cost of capital times the undepreciated book value of the facility. As input to the income statement, fixed facilities expense includes only straight line depreciation. The treatment of interest for financial reporting purposes, depreciation of facilities for tax purposes, and deferred taxes are explained in later expense routines. The following discussion describes the fixed facility expense routine for the purpose of costing the distribution system.

The initial investment in fixed facilities for the five different sizes of private distribution centers are listed in the Supporting Data System. The investment figures listed in the data base are the estimated cost of building the warehouse, laying the rail-spur tracks, and purchasing the necessary automated materials handling systems. For the health cares company, investment in materials handling equipment is 20 percent of total investment for DC sizes 1, 2, and 3 and 35 percent for sizes 4 and 5.

Materials handling equipment is depreciated over fifteen years and the remaining investment over fifty years. The information for this routine is based on a study of the private facilities operated by the sponsor company, which range in annual dollar sales volume from three million to sixty million dollars. At the end of each week, the initial investment, S, for a given DC of size e is picked from the Supporting Data System and plugged into the formula

$$\text{WKDEP}\ (\text{DC}_i) = (1-a) * \frac{S}{2600} + a * \frac{S}{780}$$

where

$WKDEP\ (DC_i)$ = the expense of depreciation for the week in process for DC_i

a = the percent of the total investment for this size of facility in materials handling equipment

2600 = 52 weeks * 50 years

780 = 52 weeks * 15 years

The total weekly depreciation charges for the company (WKDEP) are calculated from the formula

$$WKDEP = \sum_{i=1}^{2} WKDEP\ (DC_i) + \frac{SDNEQj}{52}$$

where

SDNEQj = the straight line depreciation charges for year j on all equipment added during years (1, 2,...j-1). See page   for an explanation of this value.

WKDEP is added to the income statement variable, straight line depreciation expense; and to the total physical distribution system management report variable, depreciation expense (DEPEX).

The weekly fixed facilities total cost of financing $WFTCC\ (DC_i)$ is calculated for a given facility through the equation $WFTCF\ (DC_i) = [S - ACSLD\ (DC_i)] * \frac{w}{52}$

where

$ACSLD\ (DC_i)$ = accumulated straight line depreciation for DC_i.

w = the annual weighted average cost of capital.

The annual weighted average cost of capital is calculated off-line and is exogenously inputted to the data base. WFTCF (DC_i) is added to a physical distribution system report variable, fixed facilities financing expense (FFFNX).

Inventory Cost Routine. The inventory component generates expenses against the system in two forms: the cost of ordering and the cost of carrying inventory. The cost of ordering inventory is included in communications costing and is not listed separately.

Although the carrying cost of inventory is not listed separately in the financial statements, it exists in an economic sense and consists of two elements:

1. Obsolescence and deterioration of products, taxes, insurance, and other miscellaneous items.
2. The cost of the capital invested in inventory.

The first element consists largely of general items and is included in Selling and Administrative Expense in the income statement. A true measure of the cost of capital does not appear in the financial statements. While an interest expense is subtracted from net operating income, it certainly does not represent the cost of all capital used by the company. The limited measure offered by interest expense does not identify the functions responsible for the expense. Thus, the cost for carrying inventory listed in the physical distribution costing report cannot be identified in the financial reports.

The weekly cost of carrying inventory (WCCIN), which is an input to the physical distribution system report is calculated with the following equation:

$$WCCIN = INVTY * \frac{Z}{52}$$

where

INVTY = the level of the balance sheet variable inventory at the end of each week.

Z = w + c

c = the annual per unit cost of taxes, obsolescence, and other miscellaneous expenses of carrying inventories.

WCCIN is added to the physical distribution system report variable, inventory carrying cost (INCST).

Cost of Debt Routine. The routine for calculating and reporting interest expense in the model is associated with the event DAILY and with the event WEEKLY. Debt exists in the modeled firm in two essential forms: short term debt and long term debt. Short term debt is modeled assuming a revolving credit agreement under which the firm may borrow up to two million dollars. Interest charges are 6 percent per annum for the outstanding balance and .25 percent per annum for the unused balance.

At the end of each day, the amount of outstanding short term loans is added to an accumulating variable, short term lean dollar days (STLDD), which totals the number of dollar days on which outstanding interest must be paid. At the end of each week, STLDD is multiplied by $\frac{.06}{52}$ to determine the weekly interest charge on outstanding short term debt (WISTD). The weekly charge for the credit agreement (WCRCA) is calculated in the following steps:

1. STLDD is subtracted from \$10MM, the amount of unused dollar days which would accumulate under the credit agreement if no borrowings occurred during the week.

2. The difference is multiplied times $\frac{.0025}{52}$ to obtain MCRCA.

The total weekly short term debt expense (TWSTD) is WISTD + WCRCA.

At the end of each day, the amount of outstanding long term loans, including the current position of long term debt, is added to an accumulating variable, long term loan dollar days (LTLDD). At the end of each week LTLDD is multiplied by $\frac{.08}{52}$ to determine the weekly interest charges on outstanding long term debt WISLD. Total weekly interest charges (TWICH) are TWSTD + WISLD. TWICH is subtracted from cash and is added to the income statement variable, cost of debt (CSDBT).

Federal Income Tax Expense Routine. Federal income taxes each quarter take on two different values, the tax expense for the income statement and the actual taxes to be paid. The weekly federal income tax expense (WFTXX) is calculated using the following formula:

$$\text{WFTXX} = \frac{\$7500}{52} + .52\ (\text{WKOPY})$$

where

\$7500 = annual taxes on the first \$25,000 of earnings.

WKOPY = weekly operating income, before taxes.

WFTXX is added to the income statement variable, federal income taxes (FINCT). Actual taxes due from each week's operations (WFTXP) are calculated using the following formula:

$$WFTXP = \frac{\$7500}{52} + .52\ (ADJNI)$$

where

ADJNI = Net income, before depreciation and taxes, less accelerated depreciation.

WFTXP is added to the balance sheet variable, taxes payable (TXPAY). The difference WFTXP - WFTXX is added to the balance sheet variable, deferred taxes (DEFTX).

Accelerated depreciation for the five-year period is actually calculated at the beginning of each run and the amount of depreciation for each year is stored in the Supporting Data System. The accelerated depreciation for any given year for a particular distribution system is calculated by the following formula:

$$ACDCH_j\ (DC_i) = \frac{(1-a) * S}{50} + \frac{(a)\ (15-j) S}{120}$$

where

$ACDCH_j\ (DC_i)$ = accelerated depreciation charges for year j for (DC_i)

S = the original investment in DC_i.

a = the percent of the total investment in the facility which is in materials handling equipment

j = the year for which depreciation is being calculated.

$\frac{15-j}{120}$ = the formula for calculating SOYD depreciation for year j for an investment being depreciated over fifteen years.

Only the investment in materials handling equipment is eligible for accelerated depreciation.

For each year, $ACDCH_j\ (DC_i)$ is calculated and the total $\sum_{i=1}^{n} ACDCH_j\ (DC_i)$ is stored in the Supporting data system. Accelerated depreciation for each week is

$$\frac{\sum_{i=1}^{n} ACDCH_j}{52}.$$

Other Adjustments and Preparations of Financial Variables

The five special routines associated with the finance system are described in this section. They are:

1. Income on marketable securities.
2. Marketable security transactions expenses.
3. Quarterly Principle Re-payments on Long-Term Loans.
4. An annual Capital Budgeting Routine for replacement and additional equipment.
5. The Dividend Payout Routine.

Income on Marketable Securities Routine. The income from marketable securities is calculated each week by multiplying the accumulated dollar days of marketable securities (ADDMS), an input from the Operations Sub-system, by the daily return per dollar invested in marketable securities. The result, yield on marketable securities, is added to cash and to the income statement variable, marketable securities income (MKSCX). This routine is inactive for all experimentation performed in this research because of the relative unimportance of marketable securities for the industries modeled.

Transactions Expense Routine. When each marketable securities transaction occurs, the dollar amoung of the transaction is plugged into the formula

$$MKSTE = \$50 + \$.000025A$$

where

A = the dollar amount of the transaction

and the result, marketable securities transaction expense (MKSTE) is subtracted from cash and added to the income statement variable marketable securities transaction expense (MKSCX). This routine is inactive for all experimentation performed in this research.

Quarterly Principle Repayments Routine. The initial level of long term loans is repaid at the rate of 5 percent per year (1.25 percent per quarter) of the original loan. The even QTRPRP occurs to pay this amount in week seven and every thirteenth week after week seven for the remainder of the model (week 7, 20, 33, etc.). Principle repayments are made in the middle of the quarter to even out the heavy cash flows which occur only once per quarter. (The other heavy quarterly cash outflow is the payments of taxes, which occurs in weeks 13, 26, 39, etc.). When principle re-payment occurs, the balance sheet variables cash and long term loans are reduced by the amount of the re-payment.

Capital Budgeting Routine. The Capital Budgeting Routine actually consists of two different sub-routines:

1. Monitor and Control Facility Expansion.

2. Equipment Replacement and Addition.

The facility expansion sub-routine will occur only in the infrequent event that a distribution center outgrows its physical capacity. It is explained in the Monitor and Control Sub-System. The equipment replacement and addition sub-routine is associated with the event YEARLY, and occurs at the beginning of each year. The description of its behavior is as follows:

1. EQREP, the annual investment in replacement equipment is equal to the straight line depreciation on materials handling equipment for the previous year, which is

$$\frac{a * S}{15} (DC_i) + AMHDP_j \ (DC_i)$$

2. TINEQ, the total annual investment in replacement and additional equipment, is EQREP (1+r) where r is the rate of expansion of equipment.

3. TINEQ is subtracted from cash and the balance sheet variable PLNEQ.

4. The straight line depreciation charges on TINEQ for each year remaining in solution and the accelerated depreciation charges for each year remaining in solution are calculated and added to appropriate accumulating variables in the data base, $SDNEQ_j$ and $ADNEQ_j$

where

$SDNEQ_j$ = the straight line depreciation charges for year j on all equipment added during years (1, 2... j-1)

$ADNEQ_j$ = the accelerated depreciation charges for year j on all equipment added during years (1, 2...j-1)

The Dividend Payout Routine. The purpose of the dividend payout routine is to reflect the fact that all cash generated internally by the firm is not available for financing future operations. Dividends are paid quarterly and are based on the following decision rule:

> If quarterly earnings are > 0 , dividends = 0. Otherwise, dividends = .7 quarterly earnings.

This routine is called by the event QUARTERLY.

The Operations System: Monitor and Control Sub-System

The Monitor and Control sub-system performs two important general functions:

1. The supervisory function, the organizing element of the simulator, schedules events and activities so that each event occurs at the right time and the necessary information flows into and out of the various routines of the operating system as required.

2. The Controller function provides the capability of monitoring the value of certain variables of the model, comparing those actual values to standard, and adjusting the model when elements of the system are out of balance.

The supervisory function is discussed earlier in this chapter. This section describes the controller function.

The Controller Function

In the basic LREPS model, LOCATE, a major routine of the controller, monitors system performance to determine when and where new facilities should be brought into solution. In LREPS-F, the number of facilities in solution are held constant within experiments. Therefore, LOCATE is deactivitated and new facilities are added exogenously for experimental purposes.

The other activities of this function which require explanation are inventory management and facility expension.

Inventory Management. The purpose of the inventory management routine is to calculate the parameters for the inventory control routine in the Operating sub-system. The critical variable is inventory on hand for each tracked product, IOH (ITP). The parameters which are necessary for each tracked product are M (ITP), which is the level to which inventories for the tracked product are to be replenished; ROP (ITP) which is the level of IOH (ITP) at which inventories should be re-ordered; and M (ITP) - IOH (ITP), which is the amount which must be re-ordered to replenish IOH (ITP) to M (ITP).

The equations which are used in monitor and control to calculate these parameters are:

$$M = (EOQ + ROLTM) * DEM$$

and

$$ROP\ (ITP) = DEM * (ROLTM + BUF)$$

where

DEM = the daily sales forecast for this tracked product for DC_i.

EOQ = the number of days sales in the re-order quantity for this tracked product.

ROLTM = the re-order lead time for this tracked product at DC_i.

BUF = the number of days sales in safety stock for this tracked product at DC_i.

EOQ and BUF are exogenously inputted based on the inventory management policies of the sponsor company. DEM is calculated at the end of each quarter and is an exponentially smoothed sales forecast based on modeled sales from previous quarters. ROLTM is the actual experience in the model with re-orders for each tracked product at DC_i.

Faculty Expansion. The purpose of the facility expansion routine (EXPAND) is to increase the capacity of a distribution center when the quarterly volume moving through the facility exceeds 70 percent of the capacity of the facility. EXPAND is called at the end of each quarter, and if the $\frac{\text{DC Sales}}{\text{DC Capacity}}$ ratio exceeds .70, an investment is scheduled for the end of the sixth succeeding month sufficient to expand the DC to the next facility size.

The Report Generator System

The purpose of the Report Generator System is to arrange and process the output of the Operating System to generate several management and financial reports and to prepare the data for analysis. Output exists in two general forms: the operating results for each time period and the level of status variables at the end of each period. Reports which are generated for this research are:

1. The Individual Distribution Center Management Report.
2. The Total Physical Distribution System Management Report.
3. The Balance Sheet.
4. The Income Statement.
5. The Financial Ratio Report.
6. The Statistical Analysis Report.
7. The Comparative Incremental Report.

