THE INVENTORY AND DISTRIBUTION POLICIES
OF A LARGE INDUSTRIAL RUBBER GOODS FIRM

by

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This thesis describes the results of a study of the warehousing and distribution problems of a large manufacturer of industrial rubber goods. The basis of this study is a heuristic program for locating warehouses which was developed by John Liberatore. This program was the first to include both a revenue sector which describes a customer's sales volume as a function of the order cycle time he experiences and an inventory sector which describes the inventory level maintained by a warehouse as a function of the demand requirements of the customers assigned to it. A description of this program is followed by a description of the company which has been studied. Next, the problems of data collection and of establishing the proper values for the variables required by the program are examined. Then, the results of a number of runs are described and compared. Lastly, a number of observations on the successes and failures of the program will be drawn together, and the results of the runs will be used to determine a future course of action for the company.

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CHAPTER I

AVAILABLE TECHNIQUES FOR PHYSICAL DISTRIBUTION SYSTEM PLANNING

With the recent trend towards declining profit margins, American industry has been looking to reduce costs in other than the traditional area of manufacturing. One area which has been receiving an increasingly large amount of attention has been the physical distribution system. In their book, A New Approach to Physical Distribution, Arbury and a group from Harvard list six reasons why managers are beginning to look at physical distribution as an area where a firm's performance can be improved:

1. Domestic and foreign competition has caused a profit squeeze in many industries.

2. Distribution is of high relative importance in a company's cost structure.

3. Opportunities to improve the current performance of the distribution function are increasing.

4. Costs of carrying inventory are rising, so that pressure has increased within the company to look at physical distribution.

5. The task of distribution management has become more difficult.

6. As competition becomes more intense, companies are placing greater emphasis on customer service.

The physical distribution system of a firm is only a subset of the larger logistics system which includes "the total flow of materials, from the acquisition of raw materials to the delivery of a finished product to the ultimate user."\(^2\) The physical distribution system "refers to that portion of the logistics system concerned with the movement of products from the seller outward to the customer or consumer."\(^3\) Furthermore, the four major components of the physical distribution system are:\(^4\)

1. Transportation, including local delivery
2. Storage of product
3. Manufacturing and converting capability
4. Communications and control


\(^3\) Ibid., p. 2.

\(^4\) Ibid., pp. 2-3.
The task of reducing the cost of the physical distribution system is not an easy one. As the size of the distribution system grows, so do its complexities, and so does the problem of cost reduction. To help alleviate this problem, a number of heuristic and algorithmic techniques have recently been developed. The great majority of these approaches, however, oversimplify the problem to such an extent that they omit at least one important aspect of the system. One of the more encompassing models determines the following elements for physical distribution planning:

1. Location and size of warehouses
2. Guidelines for inventory management
3. General transportation policy
4. Optional service level.\(^5\)

It is important to notice that sales as well as costs are affected. It is for this reason primarily that a model of broad scope should be profit maximizing as opposed to cost minimizing. Perhaps, at this point we should briefly look at some of the techniques which are available to assist in physical distribution planning.

\(^5\) Arbury et al., *op. cit.*, p. 55.
Simulation

One such technique is simulation, a mathematical representation of a company's distribution system.\(^6\) It is the attempt of a simulation model to take into account each of the important factors involved such as transportation costs, fixed and variable warehouse costs, inventory costs, demand patterns, service reliability estimates, product mixes, and a number of other important elements. The emphasis in this type of model is on establishing the proper relationships between the various factors to permit the testing of various alternatives and to examine the resulting costs and profits. In general, the simulation model tends to look at the dynamic behavior of an organization. One such modeling approach, Industrial Dynamics, examines the information-feedback characteristics of industrial activity to show how organizational structure,

amplification (in policies), and time delays (in decisions and actions) interact to influence the success of the enterprise. Essential to the Industrial Dynamics model is the identification of one or a number of feedback systems. With Industrial Dynamics, as with all other simulation models, a new model must be developed for each firm since few organizations can be modeled in the same way. It is in part for this reason that more attention in the past has been given to the development of a number of algorithmic and heuristic techniques.

Mathematical Programming

Prior to the late 1950s little work had been done to develop the concept of mathematical programming capabilities. To a large extent, this was the result of a lack of sufficient computational power. Without it, the vast amount of work needed to obtain solutions to these complex formulations would have been prohibitively expensive and time consuming. One of the first procedures to solve the warehouse location problem was presented by Baumol and Wolfe

in 1958. Baumol's solution was an iterative algorithm using a basic linear programming formulation to allocate warehouses and attempting to incorporate a non-linear cost function. They do not, however, account for a fixed component in the warehouse variable cost function, and in comparing the results of their model with those obtained from others, their solutions have been poor. Shortly thereafter, in 1960, Balinski and Mills attempted an integer programming solution to the distribution problem. Kuehn and Hamburger in commenting on the Balinski-Mills paper conclude that the Balinski-Mills model is not well suited to handle decreasing marginal cost functions and that their solutions tend to significantly deviate from optimality.


The next major contribution to this area was proposed by Kuehn and Hamburger in 1963.\textsuperscript{11} The problem, as stated in their paper, is to determine the geographical pattern of warehouse locations which will be most profitable to the company by equating the marginal cost of warehouse operations with the transportation cost savings and incremental profits resulting from a more rapid delivery.\textsuperscript{12} Their program is based upon three principal heuristics:\textsuperscript{13}

1. Most geographical locations are not promising sites for a regional warehouse; locations with promise will be at or near concentration of demand.

2. Near optimum warehousing systems can be developed by locating warehouses one at a time, adding at each stage of the analysis that warehouse which produces the greatest cost savings for the entire system.

3. Only a small subset of all possible warehouse locations need be evaluated in detail at each stage of the analysis to determine the next warehouse site to be added.

These heuristics provide the basis for the first part of their program which searches through all potential warehouses.

\textsuperscript{11} Ibid., pp.643-666
\textsuperscript{12} Ibid., p. 643
\textsuperscript{13} Ibid., p. 645
to provide an initial solution set. The second part of their program, "The Bump-Shift" routine, is intended to eliminate those warehouses which have become uneconomical as a result of the placement of subsequent warehouses. When compared with the solutions generated by other models, Kuehn and Hamburger cite evidence that their model fares well. More will be said about this model later since it will serve as the basis for much of the work that follows.

Shortly thereafter, in 1964, Manne developed a procedure similar to that of Kuehn and Hamburger. Manne called his algorithm SAOPMA, Steepest Ascent One Point Move Algorithm, and presents a complicated geometric description of his algorithm which it is not necessary to describe here. It is sufficient to note that the additional complexities which have been added by Manne do not yield sufficiently better solutions to justify them.

Two years later a group from Esso Research and Engineering Company presented an article which extended heuristic programming techniques to handle the effect of

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economics of scale on warehouse costs.\textsuperscript{15} In their algorithm they suggest the idea of the "drop" approach instead of the "add" approach which had been used in Kuehn-Hamburger. In the "drop" approach all potential warehouses are initially assumed to be open, and they are eliminated one at a time, each elimination producing a lower cost formulation. The authors admit that their solutions were no better than those of the Kuehn-Hamburger model. The importance of this model is in its extensions for handling warehouse costs.

The most recent model was proposed by Liberatore in a Master's Thesis during the summer of 1970.\textsuperscript{16} It will only be necessary to examine this model briefly now since it will serve as the basis for a case study and will be described in detail later on. The basis for Liberatore's model is the Kuehn-Hamburger model which has already been discussed briefly. Liberatore has expanded this model to


produce a profit maximizing model which "would provide an optimal or near optimal location pattern while taking into explicit account warehousing and inventory costs as well as the effects of the location pattern on demand".

Summary

It had been the attempt of this Chapter to provide a short introduction to some of the techniques which are currently documented for dealing with some of the problems of physical distribution systems. In the next Chapter we shall examine the current inventory and distribution operations of a large industrial rubber goods firm. Chapter II will attempt to describe these operations and focus on those problem areas which might be helped by some of the techniques which are outlined in Chapter I. In Chapter III we shall look at the model which was chosen to focus on the major problem areas and describe why that model was picked. In Chapters IV and V we shall examine the problems of data collection, the figures which were used and how they were derived, and the results and comparisons of a number of runs of the model. In the last chapter we shall look at how it might be bettered, what the company should do, and areas of further investigation.
CHAPTER II
THE COMPANY DESCRIPTION

The American Biltrite Rubber Company is a large manufacturer of rubber and vinyl products for both industrial and consumer use. Sales in 1969 rose 4.8 per cent over the previous year to a recent high of $167,068,962 while corporate earnings rose 3.4 per cent to $3,771,550. The company consists of four primary operating divisions, The American Synthetic Rubber Corporation, The Amtico Floor Coverings Division, the Biltrite Footwear Products Division, and the Boston Woven Hose and Rubber Division. All are wholly owned operating divisions except for the American Synthetic Rubber Corporation, which is a 55% owned subsidiary. It is only necessary to briefly describe the Amtico and Biltrite divisions since the rest of this thesis shall be concerned with the Boston Woven Hose Division.

The Amtico Floor Coverings Division is one of the nation's leading producers of both carpet and resilient flooring. Amtico maintains a reputation for styling and quality leadership in the industry and has recently been engaged in expanding its sales and marketing abilities. The Amtico division has two manufacturing facilities in Trenton, New Jersey, one in Dalton, Georgia, and one in
La Mirada, California. Most of this division's sales are to distributors who are located in most major cities throughout the country.

The Biltrite Footwear Products Division is the industry's leading supplier of heels and soles. Although shoe production in the United States declined almost 10 per cent in 1969, Biltrite maintains a commanding position in supplying soling to shoe manufacturers. The Cat's Paw Rubber Company, an independent subsidiary whose name is extensively advertised and recognized, is the nation's major supplier of rubber heels to shoe rebuilders. The primary manufacturing plants are located in Chelsea, Massachusetts and Ripley, Mississippi.

The Boston Woven Hose Division

The Boston Woven Hose and Rubber Division accounts for slightly less than 25 per cent of corporate sales and produces ten major product lines:

1. Flat Belts
2. Power Transmission Belts (V-Belts)
3. Packing
4. Matting
5. Molded Hose
6. Hydraulic Hose
7. Fire Hose
8. Garden Hose
9. Tape
10. Sports Surfaces

The primary manufacturing facilities for this division are located in Cambridge, Massachusetts and Hohenwald, Tennessee. The divisional headquarters are located in the Cambridge plant which produces a wide variety of this division's products and accounts for approximately 50 per cent of divisional sales. Most of the hose production has been transferred from the Cambridge facility to Hohenwald. The hose production at Hohenwald accounts for somewhat less than 40 per cent of divisional sales. The tape operations are located in Garfield, New Jersey, and provide only 5 per cent of sales. Lastly, the division maintains a plant in Stoughton, Massachusetts for the production vinyl garden hose and shares a plant in La Mirada, California with the Amtico division for the production of vinyl garden hose.

The product lines, however, consist of several thousand products, and many of them require either a special or an entirely different marketing effort. In
addition to the divisional sales organization, each of the above products is represented by a product sales manager whose responsibility it is to develop and market that particular product line. Furthermore, the division maintains a field sales force to concentrate on sales to distributors since field sales make up about 60 per cent of the division's sales. Industry wide, field sales account for 45 per cent of the business which means that Boston Woven Hose is more highly dependent on distributor sales than the rest of the industry appears to be.

The field sales organization is headed by the Sales Vice President. Reporting to the Vice President are four Regional Sales Managers who supervise forty-five District Managers (salesmen). The District Managers are all salaried and receive no commissions. The function of the District Managers is to help the distributors in whatever way possible. The District managers are held responsible for establishing sound effective distribution in their respective areas and for advising distributors on training their own salesmen and on guidelines for inventory management. The BWH Division currently sells to approximately 250 full line distributors, only 50 of whom would be considered major distributors.
These distributors deal primarily with the replacement market and service a wide variety of customers. The steel industry, the auto industry, the chemical industry, and the mining industry are just a few of the division's customers.

At this point it would be valuable to look at the competition faced by BWH. Since BWH produces a widely varied product line, its competitors range from those who compete in only one line to those who maintain an equally varied line. They also vary from the large industrial giants of the rubber industry to smaller, more specialized competitors. In general, labor and raw material costs tend to be fairly uniform throughout the industry so that innovations in processing and product composition play an important part in reducing manufacturing costs and improving product quality. In addition to this, sales effort, company reputation, and reliability and length of delivery time are important determinants of market share.