Individual Distribution Center Management Report

All items in this report are operating results. The purpose of the report is to facilitate the measurement of changes in cost and service between experiments. The report is printed quarterly for both DC's for all experiments with two facilities and the variables reported are as follows: total number of stock-outs; average days delay per stock-out; standard deviation days delay per stock-out; percent of total dollar sales delivered within normal order cycle times of four, five, six, seven, and eight or more days, respectively; outbound transportation costs; inbound transportation costs; throughput costs; and communications costs.

Total Physical Distribution System Management Report

All items in this report are operating results. The purpose of the report is to record the quarterly measures of service and cost for the total system. The variables reported are the same variables for the total system that are reported in the Individual Distribution Center Management Report, plus the economic cost of carrying inventories; the depreciation expense on private facilities; the economic cost of financing the private facilities; and the total cost of the physical distribution system.

The Balance Sheet

The balance sheet is a special arrangement of the levels of various financial status variables and can be printed as often as daily. It is stored on output tape weekly and printed quarterly. The items in the balance sheet and the routines which effect the level of each item are listed in Table 3.1.

The Income Statement

All items in the income statement are operating results. It is stored on output tape weekly and can be printed for any integer multiple of one week. For this research, it is printed quarterly. The items in the income statement and the routines associated with each item are listed in Table 3.1.

The Statistical Analysis Report

The purpose of this report is to summarize the output of the experiments to facilitate analysis of the results. The statistics generated by this report include:

1. The mean average and standard deviation of the twenty quarterly values for each variable in the Total Physical Distribution System Management Report, the Balance Sheet, the Income Statement, and the Financial Ratio Report.

2. A simple linear regression equation describing the relationship between quarterly sales and the quantity (Net Income + .05 Interest + Depreciation).

3. A simple linear regression equation describing the relationship between quarterly sales and the quantity (Net Income + Depreciation - Principle Re-payment).

4. The total, explained, and residual sum of squares; and the co-efficients of determination and correlation for the equations in (2) and (3).

The mean and standard deviation of the quarterly values are used to compare the experimental results in summary form. The equation $X = \frac{a}{b}$ formed by transforming the regression co-efficients is the break-even level of quarterly sales, which offers a composite measure of the extent to which a particular warehouse decision has affected downside risk of the firm. Changes in total variance of adjusted net income between experiments measure the shift in cash flow volatility resulting from each decision alternative. Changes in explained variance measure the sensitivity of net cash flows to the shifts in operating and financial leverage which results from the warehousing decision under study. Changes in residual variance measure the shifts in unexplained volatility resulting from each alternative. Unexplained variations in net cash flows are especially critical because they cannot be anticipated through sales forecasting.

The Financial Ratio Report

The ratios in this report were selected based on the following criteria:

1. The ratios identified by Carlson as effective predictors of "financial efficiency" in univariate analysis were included.[2]
2. Those ratios identified in three or more of the studies in the literature review as effective predictors of corporate failure were selected.
3. Ratios which measure certain aspects of financial position not measured by the ratios identified in (1) and (2) were added by the researcher.

The selected ratios and the formulas for calculating them are as follows (see pages 57-64 for definitions of symbols):

Ratio	Formula
$\frac{\text{Current Assets}}{\text{Current Liabilities}}$	$\frac{\text{Cash + ACCRC + INVTY + MKTSC}}{\text{ACCPY + TXPAY + STDBT}}$
Acid Ratio	$\frac{\text{Cash + ACCRC + MKTSC}}{\text{ACCPY + TXPAY + STDBT}}$
Cash Turnover	$\frac{\text{Quarterly Sales}}{\text{Average Weekly Cash Balance}}$
$\frac{\text{Working Capital}}{\text{Total Assets}}$	$\frac{\text{Cash + ACCRC + INVTY + MKTSC}}{\text{TOTAS}}$
$\frac{\text{Net Working Capital}}{\text{Total Assets}}$	$\frac{\text{Current Assets-Current Liabilities}}{\text{TOTAS}}$

Ratio	Formula
Fixed Asset Turnover	$\frac{\text{Quarterly Sales}}{\text{Average weekly level of Fixed Assets}}$
$\frac{\text{Debt}}{\text{Equity}}$	$\frac{\text{TOTAS} - \text{SHEQT}}{\text{SHEQT}}$
$\frac{\text{Debt}}{\text{Total Assets}}$	$\frac{\text{TOTAS} - \text{SHEQT}}{\text{TOTAS}}$
Return on Assets	$\frac{\text{EAFIT}}{\text{TOTAS}}$
Return on Equity	$\frac{\text{EAFIT}}{\text{SHEQT}}$
Debt Service Coverage	$\frac{\text{EAFIT + CSDBT + SLDPX}}{\text{CSDBT + Principle Re-payments}}$

Two of the ratios, return on assets and return on equity, are measures of performance. Each of the other ten ratios measures some aspect of financial position.

The Comparative Incremental Report

The purpose of this report is to compare the output between experiments. The report is printed quarterly and consists of the following elements:

1. The difference between each experiment and the base experiment of its experimental set of the quarterly value of the 61 variables in the Total Physical Distribution System Management Report, the Balance Sheet, the Income Statement, and the Financial Ratio Report.

2. The quarterly percentage change for each of the values in (1).

3. The twenty quarter average of the percentage changes reported in (1).

4. The standard deviation of that average.

5. A ranking of the 61 variables on the basis of average quarterly percentage change.

6. A ranking of the 61 variables on the basis of standard deviation quarterly percentage change.

Concluding Remarks

The output from the Report Generator System is the input to the analysis of experimental results. The findings from the analysis are reported in Chapter V and the output from the Report Generator is reported there in summary form as deemed necessary for discussion of the findings. Before the findings are reported, however, an explanation of the experimental design is presented.

CHAPTER III--FOOTNOTE REFERENCES

[1]Merton H. Miller and Daniel Orr, "A Model of the Demand for Money by Firms," Quarterly Journal of Economics, (August, 1966), p. 413-415.

[2]C. Robert Carlson, "A Financial Efficiency Model," (unpublished dissertation, Michigan State University, 1971).

CHAPTER IV

EXPERIMENTAL DESIGN

The first step in this research is the development of a dynamic computer simulation model on which necessary experimentation can be performed. The attainment of this intermediate stage is fulfilled through LREPS-F which is performing according to design specification and which is described in the foregoing chapter. The remaining steps center on experimentation on the model. The purpose of this chapter is to explain the design of those experiments.

The chapter is divided into two major sections. First, a general review of techniques and problems involved in design of computer simulation experiments is presented. By necessity the review is limited to general topics specifically pertinent to the design of experiments for this research. For a broader treatment, the reader is referred to Naylor.[1] In the second section, problems involved in the design of experiments on LREPS-F are discussed in the context of the general treatment, and the experimental design resultantly adopted is described.

Techniques and Problems in the Design of Simulation Experiments

Motives for Experimentation

Experimentation on simulation models is conducted for one of two general purposes, according to Naylor.[2] The first and by far most popular motivating factor is the desire to converge toward the optimal state (solution) for some real world process. A second, less common motive is to make a rather general investigation of the relationship between variables in the model in search of the "underlying mechanisms governing the process under study."[3]

Experimental Variables: Factors and Responses

Model variables for purposes of experimentation are divided into factors and response variables.[4] Factors, which are sometimes called independent variables, will usually be model parameters or exogenous inputs. Response variables, which are sometimes called dependent variables, are endogenous or output variables.[5] The purpose of experimental design is to test the effect of variations in certain factors (called test factors) on a response variable.

Not all independent variables which may affect a response variable in the real world are included as test factors in simulation experimentation. Some factors are included and observed in order to improve the precision (degree of explained variation) of the experimentation. Other independent variables in the real world which might affect the response variable are excluded in the interest of model efficiency. The role which these variables might play in the real world is represented within the model by the random character of the included exogenous variables.[6]

However, the inclusion of random, non-test factors need not distort the measurement of the effects of the controlled test factors on the response variables. Conditions of ceteris paribus, while unattainable in real world experiments, can often be achieved in computer simulation by using a common sequence of pseudorandom numbers on repeated computer runs. Thus, as Conway explains, the simulation experimenter can attain "perfect homogeneity of experimental medium" between experiments, even though random variations in exogenous variables are included within experiments.[7]

Statistical Inference in Experimental Design

The purpose of statistical inference from experimental results is two-fold:[8]

1. To determine if observed differences in the response variable between experimental runs could have occurred by chance rather than as a result of shifts in the test factors.
2. To generalize the results beyond the range of exogenous inputs considered.

Determining statistical significance of observed differences. The techniques of statistical inference most often used in the design of experiments on computer simulation are the analysis of variance techniques. However, the analysis of variance techniques (indeed all classical statistical inference techniques) are inappropriate when a common sequence of pseudorandom numbers has been used between experiments.[9] The null hypothesis of statistical inference is that there is no inherent difference between two or more sets of experimental results, that the observed differences occurred simply because of chance factors. A basic assumption is that the various experiments are independent of each other. In experimentation using a common sequence of pseudorandom numbers, as many exogenous variables as possible except for the test factors are held constant between experiments. By limiting these sources of residual variation a high degree of dependence between experiments is purposefully established.[10] Thus, some actual difference between the model outputs is expected and the failure of a technique of statistical inference to reject its null hypothesis would demonstrate a power deficiency in the statistical test, not the absence of output differences between the experimental runs.[11]

Even when the statistical test rejects the null hypothesis (recognizes the dependence between experimental outputs), the experimenter's objectives have likely not been served. He is most likely interested in how large a difference is exhibited between different experiments and between which experiments the largest differences are exhibited.[12]

Generalizing results beyond the range of test factors considered. Generalization of the results on the response variable of a small sample of values for the test factors to the larger population technically assumes that the levels of the test factors studied have been randomly selected.[13] While generalization therefore requires the use of statistical inference techniques, it is much more important when research is undertaken to experimentally search for the optimal solution to some problem. When the motive of the research is to study the underlying mechanisms of a process, as is true in this case, the necessity of generalization through statistical inference is far less critical. However, the researcher must be careful in generalizing his conclusions from experimentation of this nature.

The Many Response Problem

The literature on experimental design has established the capability of analyzing the simultaneous effects of four or more test factors on a single response variable, although the math involved becomes greatly complicated as the number of factors increases. However, experimental design techniques are virtually non-existent for multiple response experiments.[14] The multiple response problem, which occurs frequently in computer simulation experimentation, can exist in either or both of two aspects:[15]

1. The experimental output may consist of several response variables.

2. The researcher may wish to observe the output of a particular response variable as a time series (i.e. observe a different value for each year, month, or other convenient time period).

It is often possible to avoid the many response problem by treating an experiment with many responses as many experiments each with a single response. Or several responses could be combined and treated as a single response. However, it is not always possible to bypass the many response problem; often, multiple responses are inherent to the situation under study. Experimental design techniques in such situations are usually unique to the specific situation.[16]

Design of Experiments on LREPS-F

Motive for Experimentation

The underlying motive for experimentation on LREPS-F is to study the nature of the interaction between warehousing decisions and variables in the finance sub-systems of modeled firms in two industries under specified conditions. It is of the second, less common class of motives which Naylor describes as "the search...for the underlying mechanisms governing the (real world) process under study."

Test Factors, Non-Test Factors, and the Homogeniety of Experimentation

The test factors in this experimentation are the warehousing system alternatives; the sales growth rate bias; and the modeled industry (firm). The levels of each test factor to be studied are subjectively selected rather than randomly drawn.

LREPS-F includes several non-test factors which are included to improve the "precision" of the simulation. The level of daily sales and the geographic and product characteristies of daily sales are examples of non-test factors which are included. Random variations in these and other model non-test factors within experiments also represent the effect on the response variables in the real world from independent variables (factors) which are omitted from the model in the interest of efficiency. However, the effect of these random non-test factors is held constant across experiments through the use of a common sequence of psuedorandom numbers. Although many of the output variaables and observed exogenous variables vary widely within experiments, the results are exactly replicated if the simulation is repeated with no exogenous changes in test factors. Further, the values of the random non-test factors are exactly duplicated between experiments except in situations in which the non-test factors are affected by changes in test factors. Thus, conditions of perfect homogeneity of experimental medium are obtained and the observed differences in response variables between experiments are entirely attributable, either directly or indirectly, to shifts in the test factors.

Response Variables and the Multiple Response Problem

The response variables of primary interest in this experimentation are the finance sub-system variables discussed on pages 57-64. Responses of the distribution subsystem variables to shifts in the test factors are used by the researcher to identify the effects of factor shifts on the finance variables. As such, the distribution variables probably are also response variables, although they might be classified as non-test factors.

Including distribution variables, there are sixty-one response variables. In each experiment, the value for each response variable during each quarter for five years is reported. Thus, for purposes of experimental design this research suffers from both aspects of the multiple response problem. By working with twenty quarter average data, a general technique recommended by Naylor, the second aspect of the multiple response problem is rectified. In attacking the problem of a large number of response variables, Naylor reports that sometimes each response variable within an experiment can be treated as a separate experiment. Across thirty experimental runs, this solution would require 1830 statistical tests of experimental results. The sheer numbers involved would render the analysis almost meaningless. Furthermore, several of the financial variables have little meaning standing in isolation from each other. For these two reasons treating the response variables as separate experiments is rejected as a feasible technique of experimental design. When multiple response variables are inherent to the process studied, as is true in this case, there are no generally accepted techniques of experimental design.