The Inventory-Distribution System

To insure quick and reliable deliveries to its customers, BWH maintains seven regional warehouses in addition to the two factory warehouses located in Cambridge
and Hohenwald. Furthermore, in a number of select areas BWH maintains consignment stocks. The consignments serve a twofold purpose. First, they represent an effort to obtain sales in an area where BWH is currently weak in distribution, and second, they will hopefully serve as the basis for establishing a distributor in the near future. BWH has recently completed a study of consignment stocks and is currently in the process of reducing both the number of consignment accounts and the level of consigned inventory.

Responsibility for inventory levels and inventory reporting at BWH is extremely complex. The ultimate responsibility rests with Mr. Jim Flounders, who is vice president in charge of planning and inventory control. Mr. Flounders' position, however, is primarily a staff function which means that he has been given responsibility for an area over which he has only limited control. Mr. Flounders must work closely with two plant general managers, the inside (product) sales organization, the outside (field) sales organization, and the warehouse managers, none of whom have direct responsibility for the level of inventory. The office managers of the warehouses, for example, have the
responsibility of maintaining their inventories within predetermined guidelines but have no incentive to take part in improving turnover or warehouse effectiveness. Similarly, the sales people forecast annual sales upon which inventory considerations are based, but they are not held accountable for inventory fluctuations which occur as the result of poor forecasting.

At the present time BWH is also experiencing difficulty in keeping accurate, up-to-date inventory balances. In part, this is caused by a lack of uniformity in reporting procedures, by a lack of uniform product codes, and by the current confusion which has resulted from attempts to automate the old order entry system. There are two basic types of orders which are processed through the system; regular orders and emergency orders. As a typical order arrives at the plant, either directly or through a warehouse, it is sent to the Order Department where it is assigned an order number. Next, it is forwarded either to the Credit Department, if a credit check is necessary, or to the appropriate product representative in the Sales Department where the order is edited, priced, and a product code is assigned. It is then returned to Order Control
where it is grouped into a lot and sent to Data Processing for keypunching. That night it is punched and printed, and the next day it is sent to stock records. An emergency order is executed differently. The Sales Department obtains all relevant information from Order Control and Stock Records on the telephone and sends the order directly to shipping. In general, it takes a regular order from three to five days to be processed through the Cambridge plant. An emergency order, however, can be processed the same day that it is received. Another feature of the order entry procedure which should be noted is the dual effort that is required to maintain both the manual stock records inventory and the automated data processing inventory.

The final stage of the order entry system is the preparation of the order for shipping. Some orders can be shipped out immediately while others can be delayed for a week or more if stock is not available or if enough stock has not been accumulated to fill a pool car. Since the institution of a new policy last June, practically all customer orders, except those destined for New England, are shipped first to a warehouse and then reshipped to the customer. Freight rates, of course, are regulated by the
Interstate Commerce Commission, and company policy concerning shipping costs is determined primarily by the industry price leaders and not by BWH. Presently, BWH will pay the freight on shipments of over 500 pounds. This 500 pounds cannot include:

1. Made to order items manufactured in different plants.
2. Combinations of different orders with different order numbers.
3. Partial shipments of stock items when the balance of the order can be shipped within 14 days of receipt of the order.

On shipments of less than 500 pounds, the customer must pay the freight cost, but only that portion which results from shipping from the warehouse. BWH still pays that portion from the factories to the warehouses. The customer will pay the freight on any merchandise which is returned for credit or exchange and will incur a 10% handling charge.

A recent study of BWH's Chicago warehouse has shown that for the month of October, 1970, the average size of an order placed on that warehouse was $115. Although on an order of that size the customer must pay the freight, it still requires costly handling and paperwork. In many
cases these small orders are composed of more than one item. Of those orders greater than $500 (assuming an average of $1.00 per 1 pound of merchandise) the majority of them average in size between $500 and $1,000.

**Important Characteristics for the Choice of a Model**

Thus far, it has been the attempt of this chapter to describe some of the general characteristics and policies of BWH. In the rest of this chapter we shall focus on those aspects of BWH's distribution system which were important in the choice of Liberatore's model as a technique for examining alternatives to the current system.

In the past BWH has sold over 80% of its goods to a re-seller, and through the first half of 1970, this segment accounted for 87% of BWH's business. In the re-seller segment approximately 50% of the business is with industrial distributors, and the remainder is with coupling manufacturers and others who further process BWH's products and resell them. The industrial distributor market has proven to be the most stable and most profitable segment of BWH's business. On the other hand, it is this segment which requires full product lines and high degree of customer service. It is basically for this segment of the market that
BWH maintains its seven company run warehouses in addition to its factory warehouses. Recently, however, the cost/effectiveness of these warehouses has been questioned. On one hand are the benefits to be gained from increased sales as the result of better customer service and from cheaper bulk shipping rates which can be obtained on shipments from the factories to the warehouses. On the other hand, the costs, both fixed and variable, of maintaining warehouses, the costs of holding inventories, and the costs of maintaining a more complex organization have been rising at a high rate. For example, to maintain an adequate supply of inventory of just one product in seven warehouse locations requires far more inventory than if it were held only in the factory warehouses. Furthermore, the complexities of forecasting demand for each stocking location so that proper inventory levels can be determined are increased. It is not uncommon for an item to be out of stock in one part of the country while the same item is overstocked in a different region. When a company produces thousands of different products, as in the case of BWH, there are large potential savings which could result from a properly managed inventory-distribution program.
It was decided that it would be impossible within the time constraints imposed on this thesis to examine any of BWH's detailed inventory policies. There were, however, a number of available techniques which would allow an in-depth analysis of BWH's current warehouse locations and policies. A brief description of these techniques was presented in Chapter I, and the one which was finally chosen to study BWH's current warehousing locations is "The Development and Evaluation of a Modified Heuristic Program for Locating Warehouses", presented in a Master's Thesis in September, 1970, by John A. Liberatore. The next chapter will describe the model and why it was chosen.
CHAPTER III

LIBERATORE'S MODEL

Two characteristics which are common to all mathematical programming models for distribution systems planning are simplifications and assumptions. In most instances it is the accuracy of these simplifications and assumptions that determines how close a model conforms to reality. It is not the intent of this paper to argue whether or not a model which appears to conform to reality but yields poor results is more valuable than one which is oversimplified but yields better results. It is sufficient to say that this paper is most concerned with a model whose results most resemble reality. At the same time, a model which is too simple to allow us to examine the effects of varying any of the major determinants of costs would not have enough flexibility to suit our purposes. In Chapter I four important elements of physical distribution planning were listed as: the location and size of warehouses, guidelines for inventory management, general transportation policy, and optimal service level.

Of those models presented in Chapter I most of them are missing one or more of these elements. Each of them represents a significant step forward in the development
of a better model, and each presents a different approach to some aspect of the simplifications which are necessary. One of the more flexible models which has yielded consistently better results than its predecessors is presented in a 1970 M.I.T. Master's thesis by John A. Liberatore.¹

First, Liberatore describes his model of the major elements of a physical distribution system. His model contains four sectors: revenue, shipping, warehousing, and inventory. He then develops a heuristic program to generate good warehouse location patterns and to assign customer centers to the warehouses. The model and program will be described below. (For a more complete description one can refer to Liberatore's thesis.²) Briefly, Liberatore outlines the four sectors of his model as follows:

1. **Revenue** sector consisting of

   (a) Customer demands
   (b) Logistics gross margin per unit

2. **Product movement** sector consisting of

   (a) Transportation costs between factory and warehouse

   (b) Transportation costs between warehouse and customer

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1. Liberatore, *op. cit.*

2. Ibid.
3. **Warehouse** sector consisting of

(a) Capital charges resulting from investment in warehouse facilities

(b) Variable warehousing expenses arising from order processing and material handling and warehousing

4. **Inventory** sector

**The Revenue Sector**

It was Liberatore's belief that in designing a distribution model there should be some portion to reflect a service elasticity of demand. This is not a new idea but is one that has never before been included in a programming formulation of the problem. The revenue sector attempts to describe a customer's sales volume as a function of the order cycle time required to serve him.

This section is one of the primary reasons why this model was chosen for BWH. The principle reason for the existence of BWH's inventories and warehouses is to maintain an adequate level of service to support its current sales level. It is estimated by the sales department that a significant decrease in service time would result in increased sales of up to 10%. Service time could be decreased by either decreasing the number of stockouts or increasing the number of warehouse locations. This model
is capable of examining the tradeoffs between decreasing service times and the additional costs of maintaining the warehouses and inventories necessary to do so.

To formulate adequately the relationship between demand and order cycle time, the model splits it into two parts. The first part is the time which results from the actual movement of goods and is based upon the distance between the customer and the warehouse serving him. The second part, which in many cases represents more time than the first part, is the time that it takes to process an order from its receipt until it is finally shipped from the warehouse. This part is dependent upon a firm's order processing and material handling abilities, the spatial layout of warehouses, and internal transportation systems. To cope with both these parts, the model is designed to "solve for the 'optimum' set of warehouse locations using a wide range of parameter sets to relate order cycle time to distance." To determine the sales revenue, a forecast of the maximum yearly demand is made for each customer center. These forecasts should be expressed as random variables normally distributed with a known mean and standard deviation. These forecasts are

3. Ibid., p. 53
then adjusted to determine the percentage of this demand which is actually realized depending on the order cycle time to serve a customer center from the warehouse nearest it. The figure which is used for unit sales revenue is expressed exclusive of distribution costs since the costs of distribution will be subtracted during the running of the program.

The Product Movement Sector

This sector is based on the assumption that transportation costs are a linear function of distance. At first, it was unclear how accurate this assumption would be in an actual situation, but, as will be shown later, the results turned out surprisingly realistic. With a slight program modification actual shipping rates could have been used, but it was decided that the linear assumption was good enough to yield the results similar to those obtainable with the use of actual rates.

There are, however, a number of other issues in this area with which this model does not adequately deal. The model assumes that all shipments from BWH's factories to its warehouses are based upon full truckload rates and that all shipments from warehouses to customer centers are
based upon truckload rates for shipments of 500 to 1000 pounds. This model does not account for the cheaper carload rates and does not attempt to balance the costs of waiting for carload shipments against the cheaper carload rates that would result from waiting. Furthermore, it assumes that all goods are routed through warehouses and that there are no direct shipments to customers. It is not felt that the failure to deal with these issues hurts the performance of a model. In fact, the additional complexities which would result from the inclusion of these issues would probably not yield sufficiently better results to justify including them. These issues are, however, important and should be the subject of an independent study.

This section is extremely important since shipping costs are a major portion of the total distribution costs.  

**Warehouse Sector**

For each potential warehouse site, there are two primary cost components; a fixed cost which is independent of throughput and a variable cost which is proportional to throughput. These costs are composed of: packaging materials, maintenance materials, utilities and operating
costs, payrolls, rents, depreciation, insurance, overhead, and taxes. How these costs were divided will be explained later.

The fixed cost portion of warehouse costs is relatively straightforward and is expressed in dollars/year. The variable cost portion attempts to take into account possible economies of scale in warehousing. The model assumes a curve of five cost segments, and the cost is expressed in dollars/unit for different units of throughput.

Inventory Sector

This sector of the model is by far the most complex, but it attempts to incorporate inventory costs in a manner which had not been tried before. Previous approaches had either ignored inventory costs or attempted to incorporate them into the warehouse cost curve. Neither of these approaches adequately deals with the problem since inventory levels do not vary linearly with warehouse throughput and since "the greater the number of separate inventories, the greater the investment in inventory must be for a given total volume of sales"\(^4\). For BWH this is an extremely important part of the model. BWH produces so many product lines that to adequately stock each warehouse means the

\(^{4}\) Ibid., p.73
addition of large amounts of inventory over what would have to be stocked if all inventory was stored at one location.

The theoretical basis for this sector of the model is Bowman and Petter's Standard Economic Order Quantity model. Since the derivation is complicated, we will not repeat it here but will only summarize a step-by-step analysis of how this inventory model would theoretically be used.5 The program would open a tentative set of warehouse locations and would allocate customer centers to the open warehouses. Then, using the allocation for each warehouse, the parameters of the probability density function of the expected demand (normally distributed) on the warehouse would be determined. From the inventory holding costs and shortage costs and using the parameters of the expected sales distribution and a table of normal curve areas, the required level of inventory for each warehouse can be found. In Liberatore's final version he developed an alternative procedure which allows testing the sensitivity of the system design to inventory considerations without determining a specific value for the inventory shortage cost.