Statistical Inference

The use of statistical inference on the experimental results from LREPS-F is technically inappropriate for two reasons:

1. The common sequence of pseudorandom numbers is used, thus assuring the high degree of dependence among experiments.
2. The experiments have multiple responses, which is a condition not conducive to experimental design techniques.

For measuring the effects of a shift in a single test factor (alternative warehousing systems, but for a given growth rate and firm), the failure to meet the requirements for statistical inference is not critical. When only one test factor is changed, the differences in response variables between experiments are entirely the result of the shift in this factor. The concept of significance in this context loses its popular inferential meaning and means not whether the observed differences do in fact exist, but whether they are sufficiently meaningful to merit reporting and analysis. In the interest of efficiency, they cannot all be analyzed and reported and the decision of how large a change should be to merit discussion is by its nature a subjective one.

Testing the significance of differences between experiments is not the only general purpose of statistical inference in experimental design. The other purpose, of statistically generalizing the results to levels of the test factors other than those specifically considered, is not of concern here because the levels of test factors were not randomly selected and the results of this research are therefore not qualified for generalization on technical grounds.

When both the warehousing system and either the growth rate assumption or industry have been changed, the observed differences in response variables might be the result of either or both of the factor shifts. Thus, statistical inference might be applicable in testing the consistency of the observed differences across growth rate assumptions and industry lines. The analysis and time required to test each individual response variable by this approach are prohibitive. Rather, the technique selected for testing the consistency of results under different growth rate assumptions and for different industries is that of comparing the ranks of the response variables on the basis of largest percentage changes. Although the assumptions of the technique are not strictly net, the Spearman Rank Correlation Co-efficient will be used because it serves the purpose of reducing the required comparison to a single measure. This technique has often been used in financial research for measuring the consistency of real world economic data over time when the assumption of independence between successive observations could not be met.[17]

The Research Design

The preceding sections of this chapter present a general discussion of experimental design techniques and the specific problems involved in designing experiments on LREPS-F. This section reports the research design adopted after due consideration of the problems discussed and several minor design problems.

Thirty experiments are performed for this research, with an experiment performed for each possible combination of five warehousing alternatives, three possible growth rates, and two modeled firms under study. The following is a listing of the code numbers used for purposes of identifying these experiments:

	Health Cares			Appliances		
Warehousing Alternative	.05	.15	-.05	.05	.15	-.05
Private at Chicago	1.01	1.06	1.11	2.01	2.06	2.11
Private at Chicago and Private at Columbus	1.02	1.07	1.12	2.02	2.07	2.12
Private at Chicago and Public at Columbus	1.03	1.08	1.13	2.03	2.08	2.13
Public at Columbus	1.04	1.09	1.14	2.04	1.09	2.14
Public at Chicago and Public at Columbus	1.05	1.10	1.15	2.05	2.10	2.15

The five experiments for a given firm and growth rate constitute an experimental set. For example, experiments 1.01 through 1.05 are an experimental set. 1.01, 1.06, 1.11, 2.01, 2.06, and 2.11 are the base experiments. It is assumed that this warehouse system is the one currently used by the firm and from which a change is proposed. For each of the other alternatives within an experimental set, only one factor (the warehouse system design) is changed from the base experiment and the changes in response variables are all directly or indirectly caused by the shift in the warehouse system. An absolute change of 10% in either the average or standard deviation value of a response variable is subjectively established as a "significant" response. The significantly affected response variables in each alternative experiment are ranked and reported. At the end of each experiment the researcher offers an explanation of the observed behavior of the response variables. These explanations are based on visual inspection (graphical and tabular) and are essential to the search for the underlying mechanisms of the interaction between warehousing decisions and finance sub-system variables.

The consistency of results between experimental sets is evaluated using the Spearman Correlation Co-efficient of the ranks of response variables of each warehousing system design with the ranks of the variables for the comparable alternatives under different growth rate assumptions and in the other modeled industry. For example, the ranks of the significantly affected response variables between Experiments 1.01 and 1.02 are correlated to the ranks for 1.06 vs. 1.07, to 1.11 vs. 1.12 and to 2.01 vs.

2.02. Although the original design was to explain only those differences which were statistically significant at the .01 level, the differences between experimental sets are visually inspected after each test. Particular interest is given in those situations in which the difference is statistically significant at the .01 level. The purpose of testing the consistency of results is to gain a better understanding of the observed interactions. Since it is documented that statistical significance loses much of its meaning in this type of research, it is considered but not assigned prime importance.

CHAPTER IV--FOOTNOTE REFERENCES

[1]Thomas H. Naylor, Joseph H. Balintfy, Donald S. Burdick, and Kong Chu, Computer Simulation Techniques (New York: John Wiley, 1966).

[2]Ibid., p. 338

[3]Ibid.

[4]Ibid., p. 332

[5]Ibid.

[6]Ibid., p. 323

[7]R. W. Conway, "Some Tactical Problems in Digital Simulation," Management Science, Volume X (October, 1963), p. 52.

[8]Ibid., p. 53

[9]Ibid.

[10]Ibid.

[11]Ibid.

[12]G. E. P. Box and William G. Hunter, "The Experimental Study of Physical Mechanisms," Technometrics, Volume 7 (February, 1965), p. 24.

[13]Naylor, op. cit., p. 325

[14]Ibid., p. 339

[15]Ibid., p. 340

[16]Conway, op. cit., p. 61

[17]James E. Murphy, "Earnings Growth and Price Changes," Financial Analysts Journal, Volume 25 (September, 1968), p. 97.

CHAPTER V

EXPERIMENTAL RESULTS AND ANALYSIS

The purpose of this chapter is:

1. To report the response variables which were significantly affected in each of the experiments.

2. To offer an explanation for these results.

3. To report the degree of consistency among the response variables for different growth rate assumptions and for the different industries studied.

4. To comment on the significance of these findings to the general understanding of the cross-functional interaction between warehousing decisions and finance sub-system variables and to report several interesting by-products of the research.

The changes in response variables from a shift to a two public warehousing system and to a one private, one public warehousing system are found to be simply combinations of the changes exhibited in shifting to a single public warehouse and in changing from a one private to a two private warehouse system. The significance of this finding is that the crucial questions in warehouse system design for financial variables appear to be public vs private warehousing and the number of warehouses included in the system. The other two alternatives are variations on these two questions. Therefore, this discussion centers on the significantly affected financial variables by shifting from one private warehouse to either one public or two private warehouses. For these purposes "significantly affected variables" are those for which the decision alternative in question causes change in the average or standard deviation quarterly value of more than 10 percent or less than -10 percent from the equivalent value in the base experiment. Twenty quarter average data are used as a solution to the time series aspect of the multiple response problem. The standard deviation is used to detect intermediate variations in the variables which would be overlooked if only one parameter were examined. The changes in distribution variables are included to help explain the changes in financial variables.

Experimentation on the Modeled Health Cares Company

The results of experimentation on the modeled health cares company and observations drawn from those results are reported in this section and are compared to the results from experimentation on the appliance company in the following section.

Addition of a Second Warehouse

.05 Annual Growth Rate in Sales. Those financial variables which are significantly affected by the addition of a private warehouse at Columbus when sales are designed to grow at 5 percent per year are ranked on the basis of largest percentage change in Table 5.1. The distribution variables which are significantly affected by this alternative are ranked on the basis of largest percentage change in Table 5.2.

Analysis of the reasons for these results identifies three direct effects to which the other changes can be traced:

1. The average level of inventories increases by $299.5 thousand.

2. The average level of accounts payable declines by $130.2 thousand.

3. Average quarterly net earnings drop by $9.8 thousand partly because of the increased interest expense on the short term loans required to offset the change in inventories and accounts payable; and partly because the cost savings from reduced outbound transportation expenses is not sufficient to offset the increases in the inbound transportation, throughput, communications, and facility expenses.

These three basic changes are reflected through significant changes in the financial ratios and statistics in the following ways:

1. Debt/net worth and cash turnover increase and the acid ratio deteriorates, all reflecting the strain on cash and short term financing brought on by the adverse changes in inventories and accounts payable.

2. Debt service coverage deteriorates and return on both assets and equity decline, all because earnings drop and short term debt rises.

3. The levels of sales required to break-even both for profits and for servicing debt increase, indicating that the company's ability to withstand downturns has been impaired.

TABLE 5.1.--Finance Variables Singificantly Affected by the Addition of a Second Private Warehouse in the Health Cares Company.

		Quarterly Percentage Change	
Rank	Variable	Average	Standard Deviation
1	Short Term Loans	94	93
2	Interest Expense	43	46
3	Net Liquid Assets	-41	252
4	Inventories	38	70
5	Taxes Payable	-34	30
6	Debt Service Coverage	-32	29
7	Cash Turnover	32	47
8	Return on Assets	-26	73
9	Debt/Equity	-23	34
10	Net Earnings	-22	28
11	Inventory Turnover	21	33
12	Residual Variance	20	-
13	B Regression Co-efficient	-20	-
14	Total Liabilities	17	31
15	Return on Equity	-16	76
16	Break-even: Debt Servicing	16	-
17	Acid Ratio	-16	24
18	Accounts Payable	-13	20
19	Break-even: Net Income	13	-
20	Cash	- 9	30

TABLE 5.2.--Distribution Variables Significantly Affected by the Addition of a Second Private Warehouse in the Health Cares Company.

		Quarterly Percentage Change	
Rank	Variable	Average	Standard Deviation
1	4 Day ORCT	195	13
2	Stockouts	104	182
3	Inventory Expense	49	62
4	S.D. Stockout Days Delays	-34	87
5	Communications Expense	31	3
6	Throughput Expense	26	8
7	5 Day ORCT	20	3
8	Avg. Stockout Days Delays	15	53
9	Inbound Transport Exp.	15	29
10	Outbound Transport Exp.	- 8	1

4. The residual variance of adjusted net income increases, indicating that an element of instability has been added to the profit function. This element of additional instability is the increased variability of inventories and accounts payable, which result in wider swings in cash, short term loans, and interest expense.

The composite analysis is overwhelming that the financial position of this firm would be impaired by the decision to add a second private warehouse if sales grow at a normal rate. The most interesting observation in this experiment is the effect which the second warehouse has on accounts payable and inventories. This interaction is explored in more detail in relation to other experiments and in the last section of the chapter.

<u>Sensitivity Experiments: .15 and -.05 Growth Rates</u>. The ranks of financial variables which are significantly changed by the addition of a private facility at Columbus under the assumption of an annual growth rate of .15 (Experiment 1.07) and under the assumption of an annual growth rate of -.05 (Experiment 1.12) are compared to the results under the .05 growth rate assumption in Table 5.3. The ranks of the significantly affected distribution variables are compared in Table 5.4.

The Spearman Rank Correlations between the financial results of 1.02 and of 1.07 and 1.12 are .89 and .54, respectively. Thus, the results under the .15 growth rate assumption do not change substantially from those

TABLE 5.3. --Comparison of Financial Variables Significantly Affected by the Addition of a Second Private Warehouse Under Varying Growth Rate Assumptions for the Health Cares Company

	Rank			Avg. Quarterly % Change		
Variable	-.05	.05	.15	-.05	.05	.15
Short Term Loans	1	1	2	116	94	112
Interest Expense	9	2	3	37	43	35
Net Liquid Assets	1	3	1	- 85	-41	-133
Inventories	3	4	4	90	38	33
Taxes Payable	5	5	6	- 63	-34	- 23
Debt Service Coverage	18	6	5	- 10	-32	- 24
Cash Turnover	2	7	18	94	32	12
Return on Assets	7	8	9	- 41	-26	- 20
Debt/Equity	12	9	7	20	-28	- 21
Net Earnings	15	10	10	- 12	-22	18
Inventory Turnover	8	11	11	- 41	21	- 18
Residual Variance	20	12	22	6	20	-
B Regression Co-efficient	17	13	21	- 11	20	2
Total Liabilities	13	14	16	16	17	14
Return on Equity	16	15	12	- 12	-16	- 18
Break-even: Debt Servicing	19	16	13	8	16	17
Acid Ratio	10	17	14	- 30	-16	- 15
Accounts Payable	14	18	8	- 15	-13	- 21
Break-even: Net Income	21	19	15	6	13	15
Cash	6	20	20	- 46	- 9	- 6
Total Variance	11	21	19	23	-	- 11
α Regression Co-efficient	22	22	17	- 5	- 9	13

TABLE 5.4.--Comparison of Distribution Variables Significantly Affected by the Addition of a Second Private Warehouse Under Varying Growth Rate Assumptions for the Health Cares Company

Variable	Rank			Average Quarterly % Change		
	-.05	.05	.15	-.05	.05	.15
4 Day ORCT	1	1	1	204	195	191
Stockouts	2	2	2	94	104	93
Inventory Expense	3	3	3	89	49	31
S. D. Stockout Days Delays	5	4	6	42	- 34	- 20
Communications Expense	8	5	5	20	30	23
Throughput Expense	6	6	4	21	26	30
5 Day ORCT	7	7	7	21	20	20
Avg. Stockout Days Delays	4	8	9	67	15	9
Inbound Transport. Exp.	9	9	8	19	15	16
Outbound Transport. Exp.	10	10	10	- 9	- 8	- 8

of the .05 assumption, but the results of the -.05 assumption do reflect an interesting difference. Four financial ratios have at least a three position change in rank between 1.02 and 1.12. These are: cash turnover, inventory turnover, the acid ratio, and debt service coverage.