5. Ibid., p. 78
Definition of Necessary Variables

Before describing how the heuristic program developed by Liberatore works, we will define some of the more important variables that must be used as input to the program.

Let: 6

N = Number of customers to be served by the potential warehouses
NFAC = Number of factory locations
LFCLOC(i) = List of factory locations
M = Number of potential warehouse sites
LWHLOC (i) = List of potential warehouse sites
IYRSCC(i,1) = Mean of the maximum yearly sales forecast for customer center i (units)
IYRSCC(1,2) = Standard deviation of yearly sales forecast for customer center i (units)
SERELS (k) = Percentage of maximum yearly sales achieved at a customer center when it experiences an order cycle time of k days
MDIST(j,i) = Distance in miles between warehouse j and customer center i
IORYT(1) = Order cycle time for customer centers 1-100 miles from the warehouse serving it
UNREV = Sales revenue exclusive of distribution costs ($/unit)
COBNFR = Shipping costs between warehouses and customer centers ($/mile/unit)

6. Ibid., pp. 54-82
CIBNFR = Shipping costs between factories and warehouses ($/mile/unit)

IWSFXC = Fixed cost portion of warehouse cost curve ($/year)

WHSVRC (k,1) = Lower bound on warehouse cost curve segment k (units of throughput)

WHSVRC (k,2) = Slope of warehouse cost curve segment k ($/unit)

WHSVRC (k,3) = Upper bound on warehouse cost curve segment k (units of throughput)

LDTPR = Radial distance in miles that can be served by a factory within a week from the placement of an order on it

SERFAC = Number of standard deviations of the sales forecast against which inventory protection is desired

HLDCST = Inventory holding cost ($/unit/week)

The Heuristic Program

A flow chart for the final version of Liberatore's heuristic program is presented in Exhibit 1. The actual program was coded in FORTRAN IV for use on M.I.T.'s Compatible Time Sharing System on an IBM 7094 computer. The program listing is given in Appendix I and consists of the main routine and two subroutines:

7. Ibid., p. 10
EXHIBIT 1

Flow Diagram of Liberatore's Heuristic Program

1. Read in:
   a) The factory locations
   b) The M potential warehouse sites
   c) The number of warehouse sites (N) evaluated in detail on each cycle, i.e., the size of the buffer
d) Shipping costs between factories, potential warehouses and customers
e) Demand forecast for each customer
f) Cost function associated with the operation of each warehouse
g) Function relating sales to delivery time
h) Inventory costs and policy variables
i) Sales revenue per unit exclusive of distribution costs

2. Determine system's profit with only factory warehouse.

3. Determine and place in the buffer the N potential warehouse sites which, considering only the effects on their local demand, would produce the greatest increase in profit if supplied by local warehouses rather than by the warehouse currently servicing them.

4. Evaluate the profit that would result for the total system for each of the distribution patterns resulting from the addition of the next warehouse at each of the N locations in the buffer.

5. Eliminate from further consideration any of the N sites which do not offer increased profits in excess of fixed costs.

6. Do any of the N sites offer increased profits in excess of fixed costs?
   - Yes 7. Locate a warehouse at that site which offers the largest increase in profits
   - No 8. Have all M potential warehouse sites been eliminated?
     - Yes 9. Stop
1. MAIN - Accept input data defining problem, perform necessary transformations of this data, conduct heuristic search to find final "best" set of open warehouse locations, and generate solution reports.

2. ALOCAT - Accept set of open warehouses and allocate customer centers to them, return with final allocation and resulting profit

3. LOCATE - Construct from a list of undisposed warehouse locations a buffer containing those locations to be evaluated in detail during the next stage of the search

The location portion of the program is based entirely on the three heuristics used by Kuehn-Hamburger and presented in Chapter I.

The allocation routine is based on the following heuristic: 8

Customer centers will generally be serviced by the warehouse which enables it to achieve its greatest sales volume. Those assignments will need to be altered only when the new allocations lead to a greater profit for the system as a whole. The only changes in assignments that need to be considered as leading to greater system profit are those where on an individual customer center basis it appears

8. Ibid., p. 96
that an alternative warehouse would generate more revenue from the center than the warehouse currently serving it.

For further detail one can refer to Liberatore's thesis. In the next chapter we shall look at how the model was set up and at the accuracy of the data which were used.
CHAPTER IV
SETTING UP THE MODEL

In the first three chapters we attempted to trace the development of a heuristic program for locating warehouses and to describe that program. In theory, the model performs well, but what remains is to test it in an actual corporate situation. A general description of the company which was chosen was presented in Chapter II. In this chapter, we shall look at the data which were used and the assumptions which were made to adapt actual data to that required by Libratore's program.

**Number of Customer Centers \((N)\)**

Liberatore's program dimensioned the maximum number of customer centers at 50. It would have been an easy task to increase this number, but it was decided that any potential gains in doing so would be outweighed by increased running times for the program. Furthermore, little difficulty was experienced in reducing BWH's demand pattern to fifty major customer centers.

The data for this was obtained from a report made for the first time last year which listed sales from 1055 customers in 576 cities in 50 states. This list showed only those sales of products from Cambridge, Mass., and
did not account for sales from BWH's other major plant in Hohenwald, Tennessee. In many cases, a particular city's demand was so great as to make it an immediate choice for a customer center. In the rest of the instances, the choice was made either because a city was the center of a large demand area or because a city was far enough away from other demand centers that it could not rationally be assigned to any of them. The fifty customer centers chosen are located in 35 states and are listed with their yearly sales in Exhibit 2.

**Number of Factories and List of Factory Locations**

Since over 90% of BWH's sales are produced in either Hohenwald, Tennessee or Cambridge, Massachusetts, the choice of how many factories to use in the model was limited. Each of these plants, however, produces different products and experiences somewhat different demand patterns. We were unable to obtain sales data from Hohenwald which listed sales by city, as we had obtained from Cambridge. Thus, if we were to use both plants in our program, we would be forced to use less accurate data concerning customer center sales than if we were only to include Cambridge sales.
A second problem is caused by the program's assumption that all warehouses are served by the factory nearest them. Since the Cambridge and Hohenwald plants produce different products, this would be an unrealistic assumption, and it is questionable how this would have affected the results. It was decided, therefore, that all the initial runs would be made with only one warehouse located in Cambridge. Later, a number of runs would be duplicated with two warehouses, one at Cambridge and the other at Hohenwald, so that the results could be compared.
EXHIBIT 2

List of Customer Center Locations

and Potential Warehouse sites

1. Birmingham, Alabama $153,173
2. Little Rock, Arkansas 124,622
3. Phoenix, Arizona 188,820
4. Bakersfield, California 147,841
5. Los Angeles, California 653,345
6. Sacramento, California 470,426
7. San Francisco, California 255,364
8. Denver, Colorado 198,890
9. New Haven, Connecticut 274,629
10. Jacksonville, Florida 113,435
11. St. Petersburg, Florida 368,441
12. Atlanta, Georgia 498,056
13. Davenport, Iowa 28,228
14. Idaho Falls, Idaho 133,329
15. Vicksburg, Mississippi 23,564
16. Chicago, Illinois 562,739
17. Decatur, Illinois 420,521
18. Indianapolis, Indiana 404,156
19. Louisville, Kentucky 102,407
20. New Orleans, Louisiana 381,175
21. Boston, Massachusetts 1,118,233
22. Baltimore, Maryland 430,005
23. Detroit, Michigan 460,774
24. Minneapolis, Minnesota 572,199
25. Kansas City, Missouri 521,150
26. St. Louis, Missouri 377,041
27. Raleigh, North Carolina 828,337
28. Newark, New Jersey 544,747
29. Trenton, New Jersey 192,943
30. Albuquerque, New Mexico 75,063
31. Carlsbad, New Mexico 59,536
32. Binghamton, New York 120,555
33. New York, New York 1,048,415
34. Rochester, New York 169,317
35. Albany, New York 59,936
36. Cincinnati, Ohio 187,572
37. Columbus, Ohio 134,115
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<tr>
<th></th>
<th>City</th>
<th>Population</th>
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<td>39.</td>
<td>Portland, Oregon</td>
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<tr>
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<td>42.</td>
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</tr>
<tr>
<td>43.</td>
<td>Sioux Falls, South Dakota</td>
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</tr>
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</tr>
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<td>48.</td>
<td>Roanoke, Virginia</td>
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<tr>
<td>49.</td>
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</tr>
<tr>
<td>50.</td>
<td>Milwaukee, Wisconsin</td>
<td>248,679</td>
</tr>
</tbody>
</table>

$17,668,322$
Number and List of Potential Warehouse Sites

One of the heuristics upon which this program is based is that most locations are not promising sites for a regional warehouse. This is definitely true in case of BWH. Liberatore's program dimensioned the maximum number of potential warehouses at 25, and it was decided that 25 was more than enough for our runs. The 25 potential warehouse sites which were chosen are those 25 customer center locations which are underlined in Exhibit 2. These 25 warehouses were picked primarily because they were the locations with the most demand. In some cases, however, locations with large demand were not picked since they were near enough to larger demand centers that they would not be feasible as additional locations. Of these 25, 8 are presently warehouse sites for BWH: 2 factory warehouses at Boston (Cambridge) and Nashville (Hohenwald) and 6 warehouse locations at Los Angeles, Atlanta, Chicago, Minneapolis, Newark (Moonachie), and Dallas.

After examining the initial runs, it was decided that there was little need to continue with 25 potential sites since (1) many of these sites would not really be feasible due to other considerations, and (2) the running
time of the program increases significantly as the number of potential warehouses increases. As a result, the majority of the runs were made using only the 8 warehouses currently maintained by BWH.

Mean and Standard Deviation of Customer Center Sales

Since sales data for the customer centers were only available for one year, it was impossible to establish a mean and standard deviation for sales. Instead of a mean, the previous years sales statistics were used. A standard deviation of 20% was assumed. It is believed that these figures are relatively close to those that would have been used if a mean could have been established. A standard deviation of 20% appeared to be reasonable. When the program was run with two factory locations, we assumed that the demand pattern was simply twice that of one factory. The standard deviation remained at 20%. While these assumptions might not be exactly true-to-life, it is felt that they are close enough to give some indication of how the system would react with two factories. In addition, a few runs were made with one factory experiencing a 10% increase in demand at each customer center, but the results were the same as with the original figures.
Service Time Variables

There are three basic variables which are intended to reflect the effect of warehouse location on system profits. The first (LDTPR) is the radial distance in miles that can be served by a factory within a week from the placement of an order on it. At BWH this figure varies widely, depending on what the product is and how it is to be shipped. Initially, a value of 2,000 miles was used even though it is doubtful that a warehouse that far away could be served within one week. As a comparison, the same data was run with this variable set to only 400 miles. This was considered more realistic since in many cases it takes practically a week before the order even reaches the shipping department. The final location patterns were the same in both cases, but as would be expected, the inventory holding costs were slightly higher in the second case. It was decided to use the value of 400 miles for the rest of the runs.

The second variable (SERELS) is the percentage of maximum yearly sales which is achieved at a customer center depending on the number of days delivery time. We have chosen the same values as Liberatore used in his example
since they also appeared to be reasonable for BWH. These values are:

```
SERELS (1) = 1.00  
SERELS (2) = 0.90  
SERELS (3) = -0.82 
SERELS (4) = 0.76  
SERELS (5) = 0.76  
```

This means that if a customer center experiences only a one day delivery time, he will receive 100% of the maximum yearly sales. If, on the other hand, the delivery delay is two days, sales will be only 90% of the maximum, etc. Since the sales department at BWH maintains that with the current warehouse pattern practically any location can be served within one day, it is felt that the above is fairly representative of how sales would react to these various service times.

The service times are determined by the third variable (IORCYT) which is the order cycle time for customer centers 1*100 miles from the warehouse serving it. For example, an order cycle time of 5,5,5,10 would result in an order cycle time of one day if the warehouse is within 500 miles of the customer center, two days if it is between 500 and 1,000 miles, three days if it is between 1,000 and 1,500 miles, four days if it is between 1,500 and 2,500 miles, and five
days if it is further than 2,500 miles. During the runs this value was constantly varied to examine the effects that changes in delivery time would make on the final location pattern. Values which were tried were:

\[
\begin{align*}
&\text{IORCYT} = 25,0,0,0 \\
&\text{IORCYT} = 3,5,5,12 \\
&\text{IORCYT} = 5,5,5,10 \\
&\text{IORCYT} = 7,7,7,7
\end{align*}
\]

An order cycle time of 25,0,0,0 means that any customer center can be served from anywhere in the country within one day. The effect of this is to temporarily remove any delivery considerations from the model so that we can look solely at how transportation and inventory holding costs affect the systems profits.

Matrix of Distances

Since both shipping costs and a large portion of the allocation procedure are based upon the distances between potential warehouses and the customer centers, it was important to pick accurate distances. To do this, we used a Rand McNally Road Atlas which contained a chart showing the road mileage between major U. S. cities. This chart was intended for use by truckers, and limited access highways were utilized in computations where most practical even though they were not the shortest routes. Since we
were dealing with shipping distances, it was felt that this was the most accurate data which could be used. The matrix of these distances is presented in Appendix 2.

**Inbound and Outbound Shipping Costs**

Having established the appropriate distances between various cities, it then became necessary to determine the shipping costs between the factories and warehouses and between the warehouses and customer centers. The first step was to collect the actual shipping rates between a number of customer centers and potential warehouse sites. Since these rates are based upon the number of pounds in a shipment, it then had to be decided which rates to use. For shipments from factories to warehouses it was decided to base the rates on full truckload shipments. In a few cases a "piggy-back" rate, approximately half of the truckload rate, could have been used. The program, however, allows only one rate, and since piggy-back service is only available between a few cities, it was decided that shipping costs between factories and warehouses should be based upon truckload rates. Piggy-back rates are available from Cambridge to Chicago, Dallas, and Los Angeles and from Hohenwald to Los Angeles. Although these rates will not be used, it should be remembered that their
use would tend to increase the profitability of locating warehouses in Chicago, Dallas, and/or Los Angeles. The resulting inbound shipping costs were calculated to be $.02/mile/unit. (a unit consists of either 1,000 pounds or $1,000 and will be explained later in this chapter). The calculations are presented in Exhibit 3 and are calculated between Boston and various locations. The resulting figure was then checked using the actual rates for different locations. In over 50% of the 20 rates checked, the variance from the actual was less than 8% and in only 2 cases was the variance over 20%.

The method for calculating outbound shipping costs was similar to that of calculating the inbound costs except that the rates which were used were different. The rates used were based upon shipments of 500-1,000 pounds. A study performed in February of last year showed that the average order size of the 781 orders processed during the second week of the month was $711. In a further breakdown by region, the average order size was $797 in the East, $632 in the West, $692 in the South, and $723 in the Midwest. The resulting outbound shipping costs were calculated to be $.05/mile/unit. The calculations are presented in Exhibit 4.
EXHIBIT 3

CALCULATIONS OF INBOUND SHIPPING COSTS

\[ \text{Cost ($/unit/mile)} = \frac{(\text{Rate/1001bs.}) \times (1000 \text{ lbs./unit})}{(100 \text{ lbs.})} \times (\text{Distance in miles}) \]

- **Boston-Atlanta**
  \[ \frac{(2.19) \times 1000}{100 \times 1068} = 0.0205 \]

- **Boston-Moonachie**
  \[ \frac{(0.39) \times 1000}{100 \times 216} = 0.0180 \]

- **Boston-Chicago**
  \[ \frac{(2.15) \times 1000}{100 \times 975} = 0.0220 \]

- **Boston-Dallas**
  \[ \frac{(3.61) \times 1000}{100 \times 1819} = 0.0200 \]

- **Boston-Los Angeles**
  \[ \frac{(6.22) \times 1000}{100 \times 3052} = 0.0205 \]

Therefore:

Average Shipping Cost = \$0.02/mile/unit

*Based on truckload rates*
EXHIBIT 4

CALCULATION OF OUTBOUND SHIPPING COSTS

\[
\text{(Rate/100lbs.)} \times (1000 \text{ lbs./unit})
\]

\[
\text{Cost ($/unit/mile)} = \frac{(100 \text{ lbs.})(\text{Distance in miles})}{(100 \text{ lbs./unit})}
\]

Boston-Atlanta

\[
\frac{(5.42)(1000)}{100} = \frac{5.42}{100} \times 1000 = 0.051
\]

Boston-Moonachie

\[
\frac{(2.48)(1000)}{100} = \frac{2.48}{100} \times 1000 = 0.110
\]

Boston-Chicago

\[
\frac{(2.15)(1000)}{100} = \frac{2.15}{100} \times 1000 = 0.059
\]

Boston-Dallas

\[
\frac{(8.29)(1000)}{100} = \frac{8.29}{100} \times 1000 = 0.045
\]

Boston-Los Angeles

\[
\frac{(11.23)(1000)}{100} = \frac{11.23}{100} \times 1000 = 0.037
\]

Therefore:

Average Shipping Cost = \$0.05/mile/unit

*Based on shipments of 500 to 1000 pounds
With a slight program modification we could have used actual shipping costs, but the assumption of costs being linear with distance proved more accurate than expected, so it was not necessary. The resulting outbound shipping costs proved to be 2½ times as great as the inbound shipping costs. This is not unrealistic in light of current transportation costs in this country. In fact, it is expected that each of these costs will rise approximately 10% over the next year.

Inventory Holding Costs and Desired Service Level

These two variables control the inventory segments of Liberatore’s model. The first, inventory holding cost, is expressed in dollars per unit per week. Two values were chosen for this variable: $0.00/unit/week, and $5.00/unit/week. By setting the holding cost to zero, we eliminate the inventory sector from our model. This enables us to examine changes in the other variables without introducing the complexity of an inventory holding cost. The inventory holding cost of $5.00/unit/week corresponds to approximately 25% of the unit selling price per year. When run with BWH’s current warehouse location pattern and Liberatore’s optimal inventory allocation scheme, this value
resulted in an inventory holding cost of 6% based upon BWH's present inventory level of $5,000,000.

Little use was made of the SERFAC variable, the number of standard deviations of the sales forecast against which inventory protection is desired. The primary reason for this was the difficulty in determining the proper value of this variable. In addition, Liberatore noticed that strange behavior resulted when this variable was changed while running with his sample data. It was decided to set SERFAC equal to 2 for almost all runs and vary it only in a few cases to examine its effects.

Fixed and Variable Warehouse Costs

Data concerning warehouse costs was collected from an IBM report which is published monthly and which lists all warehouse related costs for each warehouse. Fixed costs include: depreciation, building rentals, real estate taxes, amortization, insurance, and a portion of certain other expenses without which the warehouse could not exist. The costs of maintaining the factory warehouses were not included, since Liberatore's program does not assess any cost for factory warehouses. A simple average of these costs for all six field warehouses was used. The resulting
warehouse fixed cost is $18,000 per warehouse per year. The variable warehouse costs averaged $41,000 per warehouse per year, or $246,000 per year for all six warehouses. It was somewhat difficult to determine how to quantify any economies of scale, if there were any. By examining the history of the Moonachie warehouse, the most recent one, certain economies of scale were determined to be applicable when the aggregate warehouse throughput exceeded $2,000,000 per year. For levels below this, the slope of the warehouse cost curve segment is $20/unit, and for levels greater than this, the slope has been set to $15/unit.

Sales Revenue

As has been mentioned before, BWH produces a wide variety of products which sell for different prices and have different values per pound, for example: matting - $.32/pound, packing - $.65/pound, flat belts - $.87/pound, fire and hydraulic hose - $1.40/pound, and power transmission belts - $3.00/pound. Since the program allows only one value, it was decided to use an average weighted by product sales. The resulting value was approximately $1.00/pound. A unit therefore, consists of either $1,000 or 1,000 pounds of merchandise.
By examining BWH's monthly profit and loss statements for 1970, operating profits for the Cambridge plant have been averaging approximately 2.5% of sales, and for the Hohenwald plant have been averaging approximately 12% of sales. Distribution expenses attributable to both plants were approximately 8% of sales. For the initial runs made with one plant, UNREV, sales revenue exclusive of distribution costs, was set at $100 per unit, or approximately 10% of sales. In some runs a sales revenue of $120 per unit, or 12%, was used to examine how higher profit margins would affect the distribution pattern. The $120/unit figure was used in runs with two factories, except for two runs in which a $200 per unit sales revenue was tried. Values for all variables necessary to run Liberatore's program have now been determined. In the next chapter, the results of these runs will be presented.
CHAPTER V
THE RESULTS OF THE RUNS

It should be remembered that the purpose of this thesis is twofold. First and foremost is the desire to provide Boston Woven Hose with assistance in evaluating their current distribution and warehousing system. Second is the desire to test the model proposed by Liberatore in an actual corporate situation. To best accomplish these goals, we have used Liberatore's program to run four groups of data. The first group consists of two runs with previously specified location patterns. The purpose of these runs is to provide a basis for comparison of results and to determine the accuracy of those figures which were presented in Chapter IV. The second group is those runs with one factory location and a unit revenue of $100. These runs are executed with both eight and twenty-five potential warehouse sites. The third group also consists of runs with one factory, but the effect of raising UNREV to $120 and varying the order cycle times is examined. In one run a unit revenue as high as $160 was tried. The fourth group was run with two factory locations and twenty-five potential warehouses. The effect of varying the order cycle time is also examined.
The results of these runs are hardly startling, and the general trend of the results might easily have been predicted. As inventory costs are eliminated, the number of warehouses located by the program increases. Similarly, as the unit revenue increases, the number of warehouses located also increases. Furthermore, the runs confirm some of the observations made by Liberatore in his thesis. The effect of varying IORCYT is indeed significant. In addition, as the revenue generated by the system is reduced, inventory costs play a more important role. In approximately half of the runs, however, both the revenue and the inventory sectors were eliminated by setting IORCYT = 25,0,0,0 and HLDCST = 0.0. This constrained the problem to that of cost minimization.

A summary of the results of these runs is presented in Exhibit 5.

The First Group of Runs

The primary run of this group was an examination of BWH's current location pattern. To do this, a special feature of the program was utilized which permitted declaring a specified set of warehouses as open. The program, therefore, skips the LOCATE subroutine and simply allocates the customer centers to the open warehouses and
**EXHIBIT 5**

**SUMMARY OF RESULTS OF RUNS**

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<tr>
<th>IORCYT</th>
<th>INV HLD SER</th>
<th>UN-REV</th>
<th># WHSES USED</th>
<th>NUMBERS OF WAREHOUSES IN SOLUTIONS</th>
<th>INBOUND SHIP COSTS</th>
<th>OUTBOUND SHIP COSTS</th>
<th>INV WHSE COSTS</th>
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<td>72</td>
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<td>794</td>
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<td>794</td>
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<td>1,262</td>
<td>819</td>
</tr>
<tr>
<td>25,0,0,0</td>
<td>25 2 160 25</td>
<td>21 5 16 41 25 39 27</td>
<td>2,821</td>
<td>346</td>
<td>225</td>
<td>17</td>
<td>286</td>
<td>108</td>
<td>984</td>
<td>1,837</td>
</tr>
<tr>
<td>25,0,0,0</td>
<td>0 2 120 25</td>
<td>21 44 5 16 28 39 45 41 27</td>
<td>4,231</td>
<td>387</td>
<td>322</td>
<td>-</td>
<td>546</td>
<td>126</td>
<td>1,382</td>
<td>2,849</td>
</tr>
<tr>
<td>25,0,0,0</td>
<td>0 2 120 8</td>
<td>21 44 5 16 28 45</td>
<td>4,231</td>
<td>329</td>
<td>483</td>
<td>-</td>
<td>528</td>
<td>72</td>
<td>1,414</td>
<td>2,817</td>
</tr>
<tr>
<td>3,5,5,12</td>
<td>5 2 200 25</td>
<td>21 44 5 16 41 45 39 27</td>
<td>6,896</td>
<td>387</td>
<td>333</td>
<td>715</td>
<td>526</td>
<td>108</td>
<td>2,070</td>
<td>4,825</td>
</tr>
</tbody>
</table>
determines the relevant costs. The results of this run are presented in Exhibit 6, together with the actual figures for the first 11 months of 1970. The numbers in the parentheses represent the figures expressed as a percentage of sales. The results of the computer run fare well. The largest variation is in shipping costs where the actual figures are a 1% greater portion of the total distribution costs than the computer generated shipping costs. This is not unexpected, since the model has assumed that shipping costs are a linear function of distance. The allocation of customer centers to warehouses upon which the program based its costs and revenues is presented in Exhibit 7. Since the results of this run correspond closely to BWH's actual figures, they will be used as the basis of comparison with later runs.