These differences in responses between growth rate assumptions occur basically for two reasons. First, the exponential smoothing sales forecasting technique causes forecasted sales and thus inventory levels to be below actual sales during upturns and above actual sales during downturns. Splitting the single demand forecast into two forecasts aggravates this forecast error. The result is that the difference in inventories between a one and two warehouse system is larger under a period of sales decay than during a period of sales growth.

Second, when sales decline within an experiment, a partial liquidation of inventories and accounts receivable occurs. This results in a build-up of cash and a partial re-payment of short term loans. Therefore, the decline in accounts payable and the increase in inventories which results from adding the second warehouse can be financed largely from cash when sales are decaying (Experiment 1.12). When sales are increasing, the levels of cash are minimal because inventories and accounts receivable are building up faster than accounts payable, causing a strain on cash. Thus in 1.02 and 1.07 drops in accounts payable and increases in inventories resulting from the second warehouse are financed through short term debt.

The interesting result is that the addition of the second warehouse causes a larger increase in inventories but impairs the debt service coverage ratio less during a -.05 decay in sales than it does in a .05 or .15 growth in sales. This is because the firm is in a better position to finance a second warehouse when current non-liquid assets are being worked off and serves to illustrate that during periods when firms need to undergo structural changes is often when they are least prepared to finance them. The implication is that such changes and the provision for financing them should be planned well in advance of their actualization.

Observations of Interest in the Distribution Area. The measures of distribution service efficiency offer no help in explaining the changes in the financial variables. This is because LREPS-F does not include a feedback loop between system performance and customer demand. However, some general observations are interesting concerning the service variables.

Under all three growth rate assumptions, the two distribution variables most significantly affected by the addition of a second warehouse are percent of sales delivered within four day order cycle time and the number of stockouts. The former improves by approximately 200 percent while the latter deteriorates (increases) by approximately 100 percent. The impressive improvement in delivery times quite possibly could have two favorable effects on the financial system which are not demonstrated here because of the absence of the necessary feedback mechanisms in the model. First, the improved delivery times could stimulate sales, and thus bolster the profit and cash flow picture. Second, quicker delivery could mean quicker billing and improved turnover in accounts receivable, thus improving cash flows and the cash balance. These relationships are highly conjectural, however; and just as it is difficult to model them, it is dangerous to speculate on the nature of these improvements.

The adverse effect which the increase in stockouts would have on customer demand might offset the favorable effects of improved delivery time. However, the deterioration in stockout performance in this research has little meaning on an absolute basis. Consider the .05 growth rate (Experiment 1.02). The increase in per quarter stockouts from approximately 5.1 to 7.5 represents a shift in the ratio $\frac{\text{Stockouts}}{\text{Total Orders}}$ from .0009 to .0015. The percent of orders filled on demand is still .9985 after the change. That any adverse effects would occur from such a change is doubtful.

Public Versus Private Warehousing

.05 Annual Growth Rate in Sales. The financial variables in the health cares company significantly affected by the decision to use a public instead of a private warehouse at Chicago assuming a 5 percent annual growth rate in sales are ranked in Table 5.5. The significantly affected distribution variables are also ranked in Table 5.5. The two direct effects which trigger the changes in financial ratios and statistics are as follows:

1. The investment in the facility is eliminated along with the financing, depreciation charges, deferred taxes, and interest expense associated with it.

2. Average earnings decline because the drop in depreciation and interest expense is not sufficient to offset the additional throughput expense.

These basic changes are reflected in significant changes in the following financial ratios and statistics:

1. $\frac{\text{Working Capital}}{\text{Total Assets}}$ and $\frac{\text{Net Working Capital}}{\text{Total Assets}}$ increase significantly, and the coefficient of the adjusted net income equation declines, primarily reflecting the drop in fixed assets and fixed expenses.

2. Debt service coverage improves because of the elimination of interest and principle re-payment on long term debt.

3. Return on assets and return on equity improve, indicating that the drop in investment was more than proportional to the drop in net earnings. The additional earnings of the private facility would offer a return of only 3.6 percent after taxes, on the average, over the five year period.

TABLE 5.5.--Financial and Distribution Variables Significantly Affected by Using One Public Instead of One Private Warehouse in the Health Cares Company

Rank	Finance Variables	Quarterly Percentage Change Average	Standard Deviation
1	Debt Service Coverage	144	97
2	Plant and Equipment	-100	-
3	Deferred Taxes	-100	-
4	Long Term Loans	-100	-
5	Depreciation	-100	-
6	Fixed Asset Turnover	-100	-
7	Interest Expense	- 61	13
8	Working Capital/Total Assets	45	5
9	Net Working Capital/ Total Assets	44	7
10	Net Worth	-33	5
11	Total Assets	-32	3
12	α Regression Co-efficient	-32	-
13	Total Liabilities	-31	6
14	B Regression Co-efficient	-22	-
15	Total Variance	-20	-
16	Return on Net Worth	20	50
17	Break-even: Debt Servicing	-18	-
18	Return on Assets	16	35
19	Net Liquid Assets	-15	86
20	Taxes Payable	-15	5
21	Net Earnings	-10	5
22	Cash	-10	16

Rank	Distribution Variables	Average	Standard Deviation
1	Throughput Expenses	105	10
2	Depreciation	-100	-
3	Facility Capital Expense	-100	-

4. The total variance of the adjusted net income equation declines, indicating a strong improvement in the stability of cash flows.

5. The break-even level of sales drops for adjusted net income and even more so for the level required to service the firms debt, indicating a much stronger defensive posture in case of an economic or market reversal.

That such a change renders the firm less susceptible to economic downturn or market reversals is seen in Figure 5.1 in which quarterly sales are graphed against the difference between quarterly earnings for the public and the private systems. The public system is superior for lower sales volumes because of the heavier fixed expenses in private systems, while the private system becomes increasingly superior as the sales volume increases. This is a classic illustration of the effect of leverage.

A special note on the subject of leverage is in order. The level of fixed expenses is reduced significantly in going from a one private to a one public warehousing system. This is seen in the shift in the regression α co-efficient from -\$56,400 to -\$38,100, a shift of 32 percent. However, the level of sales required for adjusted net income to break-even shifts only 7 percent (from \$1.367 million to \$1.268 million per quarter), much less than would have been expected considering that net earnings decline by only 10 percent. The depreciation flows generated by the significant increase in fixed investment are included in adjusted net income and these depreciation flows keep the level of sales required to

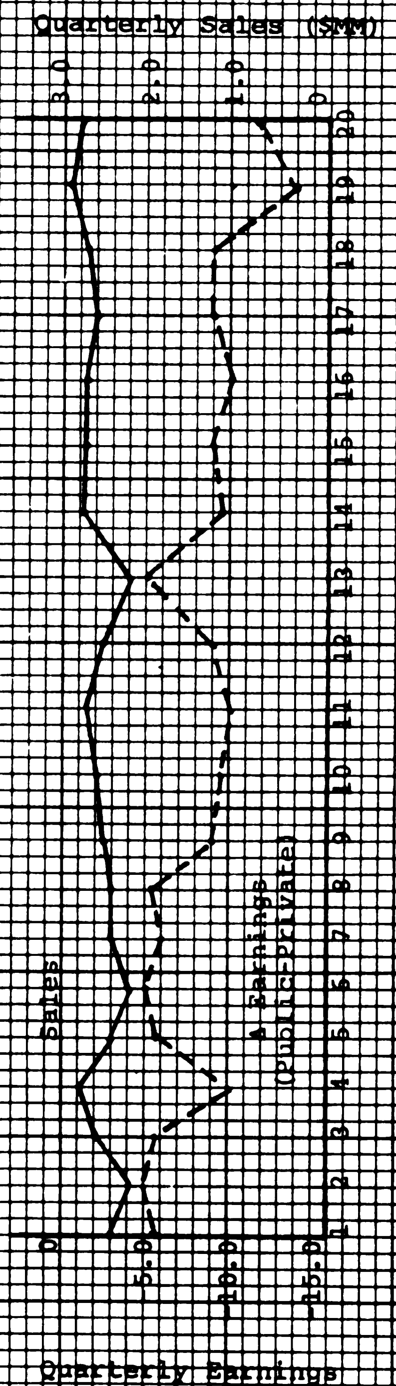


Figure 5.1.--Quarterly Sales and the Earnings Change From Experiment 1.01 to 1.04

break-even on adjusted net income for 1.01 from being much higher.

However, depreciation flows are simply a re-capture of funds expended at the time of the investment in a private facility. That net liquid assets and break-even sales for the one private facility system compare so favorably is largely because of an assumption of this research. For all experiments, it is assumed that the original investment in plant and equipment (warehouses) is made entirely with externally secured funds and that the funds are obtained 50 percent through debt and 50 percent through equity.

Another assumption which could be made is that the money needed to finance the private warehouse exists within the firm as the result of retained earnings; or if the private facility is not built, that this excess capital is put into fairly safe marketable securities yielding 6 percent per year, before taxes. The same effect can be obtained by assuming the company goes to the outside for the entire financing through equity sources and then decides not to build the public facility. Table 5.6 compares the actual effects on selected financial variables in Experiment 1.04 to an estimate of those which would have been achieved if the alternate assumption concerning financing had been used.

Under the alternative assumption, private compares much more favorably to public than before in return on

TABLE 5.6.--Comparison of Certain Key Variables to the Public vs Private Analysis Under Alternative Assumptions Concerning Source of Financing.

Variable	Private		Public		Public - Private	
	Actual	Alternate	Actual	Alternate	Actual	Alternate
Net Income[1]	46.5	54.0	38.3	50.3	-8.2	-3.7
Net Liquid Assets[1]	-83.4	66.6	-146.1	1294.9	-62.8	1228.3
Total Assets[1]	3823.1	4020.0	2614.3	3584.4		
Net Worth[1]	1955.7	2900.0	1314.0	2756.4	-641.7	-143.6
Debt/Equity	.974	.350	1.02	.268	.028	-.082
Current Ratio	2.1	2.8	2.05	4.3	.7	2.25
Return on Assets	.052	.054	.060	.056	.008	.002
Return on Equity	.100	.074	.120	.073	.020	-.001
Break-even: Net Income[2]	1.367	1.000	1.268	.866	-/099	-.134

[1] In thousands of dollars

[2] In millions of dollars

investment. However, the superiority of public warehousing as a hedge against economic downturns or market reversals is magnified. Under the alternate calculations, sales can drop 14 percent further before adjusted net income turns negative if a public instead of a private warehouse is used. Further, there are $1.228 million dollars more of net liquid assets to cushion against unprofitable periods if public is used instead of private.

The implication of this comparison is that private warehousing is typically a more risky alternative than public warehousing. If the firm goes to the outside for financing of the private facility, partly through equity, the return of capital in the form of depreciation flows can provide additional protection against reversals. However, if the firm decides on the public alternative it likely can go to the outside for the needed liquidity protection and use only a fraction as much of its outside financing capacity as would be used under the private facility alternative.

Sensitivity Experiments: .15 and -.05 Growth Rates. The ranks of financial variables which are significantly changed by the use of a public facility instead of a private facility at Chicago under the assumption of an annual growth rate of .15 (Experiment 1.07) and under the assumption of an annual growth rate of -.05 (Experiment 1.12) are compared to the results under the .05 growth rate assumption in Table 5.7. The ranks of

TABLE 5.7. --Comparison of Financial Variables Significantly Affected by Using One Public Instead of One Private Warehouse Under Varying Growth Rate Assumptions for the Health Cares Company

Variable	Rank			Avg. Quarterly % Change		
	-.05	.05	.15	-.05	.05	.15
Debt Service Coverage	1	1	6	155	107	86
Plant and Equipment	2	2	1	-100	-100	-100
Deferred Taxes	3	3	2	-100	-100	-100
Long Term Loans	4	4	3	-100	-100	-100
Depreciation	5	5	4	-100	-100	-100
Fixed Asset Turnover	6	6	5	-100	-100	-100
Net Liquid Assets	15	7	17	- 15	- 75	- 18
Interest Expense	7	8	7	- 69	- 61	- 48
Working Capital/Total Assets	9	9	8	51	45	39
Net Worth	8	10	10	52	44	33
Total Assets	12	11	11	- 35	- 33	- 28
α Regression Co-efficient	16	12	12	- 12	- 32	- 24
Total Liabilities	11	13	14	- 40	- 31	- 23
B Regression Co-efficient	17	14	13	- 12	- 22	- 28
Total Variance	14	15	9	- 17	- 20	- 35
Return on Net Worth	13	16	16	25	20	22
Break-even: Debt Servicing	21	17	21	- 4	- 18	- 6
Return on Assets	10	18	22	50	16	5
Taxes Payable	18	19	19	- 9	- 15	- 17
Net Earnings	19	20	18	- 9	- 10	- 19
Cash	20	21	20	- 6	- 10	- 7

distribution variables significantly affected under .15 and -.05 are exactly the same as under the .05 growth rate assumption.

The relative importance of financial variables remain strikingly consistent as the growth rate assumption is changed. The Spearman Rank Correlation of 1.04 and of 1.09 and 1.14 are .93 and .95, respectively. Among those variables which do exhibit a change in rank, net liquid assets rank much higher in 1.04 only because the absolute value of net liquid assets in the base experiment for the .05 growth rate is much smaller than in the base experiments for the other two assumed growth rates. The actual change in net liquid assets is about the same. The only other inconsistencies were expected. The superiority of public over private warehouses in both return on assets and in debt service coverage improves significantly as the sales growth rate declines from .15 to .05 to -.05 as the theory of leverage suggests it should.

The most interesting finding from these experiments is associated with accounts payable, which does not exhibit a 10 percent change and therefore is not listed as a significantly affected variable under any of the growth rate assumptions. However, it does experience a persistent change each time a shift from private to public warehousing is tested. The reason is that public warehousing charges generate accounts payable while many private warehousing expenses do not and therefore the shift to public warehousing can be a small but permanent source of financing. This finding is developed in detail in the last section of this chapter.

Research By-Products to Financial Analysis

Comparison of experimental results with different growth rate assumptions but with no change in the warehousing system provides interesting insights to financial analysis and control. The following is a comparison of the values of certain key financial ratios in Experiments 1.12, 1.02, and 1.07, which are the experiments with two private warehouses under the three growth rate assumptions.

	Experiments		
Ratio	1.12	1.02	1.07
Current Ratio	2.05	1.87	1.70
Acid Ratio	1.12	1.06	.94
Cash Turnover	6.91	10.02	13.32
Debt/Equity	1.07	1.18	1.34
Debt Service Coverage	1.74	2.20	2.42

This comparison is an experimental verification of the classic relationship between financial position and sales growth. As the rate of sales growth increases, earnings and return on assets and equity also increase. Yet the current and acid ratios, cash turnover, and the debt/equity ratio all experience significant deterioration. This lends strong support to the financial axiom that

profitable, high growth oriented companies often get into financial difficulty because as sales grow, inventories and accounts receivable grow faster than accounts payable. The net result is a drain on cash. This problem is especially crucial for wholesale companies because their operations revolve around the purchase, control, and selling of inventories.

The relationships between growth and the debt/equity (D/E), debt service coverage, and acid test ratios are also interesting. As the growth rate in sales increases, the D/E ratio increases because current assets increase, causing short term debt to rise. However, the debt service coverage ratio increases substantially, indicating that the increase in the D/E ratio has not hurt the company. Indeed, this type of increase in D/E is one that redeems itself as sales growth drops back off. A major implication is that only funded debt should be included in the $\frac{\text{Debt}}{\text{Equity}}$ ratio.

Likewise, in calculating the debt service coverage ratio, including the interest expense on working capital loans introduces a downward bias into the calculation. The purpose of this ratio is to determine how much protection against sales, earnings, or cash flow downturns is afforded by the current relationship between cash flows and debt servicing requirements. Since working capital loans should be redeemed from liquidating current assets as sales turn downward, liquid protection for this type of debt service is really not necessary. The implication is that only funded debt should be included in debt service coverage calculations.

As illustrated in the preceding table, the acid test ratio improves significantly as sales turn down and deteriorates when sales are increasing. Thus, the appearance of liquidity deterioration which is given by the acid test ratio as sales grow would tend to disappear if sales were to turn back down. The implication is that the acid test ratio is a very poor measure of the susceptibility of the firm to economic downturns or market reversals. Rather, its value is in signaling the danger of financing too much of the growth of the firm with short term debt, if the growth pattern is expected to continue. This analysis is tempered with the recognition that if the firm were operating improfitably, a deteriorating acid test ratio as sales increase might be a warning of impending financial difficulty.

Model Changes Required for the Appliances Company

The appliance wholesale industry is dissimilar to the health cares wholesale industry in several major respect. The demand pattern is seasonal for appliances and not for most health care products. The appliances product lines are much less diversified. Transportation and handling characteristics are very dissimilar between the two industries. Experimentation on the modeled appliances company therefore offers a good test of the consistency of research results across industry lines and this section describes the basic model changes which are required to model the appliances company.

Product and Demand Information

The data in the order file are changed to reflect the characteristics of fifty products identified in questionnaire survey responses by two companies in the appliances industry. The fifty products included product items of various styles and colors in the following product lines: washers, dryers, refrigerators, and ranges. Since inventory control is performed on each of the fifty products, tracked product extrapolation factors are unnecessary and all routines including extrapolation factors are modified accordingly.

Demand Forecasting Information

The mean and standard deviation of the distribution from which daily sales are randomly generated are left unchanged from the health cares industry. However, the seasonal weighting factors are changes from $w_i = 1.0$ for all i to the following:

4 Week Period	w_i	4 Week Period	w_i
1	.7	8	1.4
2	.7	9	1.2
3	.8	10	1.1
4	1.0	11	.9
5	1.2	12	.7
6	1.3	13	.6
7	1.4		

These weighting factors are based on the seasonal demand patterns identified in the data survey of two appliance firms.

Distribution System Changes

The two alternative distribution centers (DC's) remain Chicago and Columbus. However, reflecting the general location patterns of appliance industry manufacturers, the three supplier locations (MCC's) are changed to:

1. Benton Harbor, Michigan
2. Marien, Ohio
3. Ft. Smith, Arkansas

Changes in Costing Equations

The outbound transportation regression equations for the appliance industry are calculated based on rates provided by a transportation consulting firm and on transportation expense data provided by the respondent companies. The inbound transportation freight rates are from the same sources. Throughput, communications, and facility investment expense data are based on information provided by the respondent companies and by an independent professional society.

Balance Sheet Initialization and Model Pre-testing

The initial values of balance sheet items are established based on industry average data from the Robert Morris Associates reports for the appliance wholesale industry. Various financial and cost parameters were adjusted through pre-testing so that the model output for the base experiment is a reasonable approximation of the financial performance of the hypothetical "typical firm" in the industry.

Comparison of Results Between Industries

The results from experimentation on the modeled appliances company are reported and compared to the results from the health cares company in this section.

Addition of a Second Warehouse

The financial variables which are significantly affected by the addition of a private warehouse at Columbus for the appliances company under the assumption of growth rates of .05, .15, or -.05 are listed in Table 5.8. The ranks and the average quarterly percentage changes for those variables under each of the growth rate assumptions are also listed. The ranks and the average quarterly percentage changes in distribution variables under each of the growth rate assumptions are

TABLE 5.8. --Comparison of Financial Variables Significantly Affected by the Addition of a Second Private Warehouse Under Varying Growth Rate Assumptions for the Appliances Company.

	Rank			Avg. Quarterly % Change		
Variable	-.05	.05	.15	-.05	.05	.15
Net Liquid Assets	1	1	1	- 54	-190	-115
Short Term Loans	10	2	2	20	49	57
Interest Expense	7	3	3	23	29	32
Cash Turnover	2	4	13	47	28	8
Plant and Equipment	4	5	4	26	26	26
Long Term Loans	5	6	5	25	25	25
Depreciation	6	7	7	24	24	24
Deferred Taxes	8	8	6	22	23	25
Cash	3	9	16	- 28	- 21	- 8
Fixed Asset Turnover	9	10	8	- 21	- 21	- 21
Debt Service Coverage	15	11	9	- 9	- 15	- 19
Accounts Payable	13	12	10	- 15	- 15	- 17
Net Worth	16	13	14	9	11	8
Net Income	14	14	15	- 10	- 4	- 4
Return on Assets	12	15	12	- 16	- 7	- 9
Return on Equity	11	16	11	- 17	- 10	- 11

listed in Table 5.9.

On balance, the change to a two warehousing system has the same relative impact on financial variables in this industry as in the health cares industry. This is demonstrated by the following Spearman Rank Correlations between their ranks in the two industries, which would have been significant at the .01 level at .46.

Growth Rate	Correlation of Ranks of Finance Variables Between Industries
.05	.50
.15	.57
-.05	.55

However, there are several major differences between the two companies. The total distribution system cost changes are substantially smaller in the appliances company from addition of the second warehouse. Because of differences in freight rate structures between the two industries, the addition of a second warehouse generates much larger transportation savings in the appliances company. However, this advantage is partially offset by the heavier additional fixed facility investment for appliances, which is necessary because of the excess capacity created by the seasonal pattern of demand in the appliances industry.

The net result of the cost changes is that while the addition of a second warehouse is an improfitable move for the appliances company, it is not as improfitable as in the health cares company. This simply means

TABLE 5.9. --Comparison of Distribution Variables Significantly Affected by the Addition of a Second Private Warehouse Under Varying Growth Rate Assumptions for the Appliances Company.

	Rank			Avg. Quarterly % Change		
Variable	-.05	.05	.15	-.05	.05	.15
4 Day ORCT	1	1	1	214	210	199
Throughput Expenses	3	2	3	56	53	50
Communication Expenses	4	3	4	50	50	50
Stockouts	2	4	2	63	40	147
Facilities Capital Exp.	5	5	5	23	25	25
5 Day ORCT	6	6	6	24	24	24
Depreciation	7	7	7	24	24	24
S. D. Stockout Days Delay	9	8	8	17	- 23	- 18
Outbound Transp. Exp.	10	9	10	- 10	- 10	- 10
Avg. Stockout Days Delay	8	10	9	18	- 4	17

that the profit desirability of adding a second warehouse will vary depending upon the specific situation, which is an obvious fact not in question for this research.

Of special interest here is that the addition of a second warehouse for appliances causes inventories to increase by only one to four percent while in health cares inventories increase by 33 to 90 percent. It is generally accepted in the distribution field that safety inventories will normally increase with the addition of a warehouse and that a good approximation of that increase can be found from the formula:[1]

$$SS_n = \frac{SS_1(n)}{\sqrt{n}}$$

where: SS_n = safety stock for n locations

n = the number of locations

SS_1 = safety stock for one location

Since safety inventories are designed to be 25 percent of total inventories in the modeled companies, and since the general formula estimates the increase in safety stocks from adding a second warehouse at approximately 40%, the expected increase in total inventories is approximately 10%. The primary reason the results from this research depart from the general pattern is that the above formula is based on the assumption that demand at the two locations are independent of one another. Since sales in LREPS-F are randonly generated for the total company, and then randomly assigned to the individual DC's, there is a high degree of dependence between demand at the two locations.

The inconsistency in research results between the two industries exists because demand is relatively stable in health cares and highly seasonal in appliances. A prime advantage for using a exponential smoothing inventory forecasting technique such as the one in LREPS-F instead of using simple trend projection is that exponential smoothing will detect and forecast intermediate upswings and downturns in the demand pattern. The temporal swings detected in appliances are usually actual seasonal swings and the forecast technique is very accurate. The swings detected and forecasted in health cares are usually only random noise around the stable trend line and therefore result in a substantial amount of forecast error. This forecast error introduces instability to the level of inventories which is magnified when daily sales are randomly assigned between two locations.

Because appliance inventories are not significantly affected, the changes in short term loans, the $\frac{\text{Debt}}{\text{Equity}}$ ratio and the acid test ratio are much smaller in the appliances company than in the health cares company. Furthermore, the risk or defensive posture does not deteriorate as badly in the appliances company, which is indicated by the much smaller changes in total variance of adjusted net income and the level of sales required to break-even on earnings and adjusted net income.

Conspicuous in that they did not change substantially in importance between industries are accounts payable (A/P). The downward shifts in A/P remained approximately the same in the appliances as in the health cares company despite the substantial differences in inventories. The relationship found between the change in the number of warehouses, inventories, and accounts payable is the most striking finding of this research and is examined in detail later in this chapter.

Public Versus Private Warehousing

Those financial variables which are significantly affected by using a public warehouse instead of a private at Chicago for the appliances company under the assumption of growth rates of .05, .15, or -.05 are listed in Table 5.10. The significantly affected distribution variables under each of the growth rate assumptions are also listed in Table 5.10.