The second run was to test a basic "core" configuration of warehouses. In all of the runs made in this thesis, Liberatore's program located warehouses in Los Angeles and Chicago. Furthermore, in 60% of the runs, a warehouse was located in Newark. It was decided, therefore, to run the model with both factories and only these three warehouses. The elimination of the Atlanta, Dallas, and Minneapolis resulted in increased shipping costs of $50,000/year
EXHIBIT 6

RESULTS OF BASIC RUN

<table>
<thead>
<tr>
<th></th>
<th>Model</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>17,641 (100%)</td>
<td>16,611* (100%)</td>
</tr>
<tr>
<td>Revenue</td>
<td>1,763 (10%)</td>
<td>1,839 (11%)</td>
</tr>
<tr>
<td>Shipping Costs</td>
<td>574 (3.3%)</td>
<td>695 (4.2%)</td>
</tr>
<tr>
<td>Inventory Costs</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Variable Warehouse Costs</td>
<td>294 (1.6%)</td>
<td>250 (1.5%)</td>
</tr>
<tr>
<td>Fixed Warehouse Costs</td>
<td>126 (.7%)</td>
<td>118 (.7%)</td>
</tr>
<tr>
<td>Total Warehouse Costs</td>
<td>420 (2.3%)</td>
<td>368 (2.2%)</td>
</tr>
<tr>
<td>Total Costs</td>
<td>996 (5.6%)</td>
<td>1,060 (6.4%)</td>
</tr>
<tr>
<td>Profits</td>
<td>766 (4.4%)</td>
<td>748 (4.5%)</td>
</tr>
</tbody>
</table>

*Based on the first 11 months of 1970
## EXHIBIT 7

### ALLOCATION OF CUSTOMERS FROM BASIC RUN

<table>
<thead>
<tr>
<th>Warehouse</th>
<th>Assigned Customer Centers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boston</td>
<td>Boston</td>
</tr>
<tr>
<td>Hohenwald</td>
<td>Little Rock</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>Phoenix</td>
</tr>
<tr>
<td></td>
<td>Sacramento</td>
</tr>
<tr>
<td>Atlanta</td>
<td>Birmingham</td>
</tr>
<tr>
<td></td>
<td>Atlanta</td>
</tr>
<tr>
<td></td>
<td>Greenville</td>
</tr>
<tr>
<td>Chicago</td>
<td>Denver</td>
</tr>
<tr>
<td></td>
<td>Decatur</td>
</tr>
<tr>
<td></td>
<td>Detroit</td>
</tr>
<tr>
<td></td>
<td>Milwaukee</td>
</tr>
<tr>
<td>Minneapolis</td>
<td>Idaho Falls</td>
</tr>
<tr>
<td></td>
<td>Seattle</td>
</tr>
<tr>
<td>Newark</td>
<td>New Haven</td>
</tr>
<tr>
<td></td>
<td>Newark</td>
</tr>
<tr>
<td></td>
<td>New York City</td>
</tr>
<tr>
<td></td>
<td>Columbus</td>
</tr>
<tr>
<td></td>
<td>Richmond</td>
</tr>
<tr>
<td>Dallas</td>
<td>Albuquerque</td>
</tr>
<tr>
<td></td>
<td>Dallas</td>
</tr>
</tbody>
</table>

- Rochester
- Hohenwald
- Bakersfield
- San Francisco
- Los Angeles
- Portland
- Jacksonville
- St. Petersburg
- Vicksburg
- New Orleans
- Davenport
- Indianapolis
- Louisville
- Kansas City
- St. Louis
- Minneapolis
- Sioux Falls
- Baltimore
- Raleigh
- Trenton
- Binghamton
- Albany
- Cincinnati
- Philadelphia
- Pittsburgh
- Roanoke
- Carlsbad
- Duncan
- Houston
but reduced warehouse costs by $77,000/year. Profits, therefore, are $28,000/year greater with the three less warehouses. This does not include the additional inventory savings which would have resulted if the inventory sector had been included; nor does it include reduced sales due to increased order cycle times since that sector was also eliminated from the run. In this basic cost minimization routine, however, it should be noted that the most profitable warehouse configuration contained only three field warehouses.

The Second Group of Runs

For this group of runs only one factory was used as explained in Chapter IV. First, two runs were made with 25 potential warehouse sites and later three more runs were performed, with only eight potential sites. In all these runs UNREV was set to $100. The purpose of running the program with 25 potential sites was to determine if other than BWH's current warehouse locations might become profitable. In the first run with no inventory costs, the program located six warehouses: Boston, Hohenwald, Los Angeles, Chicago, Baltimore and Portland. (Since the program is only being run with one factory,
Hohenwald is considered a field warehouse). In this run no warehouse was located in Newark. This warehouse configuration yields a higher profit than either of the basic runs of the first group.

In the second run with 25 potential warehouses, an inventory holding cost was added. The result was a warehouse configuration with only four warehouses: Boston, Hohenwald, Los Angeles and Chicago. It should be remembered that the Los Angeles and Chicago warehouses are located in every solution. The total shipping costs are $729,000/year, more than $100,000/year over any of the previous runs.

The results are interesting when run with only eight potential warehouses. With no inventory holding costs, the warehouses located are the same as the second basic core configuration of the first group: Boston, Hohenwald, Los Angeles, Chicago and Newark. The addition of the Newark warehouse to the other four saves $105,000/year in shipping costs. When the inventory sector was added, the warehouses in Hohenwald and Newark were dropped, and a new one was added in Atlanta.
We see here one of the problems encountered in running the program. In this group two runs have been made with the same values for all the variables. One run was made with 25 potential warehouses and the other with only 8, a subset of the 25. The resulting location patterns, however, are different. In the case of 25 potential sites, warehouses were located in Boston, Hohenwald, Los Angeles and Chicago. In the case of only 8 potential warehouses, a warehouse in Atlanta was located instead of the one in Hohenwald. The configuration with Atlanta saves $64,000/year in shipping costs and results in $55,000/year greater profits. The reason for this variation is the allocation procedure. Customer centers are tentatively allocated to potential warehouse sites, and as the number of potential sites change, so will this allocation. In this case, the run with 25 potential sites located the first most profitable warehouse in Hohenwald, and the run with only 8 potential sites located the first most profitable warehouse in Chicago.

In the final run of this group, the inventory sector was eliminated and the amount of inventory protection desired was decreased. The result was 5 warehouses located
in: Boston, Los Angeles, Chicago, Newark and Atlanta. The difference between this location pattern and the one generated with a higher degree of desired inventory protection is that a warehouse was located in Atlanta instead of Hohenwald. The result is $8,000/year more profits caused by a reduction of $8,000/year in shipping costs. We have been unable to explain why the cheaper location pattern was not located in the first run.

Despite some of the problems with the program, a number of preliminary observations can be made. The addition of a warehouse in Newark results in significant savings in shipping costs for the entire system. Second, no warehouses were located in either Dallas or Minneapolis in any of the runs. Lastly, only one warehouse was located in the southeastern portion of the country. In some cases this was Atlanta, and in others it was Hohenwald. Atlanta, however, always resulted in cheaper shipping costs. A program error prevented adding the revenue sector to these runs. At one point in the ALOCAT subroutine the program sums all variable costs and revenues for each warehouse. The costs are then subtracted from the revenues. If this value should become negative, either because the costs are too large or the revenues are too small, the program will
not function. This is what occurred when the revenue sector was included with a unit revenue of only $100/unit.

The Third Group of Runs

To enable the revenue sector to be included in the runs, the value of UNREV was raised to $120/unit for this group. Since the previous group of runs showed that the basic solution set was comprised of BWH's current warehouse locations, it was decided that this group would be run with only 8 potential warehouse sites. The first run was without the inventory or revenue sectors and was to serve as a basis of comparison with the other runs of this group. The resulting location pattern was: Boston, Los Angeles, Chicago, New York and Atlanta. When this same run was made with an UNREV of $100/unit, a warehouse was located in Hohenwald instead of Atlanta.

The remaining four runs test the effect of varying both the SERFAC and IORCYT variables. In the second run the inventory holding cost was held at zero, but the desired level of inventory protection was reduced. Order cycle times were increased as radial distances from the nearest warehouse increased from 300 miles to 800 miles to 1,300 miles to 2,500 miles. The location pattern was the same as the first run with the addition of a warehouse
in Dallas. These were the only circumstances, when the program was run with one factory, which resulted in the location of a warehouse in Dallas. In spite of the addition of this warehouse, $90,000 in revenue was lost due to increased order cycle times. A total of $77,000 was saved in shipping and variable warehousing costs, and fixed warehouse costs increased by $18,000. Total profits, therefore, were only reduced $22,000 even though $90,000 in revenue was lost.

In the third run the desired level of inventory protection was returned to its original value, but an inventory holding cost of $5.00/unit/week was introduced. The order cycle time was left the same as in the second run. The result was the elimination of the Dallas warehouse. Revenues decreased by another $27,000 and shipping costs increased $10,000. Inventory costs with this configuration were $369,000/year.

In the next two runs of this group the order cycle times were increased. In the first of these IORCYT was set to 5,5,5,10. Under these conditions revenues increased $61,000 and total profits increased $80,000. Furthermore, the Atlanta warehouse was eliminated and replaced by a
warehouse in Hohenwald. Inventory costs were reduced in this run by $60,000. In the second of these runs the radial distances were again increased by 200 miles, an IORCYT equal to 7, 7, 7, 7. The result was the elimination of the Newark warehouse and the replacement of the Hohenwald warehouse with one in Atlanta. Although revenues are increased another $20,000 in this run, profits are reduced $5,000. It should be noted that the solution with the greatest revenue is not necessarily the most profitable.

In the final run of this section 25 potential warehouse sites were examined with a unit revenue of $160/unit. A small inventory holding cost of $.25/unit/week was charged. The purpose of this run was to examine how the program would locate warehouses with an extremely high profit margin. The resulting location pattern was: Boston, Los Angeles, Chicago, Pittsburgh, Kansas City, Portland and Raleigh. This was the only run in which a warehouse was located in the mid-west, and it was located in Kansas City, not Minneapolis. This configuration, however, produces shipping costs of $571,000/year, only $3,000/year less than BWH's current configuration.
The Fourth Group of Runs

In this group of runs two factory locations were used. It must be remembered that Liberatore's program assumes that all of the demand at a particular warehouse is serviced from the nearest factory. The customer center demand is simply twice the demand that was used with one factory location. In the basic run with 25 potential warehouses, and with the inventory and revenue sectors eliminated, warehouses were located in: Boston, Hohenwald, Los Angeles, Chicago, Newark, Portland, Dallas, Pittsburgh and Raleigh. Shipping costs with this configuration were $709,000/year and the resulting profit was $2,849,000/year. For the first 11 months of 1970, BWH's actual profits were $2,848,000. Adjusted to 12 months, this would result in actual yearly profits of $3,050,000. In the second run, the same values were used with only 8 potential warehouses, 6 of which were profitable: Boston, Hohenwald, Los Angeles, Chicago, Newark and Dallas. Shipping costs were $100,000/year greater than in the initial run, and total profits were $32,000 less. In the last run, the unit revenue was changed to $200 so that the revenue sector could be included. IORCYT was set to 3,5,5,12; inventory
costs were set to $5.00/unit/week; and the program was run with 25 potential warehouse sites. The resulting location pattern was the same as in the first group, but without a warehouse in Newark. Shipping costs were $720,000 and profits were $4,825,000 due to the high value of UNREV.

A number of observations are important. With a plant located in Hohenwald, Atlanta is never a profitable warehouse. Instead, Dallas becomes a profitable warehouse in all three runs. Furthermore, beyond a certain point greatly increased revenues do not yield a greater number of warehouses. Lastly, significant savings result from the introduction of warehouses in Portland, Pittsburgh and Raleigh.
Summary and Conclusions from Runs

Since the purpose of this thesis is twofold, the results shall be summarized in two parts. First, some observations on the successes and failures of Liberatore's model shall be drawn together. Second, an attempt will be made to determine how the results of these runs should affect Boston Woven Hose.

The most striking deficiency of Liberatore's program is its inability to handle small profit margins. Liberatore states "that as we decrease UNREV, we will merely get final solutions which are subsets of the solutions found for larger values of UNREV and that changing UNREV will not alter the order in which the program adds warehouses to build a final solution". He even goes so far as to hypothesize the location patterns that would result from decreasing UNREV. First, this thesis has found that if the value of UNREV becomes too low in relation to the other variables, the program will not run. Second, the runs showed that the location patterns resulting from different values of UNREV (all other things being held constant) are not necessarily subsets, and, in fact, can
be quite different. A new method for handling this portion of the allocation procedure must be developed. The model, however, would probably perform well when used with a product with a high profit margin (at least 10% of sales).

A second area which needs adjustment is the determination of variable warehouse costs. In the 14 runs made for this thesis, the difference between the largest and the smallest values of warehouse variable costs was only $40,000. In fact, the addition of four warehouses to the four "core" warehouses resulted in increased warehouse variable costs of only $18,000. In the case of BWH, the actual average warehouse variable costs are $38,000/warehouse. In part, this problem might have been circumvented by increasing the warehouse fixed costs and by decreasing the variable costs. Due to a lack of computer time, however, this was not tried.

The revenue and shipping sectors of the model work well. The addition of the revenue sector to the work done in this area is significant. It was somewhat more difficult to determine how well the inventory sector performs since the program does not provide information on which warehouse locations account for which percentage of the inventory costs. The aggregate values of inventory costs, however,
does appear to be in line with what might have been expected.

Despite these deficiencies, the results of these runs provide a sound basis for a number of observations concerning Boston Woven Hose's current warehouse location pattern. First, there is little doubt about the profitability of locating warehouses in Los Angeles and Chicago. In every run the program located warehouses in both these locations. In each case, the Los Angeles warehouse was one of the first two to be located. These warehouses are even more profitable than the model shows since "piggy-back" shipping rates are available from both Boston and Hohenwald to Los Angeles and from Boston to Chicago.

Second, Dallas is also a profitable warehouse. In runs with one factory location, Dallas was only profitable in one run with a stiff service requirement, but when two factory locations were used, Dallas became profitable in all three runs. In fact, in two of these three runs, the Dallas warehouse was located before the Chicago one. As with the Chicago and Los Angeles warehouses, the Dallas warehouse is actually even more profitable than the model represents since "piggy-back" service is also available from Boston to Dallas.

Third, there does not appear to be a need for a ware-
house in Atlanta. In each run the program located one, and only one, warehouse in the southeastern portion of the United States. In six of these runs, a warehouse was located in Atlanta, and in the other seven runs, one was located in Hohenwald. Never was a warehouse located in both locations. Since a factory warehouse is located in Hohenwald, it would appear that there is no need for a warehouse in Atlanta. This, however, is based on the assumption that the factory warehouses operate in the same way that a field warehouse would. In reality, this does not occur. Orders are processed and shipped far more quickly from field warehouses than from the factory ones. Therefore, before the elimination of the Atlanta warehouse should be considered, the factory warehouse at Hohenwald must be upgraded to carry a complete line and to process orders as a field warehouse would.

Fourth, the Moonachie warehouse appears profitable, and results in significant savings in shipping costs and provides better service to one of BWH's largest markets.

Fifth, BWH should consider the elimination of its warehouses in both Minneapolis and Cedar Rapids. In none of our 16 runs was a warehouse located in either of these
locations. In only one run was a warehouse located anywhere in the midwest, and that was located in Kansas City, not in either of BWH's current midwest locations.

Finally, the results of the runs suggest that under certain circumstances, profitable warehouses might be opened in either one or more of the following locations: Pittsburgh, Kansas City, Portland and/or Raleigh.

**Areas of Further Study**

For those interested in furthering the work done by Liberatore, the areas for investigation are almost unlimited. Earlier in this chapter, a number of areas were pointed out in which the model seemed weak. Significant work could be done in improving Liberatore's model in any of these areas. Furthermore, in many ways the model is too broad in scope. Perhaps some additional work might be done to further develop on a more micro level each of the four areas in Liberatore's thesis. Lastly, the model might be extended to include some broader assumptions. For example, an allocation scheme might be developed so that a portion of the demand at each potential warehouse site could be served from each of a number of factories instead of each potential warehouse being served by the factory nearest it.
For Boston Woven Hose also, much work remains. A large effort should be made to better define the relationship between order cycle times and the resulting sales levels. A better understanding of this relationship would lead to a more meaningful evaluation of not only BWH's distribution system, but also the proper directions in which to concentrate its marketing effort. Furthermore, an analysis similar to the one now performed should be repeated, using potential, as opposed to actual, sales data. The location pattern presented in this thesis is designed to meet BWH's current operations. Perhaps the location pattern should be developed to best take advantage of BWH's full sales potential.
BIBLIOGRAPHY

Books


Articles


INPLT 8371 9152  HEPLCH  MACTRN
COMMCA  MCIST(50,50),CTSCWC(25,50),IYRSWC(25,50,2),WKSWC(25,50,2),I
IASGC(25,50),IASGL(25,50),FINCPI(25,50),LWHLOC(25),FISCFW(25),LAWHL
2(25),IEUF(6,2),LFLOC(5),YN,NFAC,NWHS,SUBTP,SAVTP,IKOUNT,IBUF
3SZ,IWSFXC,LCSTR,FLDCST,WHSVRC(5,2),UNREV,IASGLB(25,50),IIN,ICUT,IA
4SGLS(25,50),PREV,PINSC,PCTSC,PWHVC,PINVC
COMMCA  LWHLCS(25),SERFAC
COMMCA  LWHLCS(25),CIMENSICN
COMMCA  CC8C(5),CIBNFR(5),IRCYT(38),SRELS(5),IYRSCC(50,2),IO
1RCY(4)
1IN=260
IOUT=261
C  REAC INPUT DATA TO INITIALIZE PROGRAM
C  REAC IN NUMBER CF CUSTOMER CENTRES
REAC(IIN,10)  \n10 FORMAT(5X,13)
CO 800 K1=1,5C
CO 800 K2=1,5C
800 MCIST(K1,K2)=0
CO 200 KI=1,5C
REAC(IIN,2C1) (MCIST(KI,KII),KII=1,16)
201 FORMAT(16(I4,1X))
200 CONTINUE
CO 202 KIII=1,5C
REAC(IIN,2C3) (MCIST(KIII,KIV),KIV=17,32)
203 FORMAT(16(I4,1X))
202 CONTINUE
CO 204 KV=1,5C
REAC(IIN,2C5) (MCIST(KV,KVI),KVI=33,48)
205 FORMAT(16(I4,1X))
204 CONTINUE
CO 206 KVII=1,5C
REAC(IIN,207) (MCIST(KVII,KVIII),KVIII=49,50)
207 FORMAT(2(I4,1X))
206 CONTINUE
C REAIC IN PARAMETERS OF ABSOLLTELY YEARLY DEMAND
CO 28 N11=1,N
REAC(IIN,29) (IYRSCC(N11,N12),N12=1,2)
29 FORMAT(5X,15,5X,15)
28 CONTINUE
C REAIC IN SERVICE ELASTICITY CF DEMAND AS A FUNCTION OF ORDER CYCLE
SERELS(1)=1.00
SERELS(2)=0.90
SERELS(3)=0.82
SERELS(4)=0.76
SERELS(5)=0.76
CO 21 IF=1,38
21 IORCYT(IF)=5
C REAIC IN NUMBER CF DELIVERY SYSTEM TYPES THAT WILL BE EVALUATED
PRINT 851
851 FORMAT(5X,19HREAC
851,850 FORMAT(4I4)
K1=0
CO 840 K2=1,4
IF(ICRCY(K2)) 841,840,841
841 K3=K1+1
K4=K1+ICRCY(K2)
CC 842 K5=K3,K4
842 IORCYT(K5)=K2
K1=K4
CONTINUE
C REAC IN COUTBUNC FREIGHT COSTS (W C) AS A FUNCTION OF DELIVERY SYS
C TYPE
C CBKNFR(1)=0.05
C REAC IN INBOUND FREIGHT COSTS (F W) AS A FUNCTION OF DELIVERY SYS
C TYPE
C CBKNFR(1)=0.02
C REAC IN NUMBER OF FACTORY LOCATIONS
C NFAC=1
C CONTINUE
C REAC IN LIST OF FACTORY LOCATIONS
C LFCLCC(1)=21
C CONTINUE
C CONTINUE
C CONTINUE
C PRINT 852
852 FORMAT(5X,39HREAC IN NO. OF POTENTIAL WHSE. SITES I3)
853 FORMAT(13)
C PRINT 854
854 FORMAT(5X,4CHREAC IN LIST OF POTENTIAL WHSE. SITES I3)
C EC 26 N11=1,M
C REAC 855, LWHCLCC(N11)
C 26 CONTINUE
C REAC IN VARIABLE WAREHOUSE COST FUNCTION
C WHSVC(1,1)=0.C
C WHSVC(1,2)=2C.
C WHSVC(1,3)=2C C.
C WHSVC(2,1)=2C1.
C WHSVC(2,2)=15.
C WHSVC(2,3)=9999999.
WHSVRC(3,1) = 9999999.
WHSVRC(3,2) = 15.
WHSVRC(3,3) = 9999999.
WHSVRC(4,1) = 9999999.
WHSVRC(4,2) = 15.
WHSVRC(4,3) = 9999999.
WHSVRC(5,1) = 9999999.
WHSVRC(5,2) = 15.
WHSVRC(5,3) = 9999999.

C READ IN FIXED WAREHOUSE OPERATING COST
IW SFXC = 18000
PRINT 856
856 FORMAT(5X,36HREAC IN INVENTORY HOLDING COST, X.XX)
READ 857, FLCCST
857 FORMAT(F4.2)

C READ IN LEADS TIME PARAMETER FOR FACTORY TO WAREHOUSE MOVEMENTS
LDTPO = 2000
PRINT 858
858 FORMAT(5X,2CHREAC IN UNREV, XXX.X)
READ 859, UNREV
859 FORMAT(F5.1)

C READ IN BUFFER SIZE
IBUFSZ = 5
PRINT 860
860 FORMAT(5X,18HREAC IN SERFAC X.X)
READ 861, SERFAC
861 FORMAT(F3.1)

C END OF INITIALIZATION PHASE
IFLAG = 1

C SELECT DELIVERY SYSTEM TYPE
L=1
C  PERFCRM INITIAL CALCULATIONS
C  CALCULATE CLTBCOLND SHIPPING COSTS BETWEEN EACH POTENTIAL WAREHOUSE
C  AND CUSTOMER CENTER
C
801 CTSCW(x1, x2) = C.C
C 100 JET=1,M
ITEMP1=LWHLCC(JET)
C 110 JCY=1,N
CTSCW(JET, JCY) = CBNFR(L) * FLOAT(MDIST(ITEMP1, JCY))
110 CONTINUE
100 CONTINUE
C  CALCULATE INBCUANL SHIPPING COST FOR EACH POTENTIAL WAREHOUSE SITE
802 FISCFW(K1) = C.C
C 120 JCY=1,N
ITEMP1=LWHLCC(JCY)
IMILE=1CCCG
C 130 JET=1,NFAC
ITEMP2=LFLCLCC(JET)
IF(MDIST(ITEMP2,ITEMP1)-IMILE) 803,130,130
803 IMILE=MDIST(ITEMP2,ITEMP1)
130 CONTINUE
FISCFW(JCY) = CBNFR(L) * FLOAT(IMILE)
120 CONTINUE
C  CALCULATE PARAMETERS OF ABSCLUTE YEARLY SALES IF A CUSTOMER IS SER
C UED BY ANYCNE OF THE POTENTIAL WAREHOUSE SITES
C
804 K1=1,25
804 K2=1,50
804 K3=1,2
IYRShC(K1,K2,K3)=0
804
CO 150 JET=1
ITEMP1=LWHLCC(JET)
CO 149 JCY=1
ITEMP2=MCMISTITEMP1,JCY)/1CO61
ITEMP3=ICRCYTITEMP2
TEMP4=SERELSITEMP3
IYRShC(JET,JCY,1)=TEMP4*FLCATIYRSCC(JOY,1))
IYRShC(JET,JCY,2)=TEMP4*FLOATIYRSCC(JOY,2))
149 CONTINUE
150 CONTINUE
C CALCULATE PARAMETERS OF WEEKLY SALES DISTRIBUTION
CO 805 K1=1,25
CO 805 K2=1,5C
CO 805 K3=1,2
805 WKSWC(K1,K2,K3)=C.0
SQRT52=SCRT52.C)
CO 148 JET=1
CO 147 JCY=1
WKShC(JET,JCY,1)=IYRShC(JET,JCY,1)/52
WKShC(JET,JCY,2)=FLCATIYRShC(JET,JCY,2))SQRT52
147 CONTINUE
148 CONTINUE
C PREPARE DATA PRIOR TO CALLING ALLOCATION SUBROUTINE
PRINT 862
862 FORMAT(5X,44HSEARCH AND EVALUATION OR ONLY EVALUATION, XX)
READ 333, LFLAG
333 FORMAT(12)
IF(LFLAG=99) 334,806,334
806 NWHS=M
806
CONTINUE 01830