The ranks of the distribution variables are exactly the same as those for the health cares industry. The relative importance of changes in financial variables from going to public warehousing are approximately the same as in the health cares industry. The Spearman Rank Correlations for comparison of the results of the two industries, which would have been significant at .41, are:

TABLE 5.10 --Comparison of Variables Significantly Affected by Using One Public Instead of One Private Warehouse Under Varying Growth Rate Assumptions for the Appliances Company

	Rank			Avg. Quarterly % Change		
Finance Variables	-.05	.05	.15	-.05	.05	.15
Debt Service Coverage	1	1	1	300	356	204
Plant and Equipment	2	2	2	-100	-100	-100
Deferred Taxes	3	3	3	-100	-100	-100
Long Term Loans	4	4	4	-100	-100	-100
Depreciation	5	5	5	-100	-100	-100
Fixed Asset Turnover	6	6	6	-100	-100	-100
Interest Expense	8	7	7	- 75	- 71	- 60
Return on Equity	7	8	8	80	59	53
Net Working Capital/Total Assets	10	9	9	64	55	47
Return on Assets	9	10	11	75	55	42
Working Capital/Total Assets	11	11	10	59	53	46
Net Worth	12	12	12	- 39	- 37	- 32
Total Assets	13	13	13	- 37	- 35	- 31
Total Liabilities	14	14	14	- 34	- 32	- 30
Taxes Payable	18	15	20	- 6	- 13	4
Total Variance	16	16	17	- 10	- 13	- 16
Net Liquid Assets	15	17	18	17	10	12
Debt/Equity	20	18	16	3	9	16
α Regression Co-efficient	17	19	19	- 8	- 9	- 12
B Regression Co-efficient	19	20	15	- 6	- 7	- 19
Distribution Variables						
Throughput Expenses	1	1	1	118	147	173
Depreciation Expense	2	2	2	-100	-100	-100
Facilities Capital Expense	3	3	3	-100	-100	-100

Sales Growth Rate	Correlation of Ranks of Variables Between Industries
.05	.70
.15	.83
-.05	.97

The few differences between the two industries which do exist are because the appliance industries sales patterns are seasonal and the health cares industries are not, with the result that more excess capacity exists for appliances and thus requires heavier investment in private facilities. Resultantly, public warehousing is relatively more attractive both profit-wise and in terms of return on assets and equity in the appliances industry. Because of the seasonal fluctuations in sales, the variance of net income also is relatively lower for the appliances industry if public instead of private warehousing is used.

The researcher expected that the improvement in required level of break-even sales for going to public warehousing would be much stronger in the appliances industry because of the heavier fixed investment. This did not occur because the heavier flow of depreciation generated funds from the private facility in appliances keeps the break-even level for the private facility alternative much lower than it otherwise would have been. The increased flow of depreciation funds is only a recapture of additional required investment and lends a misleading appearance of liquidity, as is explained on pages 129-134.

Warehousing Decisions, Inventories, and Accounts Payable

The most significant interactions between warehousing decisions and financial variables identified in this research are:

1. The direct effects of an additional warehouse on inventories and accounts payable and the interaction between inventories and accounts payable.
2. The effects of the increased operation expenses from warehouse system changes on the level of accounts payable.

To fully develop the interaction between additional warehouses, accounts payable and inventories it is necessary to examine the behavior of inventories and accounts payable as sales change over time. Therefore this section is presented in three parts. The first part is the general treatment of the effects of sales changes on inventories and accounts payable. The second part is an analysis of the effect of additional warehouses on inventories and accounts payable, of the interaction between inventories and accounts payable, and the implications of these findings to management sciences. The last part reports the relationship between warehousing decisions, changes in operating expenses, and changes in accounts payable and describes general principles developed from this relationship.

Sales Induced Changes in Inventories and Accounts Payable

In the following exhibit, sales, inventories, and accounts payable are portrayed by their average values over twenty quarters under growth rate assumptions of -.05, .05, and .15, respectively, with one private warehouse in the health cares industry.

Average Quarter Value ($MM)

Experiment	Sales	Inven	A/P	$\frac{A/P}{Inv}$	Inventory Turnover	Net Liquid Assets
1.11 (-.05)	2.001	.718	.688	.95	3.05	.315
1.01 (.05)	2.540	1.026	.797	.79	2.71	.083
1.06 (.15)	3.202	1.251	.932	.74	2.63	-.486

As sales rise, inventories increase and accounts payable also increase, with inventories rising faster than accounts payable, as demonstrated by the drop in the percent of inventories financed by accounts payable $(\frac{A/P}{Inv})$.

A sales induced increase in safety (buffer) inventories is financed by cash, not by accounts payable. Such an increase does not repeat itself (it is a somewhat permanent shift in the level of inventories). Although an additional purchase of safety inventories immediately causes accounts payable to increase, at the end of the allowed days of trade credit the account is paid from cash and accounts payable returns to the previous level.

But sales induced increases in re-order inventories are at least partially financed through accounts payable.

This increase in inventories repeats itself each inventory cycle and at the time of each inventory replenishment will also "replenish" the amount owed on trade account. The specific percentage of sales induced increases in re-order quantity which will be financed through accounts payable depends upon the re-order cycle time, the terms of trade credit, and the number of days before the increased sales which stimulate the increased inventories are converted from receivables to cash.

A simplified illustration of these relationships is presented in Table 5.11. The illustration is of hypothetical weekly patterns in inventories, accounts receivable, accounts payable, and cash when sales are first $10 per week and then $15 per week. The firm is one with only one product and to avoid complications to the presentation is assumed to have no operating costs and to make no profit on the re-sale of the inventories. The inventory re-order cycle is five weeks, and terms on accounts receivable and accounts payable are two and four weeks, respectively. The company policy is that safety stocks are two weeks of expected sales and re-order quantity is five weeks of expected sales. It is assumed that the company is on-going, that inventories have been replenished at the end of the first week and that the net balance in cash at the end of the first week is thirty dollars.

In the first ten weeks of operations actual and expected sales are $10 per week. In ordering inventories

TABLE 5.11--A Simplified Illustration of the Relationship Between Change in Sales and Working Capital (in dollars)

		Inventories[a]		Accounts Rec.[a]			Accounts Pay.[a]			Cash		
Week	Sales	+	Net	+	-	Net	+	-	Net	Out	In	Net
1	10	50	70	10	10	20	50		50		10	30
2	10		60	10	10	20			50		10	40
3	10		50	10	10	20			50		10	50
4	10		40	10	10	20			50		10	60
5	10		30	10	10	20		50	0	50	10	20
6	10	50	70	10	10	20	50		50		10	30
7	10		60	10	10	20			50		10	40
8	10		50	10	10	20			50		10	50
9	10		40	10	10	20			50		10	60
10	10		30	10	10	20		50	0	50	10	20
11	10	85	105	10	10	20	85		85		10	30
12	15		90	15	10	25			85		10	40
13	15		75	15	15	30			85		15	55
14	15		60	15	15	30			85		15	70
15	15		45	15	15	30		85	1	85	15	0
16	15	75	105	15	15	30	75		75		15	10
17	15		90	15	15	30			75		15	25
18	15		75	15	15	30			75		15	40
19	15		60	15	15	30			75		15	55
20	15		45	15	15	30		75	0	75	15	-5
21	15	75	105	15	15	30	75		75		15	10
22	15		90	15	15	30			75		15	25
23	15		75	15	15	30			75		15	40
24	15		60	15	15	30			75		15	55
25	15		45	15	15	30			0	75	15	-5

[a]+indicates addition during the week; - indicates deletions during the week; and net indicates the balance at the end of the week. Also weekly sales represent deletion from inventories.

during week 11, the firm expects sales to increase to $15 per week and therefore orders an additional $10 of inventories for safety stock (2 weeks times the $5 increase) and raises the re-order quantity by $25 (5 weeks times $5). Thus, inventories received in week 11 total $85 instead of $50. Actual sales, as the firm expected, go to $15 per week every week after week 11. Therefore, the inventories re-ordered each re-order cycle thereafter total $75, the new re-order quantity.

For one inventory cycle after the increase in inventories, beginning accounts payable go from $50 to $85 and then stabilize at $75. This illustrates the earlier contention that increases in safety stocks, unlike re-order quantities, are not repetitive increases and therefore do not generate a permanent shift in the levels of accounts payable.

Once the system has stabilized following the change in the rate of sales, the relationship between sales induced changes in re-order inventories, working capital, and accounts payable can be observed. The period of weeks six through ten is a stable period with sales at $10 per week and the period of weeks twenty-one through twenty-five is a stable period with sales at $15 per week. These periods are A and B, respectively. Consider the following comparison between the values of the elements of working capital at the beginning week of each period (week 6 vs 21), at the ending week of each period (week

10 vs 25), and the average value for each element over each period.

Element	A Beg.	A End	A Avg.	B Beg.	B End	B Avg.	B - A Beg.	B - A End	B - A Avg.
Inventories	70	30	50	105	45	75	35	15	25
Accounts Rec.	20	20	20	30	30	30	10	10	10
Cash	30	20	40	10	-5	25	-20	-25	-15
Accounts Pay.	50	0	40	75	0	60	25	0	20

The difference in inventories between B and A at the beginning of the inventory cycle is $35, which consists of the $10 permanent upward shift in safety stocks and the $25 of additional re-order inventories. Accounts receivable (A/R) also shows a permanent increase of $10 and the total increase in non-liquid assets (inventories plus A/R) is $45. These increases are financed by a $20 drop in cash (because the $10 respective permanent increases in safety stocks and A/R both reduce cash by $10) and by a $25 increase in A/P which occurs because of the $25 increase in re-order inventories.

At the end of the last week, the additional financing through A/P has been redeemed with cash, but all except $5 of the additional re-order inventories have been worked off. Thus only five additional dollars of cash are required. Since the increases in safety stocks and A/R are permanent, their values and their impact on cash remain the same as at the beginning of the cycle.

Based on the average values at the end of each week in the five week cycle, non-liquid assets increase by $35, which is broken down as follows: +$10 each for safety stocks and A/R and +$15 for average re-order inventories. The increases in safety stocks and A/R reduce cash by a total of $20. However, the additional working inventories decline over the entire inventory cycle and the additional accounts payable are constant until totally depleted. Thus, the average increase in accounts payable ($+20) is larger than the average increase in working inventories ($+15) which it is financing and therefore takes $5 off the strain placed on cash by safety stock and accounts receivable.

The analysis of average values over the inventory cycle is most important for multi-product companies because the many product cycles tend to balance each others peaks and valleys, with the total result being the sum of their averages. As the number of products approach one, the beginning and ending points of the cycle become more important. Whichever is the case, however, this illustration and the experimental results demonstrate that accounts payable can be a somewhat permanent source of financing for increases in re-order inventories.

Additional Warehouses, Accounts Payable, and Inventories

Although a definite positive relationship is established in the previous section between sales induced changes in inventories and accounts payable, the experimentation reveals no such relationship between inventory adjustments resulting from the addition of a warehouse and changes in accounts payable.

Indeed every experiment involving the change to a two warehouse system exhibits an increase in inventories and a decline in accounts payable. That the decline in accounts payable is approximately the same in the health cares industry and in the appliances industry, in which the average expansion of inventories are quite different, is further evidence that the resultant adjustments in accounts payable and in inventories from switching to a two warehouse system occur quite independently of one another.

The effect of an additional warehouse on inventories is explained on page 153. The decline in accounts payable occurs because with the addition of a second warehouse, the number of days required to accumulate to the minimum allowable replenishment shipment of inventories from each supplier to the individual distribution centers increases. Since orders occur less frequently, accounts payable build up less slowly. At an early stage additions to and deletions from accounts payable (A/P) begin to balance out and accounts payable stabilize. Since A/P build up slower in a two warehouse system, they stabilize at a lower level. The quarterly patterns of accounts payable in Experiment 1.01 and Experiment 1.02 are compared graphically in Figure 5.2. As can be seen, when the two systems stabilize beyond the second quarter of the first year, accounts payable in the one warehouse system consistently is at a higher level than accounts payable in the two warehouse system.

That accounts payable do not increase, but rather decline when inventories are adjusted upward by the move to a two warehouse system leads to several interesting observations of the relationship between accounts payable and inventories. As was true for a sales induced increase in safety stocks, the level of accounts payable immediately increases, but returns to its initial level at the expiration of the allowed credit period, if the move to a two warehouse system results in an increase in safety stocks.

The effect which increases in re-order inventories resulting from the addition of a warehouse, has on accounts payable is more complex. To avoid unnecessary complications, the following analysis assumes that no trade discounts are available and that the firm has an established policy of paying all accounts at the expiration of the allowed credit terms. While this analysis relates specifically to the effects of the addition of a warehouse, it pertains to any management action induced change in re-order inventories. It can be shown that

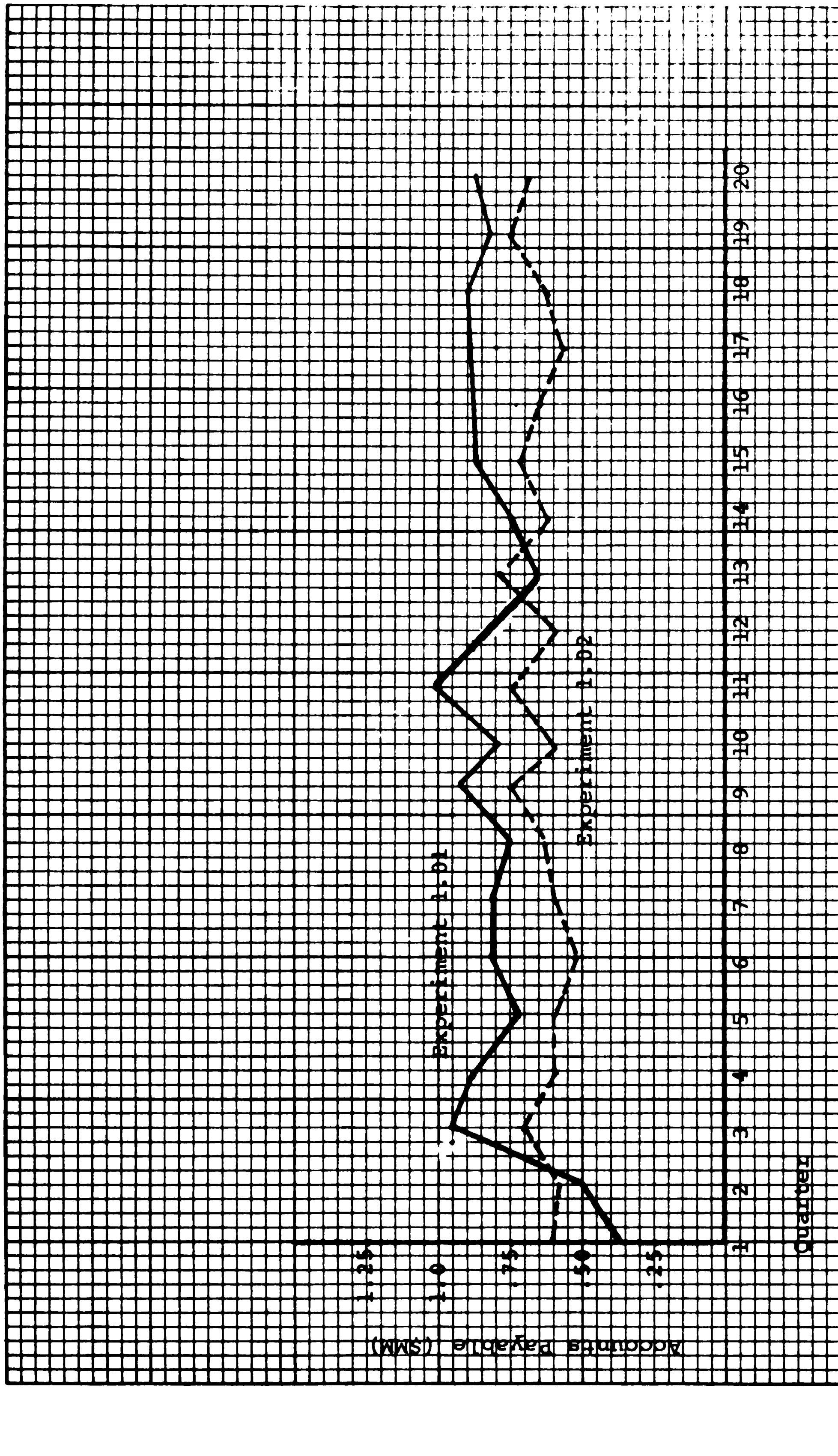


Figure 5.2.--Quarterly Accounts Payable, Experiment 1.01 vs 1.02

an increase in re-order quantity inventories, with no change in actual or expected sales, has two counter-balancing effects on accounts payable: (1) an additional amount equal to the increase in re-order inventories is added to accounts payable at the beginning of each inventory cycle, and (2) the inventory re-order cycle is lengthened by the same percentage by which the re-order quantity is increased. The net result is that a change in re-order quantity resulting from management action (that is, not because of a change in the daily sales rate) leaves the level of accounts payable unchanged. The proof of this relationship is now given.

Assume that the re-order quantity for a given product is R with constant daily sales S and inventory (re-order) cycle time $\frac{R}{S} = i_1$. The accounts payable cycle time, p, is the allowable days under credit agreement. Although the assumption is not critical to the proof, assume that $p < i_1$. Then, over the total inventory cycle the amount in accounts payable is R from day 1 to day p and 0 from day p to day i_1. Thus, the weighted average balance of accounts payable is

$$AP_1 = (\frac{p}{i_1} * R) + \frac{i_1 - p}{i_1} * 0 = \frac{p}{i_1} * R$$

Now, assume re-order quantity is increased by management action (sales are constant) to $(1+w)R$. Since S is constant, the new inventory cycle time i_2, is $(1+w)i_1$, and the new average balance of accounts payable is

$$AP_2 = \frac{p}{i_2} * (1+w)R = \frac{p}{(1+w)i_1} * (1+w)R$$

The change in accounts payable is

$$AP_2 - AP_1 = \frac{p}{(1+w)i_1} * (1+w)R - \frac{p}{i_1} * R$$

and since the terms (1+w) cancel each other

$$AP_2 - AP_1 = \frac{p}{i_1} * R - \frac{p}{i_1} * R = 0$$

It can be shown that this relationship also holds for $p > i$ and $p = i$.

Thus, a tautology is developed that exogenous changes in re-order inventories, all other factors being constant, leaves accounts payable unchanged. A corrollary to this conclusion is that the percentage of the investment in inventories which is financed through accounts payable, $\frac{p}{i}$, moves inversely to changes in re-order quantity, all other factors being constant. Since A/P is a cost free sourse of financing (assuming the company has already made its decision concerning discounts and credit reputation), it implicitly follows that the average cost of the capital invested in inventories is an increasing function of EOQ. Functionally, the average cost of capital for inventories (Ic) is

$$I_c = \frac{\frac{p}{i} * R}{R+B} * 0 + \left(1 - \frac{\frac{p}{i} * R}{R+B}\right) * k$$

where B = the investment in safety or buffer stock, which is constant, and as shown earlier not financed by inventories after the first period.

k = the average capital costs of all sources of inventory financing other than accounts payable.

$\frac{\frac{p}{i} * R}{R+B}$ = the percentage of inventories financed through accounts payable.

Since $\frac{p}{i}$ decreases by the same percentage as R increases, changes in R cause no change in the numerator but cause the denominator to increase in the term

$$\frac{\frac{p}{i} * R}{R+B}$$

Thus, the value of the term declines and the value of $(1 - \frac{\frac{p}{i} * R}{R+B})$ increases as R increases, demonstrating that I_c increases with increases of R. The relationship between re-order quantity and I_c is graphed in Figure 5.3 under the assumption that the sales rate is constant and the average cost of capital not provided by accounts payable is 10 percent per year after taxes. The weighted average cost of capital for inventories is shown to be an asymptotically increasing function for the re-order quantity.

The traditional formula for calculating economic order quantities assumes a constant value for the average cost of capital.[2] It has been demonstrated that this assumption is not always an accurate one.

Warehousing Decisions, Operating Expenses, and Accounts Payable

The comparison between any two experiments on LREPS-F with the same sales growth rate and the same number of warehouses demonstrates no change in inventories. For these comparisons, since the number of facilities does

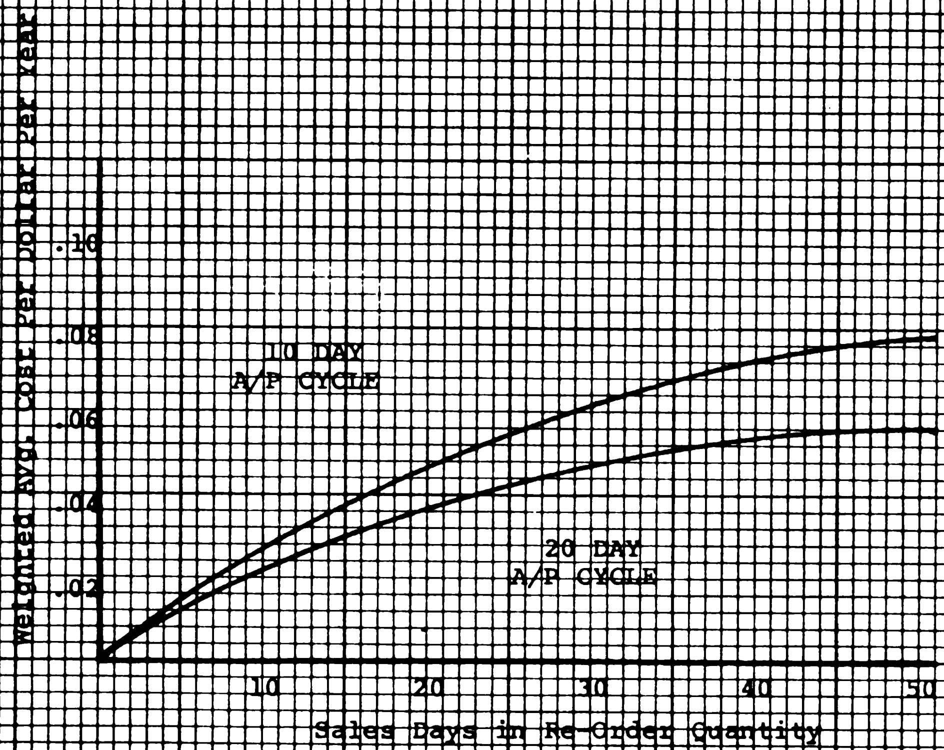


Figure 5.3.--Inventory Re-Order Quantities and the Weighted Average Cost Per Unit of Carrying Re-order Inventories[a]

[a]Assumes A/P are cost free and all other sources cost .10 per year.

not change, it was expected that accounts payable would not change. They do, however, and closer examination reveals that the reason is the relationship between operating expenses and accounts payable. The following is a listing of changes in expenses which give rise to accounts payable and the associated changes in accounts payable between all possible combinations of experiments with the same growth rate in sales and the same number of facilities in the health cares industry:

Experiments	Δ Average Quarterly Expenses	Δ Average A/P
1.01 vs 1.04	$40.9M	$39.4M
1.02 vs 1.05	56.2M	38.2M
1.06 vs 1.09	52.4M	32.6M
1.07 vs 1.10	74.3M	45.0M
1.11 vs 1.14	26.3M	23.0M
1.12 vs 1.15	40.4M	26.4M

In each case, the differences reflect the increases in throughput expenses from changing from a private to a public warehouse. The increases in accounts payable occur because of two related changes. First, in the model throughput expenses occur weekly, but deplete cash only after a five week credit grace period. Therefore, for the first five weeks of the increased throughput expense there is not an associated depletion in cash. In the sixth week, and in each week thereafter, one week of additional expenses is depleted from cash. Also, one weeks additional expenses is both added and subtracted from accounts payable, with A/P resultantly stabilizing at the amount five times one weeks additional expenses above the level of A/P prior to the increased expense.

Secondly, when public warehousing is used, 100 percent of all throughput expenses are added to accounts payable when they are first incurred. Some of the throughput expenses incurred when private warehousing is used are more immediately paid from cash. In this model, it is assumed that 50 percent of private facility throughput costs are paid from cash at the end of the week in which they are incurred and that the other 50 percent generate an account payable. Resultantly, the same amount of throughput expenses which were incurred using private warehousing will generate 50 percent more in accounts payable using public warehousing.

Mathematically, the total change in the level of accounts payable, after they stabilize, because of the shift from private to public warehousing is:

$$AP = (X_2 * a)p - (X_1 * b)p$$

Where X_1, X_2 = the weekly amount of throughput expenses for the private and public warehousing alternatives, respectively.

b, a = the percent of the weekly throughput expenses which are added to accounts payable for the private and public warehousing alternatives, respectively.

p = the number of weeks allowable under trade credit.

A note of caution is in order. After accounts payable stabilize following the change, weekly cash outflows from the additional expenses are approximately the same as the weekly additional expenses because expenses incurred in time period t are paid in t+5. Cash as a flow entity must be distinguished from cash as a status variable. The status variable cash at t is a composite of the cash inflows and outflows in t-1, t-2, t-3, ...t-n. Therefore, at any week m beyond the stabilization point (week five), the change in cash (cash flow) which will have occurred is:

$$Cash_m = m(X_2 - X_1) - [(X_2 * a)p - (X_1 * b)p]$$

where $m(X_2 - X_1)$ = the total additional expenses which have been incurred up through the mth week since the change was made.

An important part of the art of capital budgeting analysis is the necessity of estimating the cash (working capital) requirements needed to support the project under study. This research has indicated that this estimate should consider the potential changes in the level of accounts payable financing when:

1. The project results in a change in an expense which generates an accounts payable.

2. The project results in trading an expense which is paid from cash for an expense which generates an account payable; or vice versa; or results in trading an expense for one which also generates an account payable but carries different trade terms.

Indeed, this research indicates that any management decision which involves a shift in expenses should include explicit consideration of the potential impact on accounts payable.

CHAPTER V--FOOTNOTE REFERENCES

[1]Bowersox, Smykay, and LaLonde, *op. cit.*, p. 221.

[2]*Ibid.*, p. 204.

CHAPTER VI

SUMMARY AND CONCLUDING REMARKS

Although financial position is typically managed by correcting adverse changes after they occur, a more enlightened approach to financial management is to anticipate these adverse changes and prevent their occurrence. This research is based on two premises:

1. Much of the change in financial position of the firm over time is the result of overt management decisions in other functional areas of the firm.
2. Most operational decisions within the firm trigger changes, either directly or indirectly, in many of the variables of financial position.

A major step toward preventive financial management is to develop a better understanding of the effects of decisions in the functional areas on financial variables. Such an understanding will also facilitate more correct decisions in the functional areas.

The objective of this research is to study the nature of the effects of warehousing decisions on financial variables. With a fuller understanding of this interaction financial managers are better able to anticipate changes in financial position resulting from a particular warehousing decision and distribution managers are better able to make correct warehousing decisions.

To accomplish this goal, four steps were taken:

1. A dynamic computer simulation model was built upon which experimentation and sensitivity analysis could be performed to study the total impact of five alternative warehousing decisions on financial variables in two test industries.

2. The experimentation and sensitivity analysis on the model were performed, with only one variable exogenously changed per experiment and the resultant changes in financial variables were observed.

3. Those financial variables which are "significantly" affected under varying economic conditions in each of the two industries by the alternative warehousing decisions were identified from the results of the experimentation.