LAWFLC(JEAN)=JEAN 01840

CONTINUE 01850

DO 807 K1=1,25 01860
DO 807 K2=1,25 01870

IASGC(K1,K2)=C 01880

CALL ALCCAT 01900

DO 339 MIKE=1,10 01910
DO 340 MONK=1,10 01920

IASGLS(MIKE,MONK)=IASGC(MIKE,MONK) 01930

CONTINUE 01940

CONTINUE 01950

CONTINUE 01960

CONTINUE 01970

CONTINUE 01980

CONTINUE 01990

CONTINUE 02000

CONTINUE 02010

CONTINUE 02020

CONTINUE 02030

CONTINUE 02040

CONTINUE 02050

CONTINUE 02060

CONTINUE 02070

CONTINUE 02080

CONTINUE 02090

CONTINUE 02100

CONTINUE 02110

CONTINUE 02120

CONTINUE 02130

CONTINUE 02140

CONTINUE 02150
337 CONTINUE
    GO TO 199
        
334 CONTINUE
    IF(IFLAG-1) 160,811,16C
811 NWHS=NFACT
    DO 161 JEAN=1,NFACT
      JET=LWHLC(C(JEAN))
      LWHLC(JEAN)=1CC6JET
      LWHLC(JEAN)=JEAN
     CONTINUE
161 CONTINUE
    DO 812 K1=1,25
      DO 812 K2=1,5C
812 IASGC(K1,K2)=C
    IFLAG=1C
    CALL ALCCAT
    DO 165 MIKE=1,1M
      DO 165 MONK=1,1N
        IASGLS(MIKE,MONK)=IASGC(MIKE,MONK)
        CONTINUE
166 CONTINUE
165 CONTINUE
    TEMPI1=SAVTPI-FLCAT((NWHS-NFACT)*IWSFXC)
    WRITE(ICLT,9CO)
700 FORMAT(11,10X,42HSYSTEM DESIGN WITH ONLY FACTORY WAREHOUSES///)
    PFXC=(NWHS-NFACT)*IWSFXC
    TCCST=PINSC&POTSC&PWHVC&PINVC&PFXC
    WRITE(ICUT,2CCO) PREV,PINSC,POTSC,PINVC,PWHVC,PFXC,TCCST,TEMP11
    WRITE(ICUT,2CC1)
    DO 9C1 MULL=1,NWHS
      II=LWHLC(MULL)
      IV=LWHLC(II)

IF(IV-1CC) 814,814,813
813 IV=IV-1CC
814 WRITE(ICUT,9C4) IV
904 FORMAT(23X,I3)
903 FORMAT(59X,I3)
CONTINUE
CONTINUE
CONTINUE
902 CONTINUE
901 CONTINUE
160 CONTINUE
ITEMP5=0
162 CONTINUE
CALL LCCATE
IF(IKCUNT) 816,777,816
816 IF(IKCUNT-IBUFZ) 163,817,817
817 IVAN=IBLFSZ
GO TO 164
163 IVAN=IKCUNT
164 CONTINUE
NWHS=NWWFS1
INC5=C
CC 167 KIP=1,IVAN
LAW+LC(NWHS)=IBLF(KIP,1)
CC 168 MIKE=1,N
CC 169 MCNK=1,N
IASGC(MIKE,MCNK)=IASGLS(MIKE,MCNK)
169 CONTINUE
168 CONTINUE
CALL ALCCAT
ITEMP9=SAVTP1-FLCAT((NWHS-NFAC)*IWSFXC)-TEMP1
IF(ITEMP9) 818,818,170

818 ITEMP8=LAHLCC(NW+5)
LWHLCC(ITEMP8)=-59
GO TC 167

170 ITEMP7=SAVTP1-FLCAT((NW+5-NFAC)*IWSFXC)
IF(ITEMP7-ITEMP5) 167,819,819

819 ITEMP5=ITEMP7
WREV=PREV
WINSC=PINSC
WOTSC=PCTSC
WHVVC=PWVVC
WINVC=PINVC
WFXC=(NW+S-NFAC)*IWSFXC
INC5=KIP
CO 171 MIKE=1,N
CO 172 MCNK=1,N
IASGLS(MIKE,MCNK)=IASGL(MIKE,MCNK)

172 CONTINUE
171 CONTINUE
167 CONTINUE

IF(INC5) 82C,82C,198

820 WRITE(ICLT,51C)

910 FORMAT(15X,56+NC WAREHOUSE SELECTION COULD BE MADE FROM CURRENT BU
IFFER)

NWHS=NW+5-1
GO TC 162

198 ITEMP1=ITEMP5
CO 173 MIKE=1,N
CO 174 MCNK=1,N
IASGLS(MIKE,MCNK)=IASGL(MIKE,MCNK)
CONTINUE
KAT=IBUF(INC5,1)
KAL=LWHLC(KAT)
LWHLC(KAT)=KAL&1CC
LAWLC(NWHS)=KAT
TCOST=WINSC&WCTSC&WVHC&WINVC&WFXC
WRITE(ILCT,905)
905 FORMAT(1-1,10X,69F10.1,BEST WAREHOUSE SELECTION AND CUSTOMER ASSIGNMENT)
1 USING CURRENT BEST\)
WRITE(ILCT,2001)
2001 FORMAT(1-1,15X,37H CUSTOMER CENTER ASSIGNMENTS IN SYSTEM/15X,16HWAR
1EHOOSE NUMBER,1CX,36H NUMBERS OF ASSIGNED CUSTOMER CENTERS)
CC NG6 MUL=1,\&WHS
II=LAWLC(LLL)
IV=LWHLC(II)
IF(IV-1CC) 822,P22,821
821 TV=IV-1CC
822 WRITE(ILCT,5C7) IV
9C7 FORMAT(23X,13/)
CONTINUE
CONTINUE
CONTINUE
CONTINUE
CONTINUE
CONTINUE
908 CONTINUE
906 CONTINUE  
GO TO 162  
199 CONTINUE  
CALL EXIT  
END  
*ECF*
INPLT M8371 S152 ALLCAT PACTRA

SUBRCUTINE ALCCAT

!DIMCN MCIST(50,50),CTSCWC(25,50),IYRSWC(25,50,2),WKSWC(25,50,2),I

1ASGC(25,50),IASGL(25,50),FINCPI(25,50),LWHLOC(25),FISCFW(25),LAWHL

2C(25),IBUF(C6,2),LFCLOC(5),N,N,FAC,NWHS,SUBTP1,SATPI,IKOUNT,IBUF

3SZ,HSFXC,LCCT,HLDCT,WSVRC(5,2),UNREV,IASGHL(25,50),IN,OUT,IA

4SGLS(25,50),PREV,PINSC,PCTSC,PWVVC,PINVC

!DIMCN LWHLOC(25),SERFAC

ITIE=0

SAVTPI=C

PREV=C

PINSC=C

PCTSC=C

PWHVC=C

PINVC=C

CC 6C0 MIKE=1,N

CO 6C1 MCNK=1,N

IASGL(MIKE,MCNK)=IASGC(MIKE,MCNK)

6C0 CONTINUE

6C0 CONTINUE

CC 8C0 K1=1,25

CC 8C0 K2=1,5C

8C0 IASGC(K1,K2)=C

C DETERMINE PRELIMINARY ALLOCATION BASED CNLY ON DEMAND CONSIDERATIO

CC 801 K1=1,25

CC 801 K2=1,5C

801 IEVEN(K1,K2)=C

CC 5C0 JET=1,N

IASC=C

ISALES=C

00010

00020

00030

00040

00050

00060

00070

00080

00090

00100

00110

00120

00130

00140

00150

00160

00170

00180

00190

00200

00210

00220

00230

00240

00250

00260

00270

00280

00290

00300
IEC=C
CC 515 MIKE=1,NWF S
ITEP1=LAW+LC(MIKE)
ITEP2=LWF+CC(ITEP1)
IF(ITEP2-1CC) 8C3,8C3,8C2
802 ITEP2=ITEP2-1CC
803 IF(ITEP2-JET) 515,8C4,515
804 IASG=ITEP1
CONTINUE
GC TC 510
515 CONTINUE
CC 501 JCY=1,NWF S
ITEMP5=LAW+LC(JCY)
IF(ITEMP5-JET) 503,805,503
805 IEC=IEC+1
IJEVEN(IEC,JET)=JCY
806 IF(ITEMP5-JET) 806,501,501
807 IASG=ITEMP5
CONTINUE
500 IASG=ITEMP5
501 CONTINUE
IF(IEC) 8C7,51C,8C7
807 CC 502 JCY=1,NWF S
ITEMP5=LAW+LC(JCY)
IASG=ITEMP5
IF(IASGL(ITEMP5,JET)) 8C8,5C2,808
808 GO TC 51C
502 CONTINUE
510 CONTINUE
IF(IASG) 8C9,8C9,509
8C9  ITIE=ITIE61
     LTIE(ITIE)=JET
     GO TC 5C0
5C9  IASCC(IASG,JET)=1
5C0  CONTINUE
     IF(ITIE) 810,5C8,810
810  CO 5C7  JACK=1,ITIE
     ITEMP6=LTIE(ITIE)
     CC 811  K1=1,25
     IF(ITIF) 810,5C8,810
811  ITCTP(K1)=C
     CO 506  JILL=1,NWFS
     IF(IEVEN(JILL,ITEMP6)) 812,5C7,812
812  ITEMP7=IEVEN(JILL,ITEMP6)
     CO 5C5  JEFF=1,N
     IF(IASCC(ITEMP7,JEFF)) 813,5C5,813
813  ITOTP(JILL)=ITCTP(JILL)&IYRSWC(ITEMP7,JEFF,1)
5C5  CONTINUE
5C6  CONTINUE
     ITOP=0
     IASG=C
     CO 5C4  JILL=1,NWFS
     IF(ITCTP(JILL)) 814,511,814
814  IF(ITCTP(JILL)-ITCP) 504,504,815
815  IASG=IEVEN(JILL,ITEMP6)
     ITOP=ITCTP(JILL)
5C4  CONTINUE
511  CONTINUE
     IASCC(IASG,ITEMP6)=1
5C7  CONTINUE
508  CONTINUE
C ENC CF ROUTINE TC DETERMINE ALLCCATION BASED ONLY ON DEMAND CONSID
C ERATICKS

572 CONTINUE
C 816 K1=1,25
C 816 K2=1,5C
816 FI NCP1(K1,K2)= -55555.0C

C INVENTORY CONSIDERATIONS
TWHVC=C
TINVC=C
C 550 JCY=1,NH+S
ITEMP1=LAWHLC(JCY)
ITEMP1=LWHLC(I TEMP1)
IF(ITEMP1-1CC) 818,818,817
817 ITEMP1=ITEMP1-1CC
818 IMILE=1CCGC
C 551 JEFF=1,NFAC
ITEMP2=LFCCLCC(JEFF)
IF(MCIST(ITEMP2,ITEMP1)-IMILE) 819,551,551
819 IMILE=MCIST(ITEMP2,ITEMP1)