4. The results were studied for general relationships which would help explain the interaction between warehousing decisions and changes in financial variables.

There are several results of the research which should help financial management to better anticipate the effects of warehousing decisions. The significant findings are associated with the addition of a second warehouse and the use of public instead of private warehousing. Further, the research yields several by-products of interest to the general field of finance.

Addition of a Second Warehouse

Whether a particular company will want to add a second warehouse or not will depend upon the specific situation and it is not the purpose of this research to recommend an alternative. The purpose here is to study in general the significant effects which the addition of a second warehouse has on financial variables.

Warehouse Additions and Accounts Payable

Every experiment on a two warehouse system experienced a drop in the average level of accounts payable from 13 percent to 21 percent of the level of accounts payable in the comparable one warehousing system. These declines in accounts payable caused adverse changes in the following variables in varying proportions:

1. Cash dropped, causing a deterioration in liquidity position as reflected by the current and acid ratios.

2. Short term loans increased in order to take up the financing slack and this increase was reflected in the $\frac{\text{Debt}}{\text{Equity}}$ ratio.

3. The debt service coverage ratio and earnings dropped, reflecting the fact that an interest bearing form of debt (short term loans) replaced a cost free source of financing (accounts payable).

The major implication of this finding is that managers contemplating an additional warehouse should consider the adverse effects which such a decision will have on the financial structure and liquidity position of the firm and include these considerations in the decision making framework. If the additional warehouse is still deemed attractive, financial managers can anticipate the changes instead of taking corrective action after they occur.

Warehouse Additions and the Inventory-Accounts Payable Interaction

The experiments on the two warehouse system in the health cares company typically experienced an increase in the average level of inventories ranging from 33 to 38 percent above the level of inventories in the comparable experiment with only one warehouse. One experiment had a change in inventories of 90% and the reason for this abnormally large change is explained on page 118. For the appliances company, this change ranged from 1 percent to 4 percent.

It is well documented in the distribution field that safety stocks normally increase at a decreasing rate as the number of warehouses is increased.[1] The general relationship is popularly expressed mathematically as:[2]

$$SS_n = \frac{SS_1(n)}{\sqrt{n}}$$

where

SS_n = safety stock for n locations

n = number of locations

SS_1 = safety stock for one location

The general formula predicts that the increase in safety stocks from adding a second warehouse will be approximately 40 percent. Since safety inventories are designed to be 25 percent of the total in the modeled companies, the general relationship predicts a 10 percent increase in inventories for this research. However, the general formula assumes that demand patterns at the two locations are perfectly independent of each other. Sales in LREPS-F are randomly generated daily for the total company and then randomly assigned to the individual distribution centers. Thus, there is a high degree of dependence between sales patterns at the two locations, which explains the departure of these research findings from the assumed general pattern. The degree of dependence modeled may be closer to reality than that assumed in the general formula.

The inconsistency between industries in the effect of the second warehouse on inventories exists because of the exponential smoothing inventory forecasting technique used in this research. One of the prime advantages of using exponential smoothing rather than trend projection forecasting techniques is that exponential smoothing can detect intermediate upturns and downturns in the demand pattern. Since the appliances industry has a definite seasonality factor in its demand pattern, the swings detected and forecasted by the forecast mechanism usually were the actual pattern. There is no seasonal pattern to demand in the health cares industry but a substantial amount of random variation. The swings detected by the forecast mechanism in this industry were only "noise" around the trend line and resulted in a substantial amount of forecast error. This forecast error introduces instability into the inventory levels which is magnified by dividing inventories between two inventory locations.

Although the effect of the second warehouse on inventories varied widely between the two industries, the change in accounts payable was remarkably consistent. The levels of inventories and accounts payable are clearly related in most of the experimentation, but the changes in inventories resulting from the addition of the second warehouse have no effect on the level of accounts payable. Rather, the substantial increases in inventories from the additional warehouse in the health cares company caused cash to drop substantially, short term loans to rise, and causes deterioration in the liquidity, $\frac{\text{Debt}}{\text{Equity}}$, and debt service coverage ratios. The changes in these variables are in addition to the adverse effects on them from the decline in the level of accounts payable. The analysis of these results leads to several general observations concerning inventories and the extent to which they are financed through accounts payable.

First, increases in safety stock (buffer inventories) are not repetitive in nature and after the expiration of the allowed credit period, must be paid from cash. Thus, accounts payable are not a permanent source of financing for "safety" inventories. Second, increases in re-order (working) inventories which are induced by changes in the sales rate are repetitive in nature and therefore can be financed at least partially through accounts payable. The specific proportion depends upon the relationship between the re-order cycle, i, and the length of the credit period, p.

Third, increases in re-order inventories which occur because of management action such as adding a warehouse, result in an increase in accounts payable at the beginning of each re-order cycle, causing the ratio $\frac{p}{i}$ to decline. The net result of the two effects is that the average level of accounts payable is left unchanged, meaning that the increase in re-order inventories resulting from management action must be financed from some source other than accounts payable.

Finally, when $\frac{p}{i}$ declines, the proportion of inventories which is financed through accounts payable declines. Since accounts payable are (or can be) a cost free source of financing, in many cases this decline in $\frac{p}{i}$ results in an increase in the average financing cost of inventories. Thus, since management induced changes in re-order inventories cause $\frac{p}{i}$ to shift, such changes also cause the average carrying cost of inventories to shift. This demonstrates that in many cases the average cost of carrying inventories, C, is an increasing function of the re-order quantity. The traditional formula for calculating economic order quantity assumes that C is a constant.[3]

Public vs Private Warehouse Decisions

The results of experimentation indicate that the relative attractiveness of public vs private warehousing depends upon the individual company and situation. For example, the use of private warehousing required more excess capacity in the appliances company because of the seasonal demand pattern than in the health cares company. Resultantly, public warehousing is much more attractive in terms of profitability and liquidity protection in the appliances company than in the health cares company.

The experimental results offer empirical evidence of the classic relationship between fixed expenses, contribution margins, and the total leverage function. Each experiment involving a change from private to public warehousing resulted in a drop in the level of sales required to break even on net income and in the variability of earnings and cash flows. They also resulted in increases in the $\frac{\text{Net Working Capital}}{\text{Total Assets}}$ and debt service coverage ratios. These changes individually and in total reflect a much improved defensive posture against market and economic reversals if the firm uses public warehousing. The change in earnings variance and the $\frac{\text{Net Working Capital}}{\text{Total Assets}}$ ratio also indicate that the firm will not benefit as much from boom conditions using public warehousing.

Each experiment involving replacing a private with a public warehouse exhibited an increase in accounts payable of from 60 percent to 99 percent of the change in operating expenses which generate accounts payable. Analysis of this finding led to the conclusion that the level of accounts payable will shift when there is a change in the normal level of an expense which is paid on trade account or when a particular type of expense is "traded" for a type of expense which carries different trade credit characteristics.

The expenses incurred through the use of public warehousing (the warehouseman's charges) all give rise to payables. Many of the expenses incurred through the use of private warehouses, especially owned private warehouses, do not give rise to payables. Those which do (wages to labor, for example) often are for much shorter terms than the payables due public warehousemen. Thus, accounts payables shift up and are a source of financing, if private warehousing is replaced with public warehousing. This increased amount of financing through payables if public warehousing is used frees cash for other purposes, which is another reason that the use of public warehousing puts less strain on the liquidity position of the firm.

The identification of this relationship should enable managers to more accurately anticipate the total financial effects of warehousing decisions and help distribution managers make more correct warehousing decisions.

Research By-products to Financial Analysis

The comparison of experiments with the same number and types of warehouses but with different sales growth rates yields several interesting research by-products concerning the construction and use of financial ratios.

These results demonstrate that the $\frac{\text{Debt}}{\text{Equity}}$ ratio will often give misleading signals if short term debt is included in its calculation. The purpose of the $\frac{\text{Debt}}{\text{Equity}}$ ratio is to measure the extent to which the financial structure magnifies the danger of market or economic reversals. The experimental results show that short term loans have a strong tendency to work themselves off when sales turn downward and to build up when sales rise. Thus, their importance in case of market reversals is not crucial and their inclusion in the $\frac{\text{Debt}}{\text{Equity}}$ ratio can give false danger signals. For the same reasons, the debt service coverage ratio will have a negative bias if interest or re-payments of short term loans are included in its construction.

Furthermore, a weak acid test ratio is really a signal that the firm is in a poor liquid position if sales were to increase, not a danger signal of the susceptibility of the firms liquid position to downturns as is popularly believed.

Limitations and Implications for Future Research

The limitations of this research and implications for future research are discussed according to the following general problem areas:

1. The size and system characteristics of the model firms.

2. The danger of generalizing results based on distribution wholesellers to manufacturing firms.

3. The need for additional and more advanced system performance - feedback adjustment mechanisms.

4. The limited possible future states of nature tested in this research and the potential for developing flexibility as a third parameter in financial decisions.

5. The potential for using LREPS-F to attack specific problem areas in the finance field.

6. The possibility of studying the distribution - finance interaction on a broader scale.

Size and Characteristics of the Model Firms

Generalizing the results of this experimentation, which is on model firms with ten million dollars annual sales, to larger firms is dangerous. Additional research should be performed to test the consistency of the effects of the alternative warehousing decisions as the size of the firm changes.

A limitation closely akin to the foregoing is that the results observed in this study might be much different for a firm with a larger number of existing warehouses. For example, the impact of a second warehouse on accounts payable in this study occurs because of the change in the frequency with which inventories are re-ordered in the total system. The proportional change in re-order frequency from adding another warehouse to a six warehouse system, for example, would probably be much smaller than those observed in this research. Testing the consistency of findings as the number of warehouses increases is another possible extension for this research.

<u>Generalizing the Results to Manufacturing Companies</u>

Some of the results and conclusions from the study of wholesellers would not hold for manufacturing concerns. For example, the inventories purchased by manufacturing companies serve predominantly as inputs to the production process. Therefore, the simple relationship observed between the turnover of inventories and the accounts payable cycle in the wholesale industries does not exist in manufacturing firms. The relationship is complicated by the introduction of the time which the purchased materials spend as raw material and in-process inventories.

To gain a full appreciation of the interaction between two sub-systems (in this case distribution and finance) in a larger system, the total system must be modeled. The addition of manufacturing, marketing, and physical supply sub-systems to LREPS-F are seen as logical next steps in the general direction of accurate forecasting of the total effects of management decisions.

The Extent of Feedback Mechanisms

The results of experimentation might be more significant if a more complete set of feedback mechanisms were included in the monitoring function. Projects must be kept within a manageable scope, however, and model building often proceeds in a step-wise manner. Feedback mechanisms which would be added in a more advanced version of LREPS-F include modeling sales as a partial function of the level of service; modeling accounts receivable as a function of the relative proximity of customers to the distribution centers; and modeling debt management as a function of certain key financial ratios and statistics.

Possible Future States of Nature and the Concept of Flexibility

The range of possible future economic and market conditions were limited by design. Although the different growth rate assumptions covered a wide spectrum, many other changes in the state of nature could affect the performance and financial position of the firm. Such exogenous factors as changes in population location patterns, general shifts in the cost structure of one or more of the cost components of the distribution system and governmental action on depreciation and tax structures would probably influence the findings of this research.

That there is a wide range of possible future states of nature under which the firm may operate is an implication for future applications of LREPS-F. Sensitivity analysis on the model offers the opportunity to add a new dimension to management decision analysis. The research colleagues on the LREPS project term this new dimension "flexibility."

In selecting an alternative from a group of possible decisions, overt consideration should be given to how well each decision alternative can adapt to whatever the future states of nature will be. The more flexible a decision is, the more attractive it would be for possible selection. The use of multiple experimental runs on LREPS-F is an avenue by which the concept of flexibility could be added as a third dimension in financial analysis. Fuller development of this concept is a major implication for future research.

Other Future Financial Research

Cash management has been receiving much attention recently. Managers and academicians are increasingly concerned with getting optimum productivity from liquid assets without sacrificing liquidity. This model can be used to compare various quantitative cash management models for a wide range of situations. It can also be used to test the often heard criticism that the financial management of most corporations is unreasonably conservative.[4] Instead of initializing the balance sheet items in the model based on industry average financial ratios, they could be initialized based on the median of the poorest quartile for

each ratio. The objective of experimentation would be to determine how bad conditions could become before the companies would be in serious trouble; and to compare these to the similar results when industry averages are used.

Other Decision Variables in the Distribution Area

An interesting extension of this research would be to use a model such as LREPS-F to study the total impact on the finance variables of decisions made in the transportation, inventory, communications, and unitization (throughput) functions. For example, the existence of trade-offs between the costs of these various components is well documented in the distribution literature.[5] LREPS-F could be used to make changes which would result in an increase in the cost for one of the functions but which would result in an exactly offsetting cost reduction in another of the functions and the effects of such a change on financial variables could be studied.

CHAPTER VI--FOOTNOTE REFERENCES

[1]Bowersox, Smykay, and LaLonde, *op. cit.*, p. 221.

[2]*Ibid*, p. 204.

[3]*Ibid*.

[4]Donaldson, *op. cit*.

[5]Bowersox, Smykay, and LaLonde, *op. cit.*, p. 299.

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