551 CONTINUE
L1=(IMILE/LCTPR)1L
SUMWS=C
SUMWKV=C
SUMYRS=C
SUMINV=C
SUINCT=C
NUMB=G
C 565 JIM=1,H
IF(ASGC(ITEMP1,JIM)) 82C,565,82C
820 NUMB=NUMB+1
565 CONTINUE
CC 560 JIM=1,N
IF(IASGC(ITEMP1,JIM)) 821,560,821

821 SUMYRS=SLMYRS&FLCAT(IYRSW(SC(ITEMP1,JIM,1))
SUMWK=WKSC(ITEMP1,JIM,1)
SUMWKV=SUMWKV&(WKSC(ITEMP1,JIM,2))**2
FINV(JIM)=FLCAT(LI&1)*WKSC(ITEMP1,JIM,1)&(SERFAC/SQRT(FLOAT(NUMB))**2)
1)*SCRT(FLCAT(LI&1))*WKSC(ITEMP1,JIM,2)
SUMINV=SLMYNS&FINV(JIM)
CONTINUE

560 TOTINV=FLCAT(LI&1)*SUMWK&SQR(FCLAT(LI&1))*SQR(SUMWKV)*SERFAC
CONTINUE

CO 561 JIM=1,N
IF(IASGC(ITEMP1,JIM)) 822,561,822

822 FINV(JIM)=FINV(JIM)*(TOTINV/SUMINV)*52.0*HLOCST
TINVC=TINVC&FINV(JIM)
FINV(JIM)=FINV(JIM)/FLCAT(IYRSW(SC(ITEMP1,JIM,1))
SUINCT=SUINCT&FINV(JIM)
CONTINUE

561 CONTINUE
CO 562 JIM=1,N
IF(IASGC(ITEMP1,JIM)) 823,823,562

823 FINV(JIM)=SUINCT/FLOAT(NUMB)
CONTINUE

C DETERMINE VARIABLE WAREHOUSE CCSTS
JAY=C
CC 563 ILL=1,5
JAY=JAYE1
IF(SLMYRS-W+SVRC(ILL,1)) 563,825,825
825 IF(SLMYRS-W+SVRC(ILL,3)) 564,563,563
CONTINUE
CONTINUE
C SUM ALL VARIABLE CCSTS AND REVENUES FOR THIS WAREHOUSE AND ALL CUS
C I T E R O R C E N T E R S
CO 559 JIM=1,N
FINCPI(ITEMP1,JIM) = (UNREV-OTSCWC(ITEMP1,JIM)-FISCFW(ITEMP1)-WHSVRC(I,JAY,2)-FINV(JIM))*FLCAT(IYRSWC(ITEMP1,JIM,1))

559 CONTINUE
CO 7C0 JIM=1,N
IF(IASGC(ITEMP1,JIM)) 824,7C0,824
824 TWHVC=TWHVC+WHSVRC(JAY,2)*FLCAT(IYRSWC(ITEMP1,JIM,1))
7C0 CONTINUE

550 CONTINUE
SUBTPI=C
TREV=0
TOTSC=C
TINSC=C
CC 566 JIM=1,N
CO 567 JACK=1,N
IF(IASGC(JACK,JIM)) 826,567,826
826 SUBTPI=SLBTPi&FINCPI(JACK,JIM)
SALES=TYRSC(JACK,JIM,1)
TREV=TREV+UNREV*SALES
TOTSC=TCTSC+CTSCWC(JACK,JIM)*SALES
TINSC=TINSC+FISCFW(JACK)*SALES
GO TC 566
567 CONTINUE

566 CONTINUE
IF(SAVTPI-SLBTPi) 827,590,590
827 SAVTPI=SLBTPi
PREV=TREV
PCTSC=TCTSC
PINSC=TINSC
PINVC=TINVC
PWFVC=TfFVC
568 CONTINUE
569 CONTINUE
568 CONTINUE
C CETERVINE
KEi
TENTATIVE ALLCCATCIN
CC 828 K1=1,25
CC 828 K2=1,5C
828 IASCC(K1,K2)=Q
CC 570 JIM=1,9N
BEST=-5599C.C
IND1=C
CC 571 JACK=1,9M
ITEP1=LAW+LC(JACK)
ITEP2=LW+LOC(ITEP1)
IF(ITEP2-1CC) 83C,83C,829
829 ITEP2=ITEP2-1CC
830 IF(ITEP2-JIM) 58C,83C,830
831 INC1=ITEP1
CC TC 581
580 CONTINUE
IF(FINCP1(JACK,JIM)-BEST) 571,571,832
832 BEST=FINCP1(JACK,JIM)
INC1=JACK
571 CONTINUE
581 CONTINUE
IASGC(INC1,JIM)=1
570 CONTINUE
TWFVC=C
TINVC=C
INPLT  M0371  Y152  LCCATE  MACRA
SUBROUTINE LCCATE
COMMON  MCIST(50,50),CTSCWC(25,50),IYRSWC(25,50,2),WKSWC(25,50,2),I
IASC(25,50),IASCL(25,50),FINCPI(25,50),LWHLOC(25),FISCFW(25),LAWHL
2C(25),IBLCF(C6,2),LFCLCC(5),M,N,LFAC,NWHS,SUBTP1,SAVTP1,IKOUNT,IBUF
3S,WSFXC,SCFTP,FLCCST,WSVRC(5,2),UNREV,IASGLB(25,50),IIN,IOUT,IA
4SGLS(25,50),PREV,PINSC,PWTHVC,PINVC
COMMON  LWHLOC(25),SERFAC
DIMENSION  ACCPI(25),ITBLF(25,2)
DIMENSION  FINV(50)
WRITE(ICUT,506)
906  FORMAT(1HC)
 CO  4C1  MIKE=1,M
 CO  4C0  MONK=1,N
IASC(MIKE,MONK)=IASGLS(MIKE,MONK)
400  CONTINUE
401  CONTINUE
 CO  700  K1=1,25
 CO  700  K2=1,5C
700  FINCPI(K1,K2)=-55599.0
 TWHVC=C
 TINV=0
 CO  550  JCY=1,NWHS
 ITEMP1=LAWFLCC(JCY)
 ITEMP1=LWHLCC(ITEMP1)
 IF(ITEMP1=1C0)  702,702,7C1
701  ITEMP1=ITEMP1-1CC
7C2  IMILE=1CCC
 CO  551  JEJJ=1,NFAC
 ITEMP2=LFCLCC(JEJJ)
 IF(MCIST(ITEMP2,ITEMP1)-IMILE)  7C3,551,551
7C3  00010
7C4  00020
7C5  00030
7C6  00040
7C7  00050
7C8  00060
7C9  00070
7CA  00080
7CB  00090
7CC  00100
7CD  00110
7CE  00120
7CF  00130
7D0  00140
7D1  00150
7D2  00160
7D3  00170
7D4  00180
7D5  00190
7D6  00200
7D7  00210
7D8  00220
7D9  00230
7DA  00240
7DB  00250
7DC  00260
7DD  00270
7DE  00280
7DF  00290
7E0  00300
IMILE = MCIST(ITEMP2,ITEMP1)

CONTINUE

L1 = (IMILE/LCTR)**61
SUMWKS = C
SUMWKV = C
SUMYRS = C
SUMINV = C
SUINCT = C

NUM = 0

DO 565 JIM = 1, N
IF (IASGC(ITEMP1, JIM)) 7C4, 565, 704

JIM = 1, N
IF (IASGC(ITEMP1, JIM)) 7C5, 560, 7C5

SUMYRS = SUMYRS & FLCAT(IYRSWC(ITEMP1, JIM, 1))
SUMWKS = SUMWKS & WKSWC(ITEMP1, JIM, 1)
SUMWKV = SUMWKV & (WKSWC(ITEMP1, JIM, 2))**2
FINV(JIM) = FLCAT(L1 &1) * WKSWC(ITEMP1, JIM, 1) & (SERFAC/SQRT(FLOAT(NUM)))**2

SUMINV = SUMINV & FINV(JIM)

CONTINUE

TOTINV = FLOAT(L1 &1) * SUMWKS & SQRT(FLCAT(L1 &1)) * SQRT(SUMWKV) * SERFAC

DO 561 JIM = 1, N
IF (IASGC(ITEMP1, JIM)) 7C6, 561, 706
FINV(JIM) = FINV(JIM) & (TOTINV/SUMINV) * 52.0 * HLCST
TINV = TINV + FINV(JIM)
FINV(JIM) = FINV(JIM) / FLCAT(IYRSWC(ITEMP1, JIM, 1))
SUINCT = SUINCT & FINV(JIM)

CONTINUE
CC 562 JIM=1,
IF(IASGC(ITEMP1,JIM)) 7C7,707,562
7C7 FINV(JIM)=SUINCT/FLOAT(NUMB)
562 CONTINUE
JAY=0
CC 563 ILL=1,5
JAY=JAY61
IF(SUMYRS-WHRSVRC(ILL,1)) 563,713,713
713 IF(SUMYRS-WHRSVRC(ILL,3)) 564,563,563
563 CONTINUE
564 CONTINUE
CC 559 JIM=1,6
FINCPI(ITEMP1,JIM)=(LNREV-OTSCWC(ITEMP1,JIM)-FISCFW(ITEMP1)-WHRSVRC
1(JAY,2)-FINV(JIM))*FLCAT(IYRSWC(ITEMP1,JIM,1))
559 CONTINUE
560 CONTINUE
CO 708 K1=1,6
CC 708 K2=1,2
708 IBUF(K1,K2)=0
CO 7C9 K1=1,25
CO 7C9 K2=1,2
7C9 ITBLF(K1,K2)=0
IKOL=0
CO 800 JCE=1,6
IF(LWHLC(JCE)-1CC) 710,710,800
710 IF(LWHLC(JCE)>99) 711,800,711
711 ITEMP1=LWHLC(JCE)
CC 8C1 JEAN=1,6
IF(IASGLS(JEAN,ITEMP1)-1) 8C1,802,801
8C1 CONTINUE
8C2 CONTINUE
UNIS-SV=CTSCW(P(ITEMPI,FISCW(JOE),FISCW(JOE))
ADDPI(JCE) = (UNIS-SV)*FLOAT(IYRSW(JEAN,ITEMPI)) * (FLOAT(IYRSW(JOEL,ITEMPI)) * (FINCPI(JEAN,ITEMPI)/FL
2CAT(IYRSW(JEAN,ITEMPI,1)))*UNIS-SV)

C ELIMINATE FROM CONSIDERATION POTENTIAL WAREHOUSE SITES WHOSE ADDIT
IONAL CONTRIBUTION TO INCREMENTAL PROFIT IS LESS THAN THE FIXED CO
ST INCURRED BY OPENING A NEW WAREHOUSE

IF(ADP(JCE)) 712,804,804

712 LWLCC(JCE) = 55
GO TO 800

800 IKOUNT = IKLENTR+E1
ITBUF(IKOUNT,1) = JCE
ITBUF(IKOUNT,2) = ADP(JCE)
CONTINUE

C PLACE UP TO BUFSIZE POTENTIAL WAREHOUSES INTO THE BUFFER TO EVALUAT
CC 714 K1 = 1,6
CC 714 K2 = 1,2

714 IBUF(K1,K2) = 0
IF(IKOUNT) 810,810,810

810 CC 812 JAN = 1,IKOUNT
ITEMP2 = ITBUF(JAN,2)
CC 813 JEFF = 1,IBUFSZ
IF(ITEMP2-IBUFSZ(JEFF,2)) 813,813,715

715 IF(JEFF-IBUFSZ) 716,814,716

716 IBUF=IBUFSZ

815 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

717 IBUF = IBUF(JEF,-1)
IBUF = IBUF(JEF,1)
IBUF = IBUF(JEF,2)
IF(JEFF-IBUFSZ) 717,814,717

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717 IBUF = IBUF(JEF,-1)
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IF(JEFF-IBUFSZ) 717,814,717

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GO TC 815
814 IBUF(JEFF,1)=ITBLF(JAN,1)
    IBUF(JEFF,2)=ITBLF(JAN,2)
GO TC 812
813 CONTINUE
812 CONTINUE
880 CONTINUE
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920 FORMAT(1F1,5X,29PBUFFER OF WAREHOUSE LOCATIONS/10X,16HWAREHOUSE NUM
    MBER,10X,3C*ESTIMATE OF INCREMENTAL PROFIT/6(12X,I3,20X,I7/))
RETURN
END
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