A PRELIMINARY INVENTORY STUDY OF A STORES INVENTORY

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TABLE OF CONTENTS

0.0 INTRODUCTION

This report is concerned with the study of the prevailing inventory practices in a maintenance and supplies store connected with Kansas State University, Manhattan, Kansas. Various case studies are available in the literature for particular problems in inventory control. This report is based on the study of the overall inventory system with respect to its objectives, organization, procedures and decisions. The system was studied in relation to its three functional segments: storekeeping, recordkeeping, material requisitioning, and its control procedures. An effort was made to evaluate some inventory decisions made in the present practice and to check the applicability of the selective control of inventories particularly to the supplies type of inventory.

It would be proper to define here some terms related to this subject. "Inventory is an all inclusive term for the multitude of movable materials, supplies and parts housed in storerooms or warehouses awaiting processing, assembling, fabrication or shipping (10), P. 1. Inventory is also referred to as the value of these goods, or the counting and listing of them. Frequently it is used to designate a detailed list of articles, with perhaps the description, identification number, quantity and value. Also a lot more is

said about inventory as money:

Inventory is money temporarily wearing the guise of materials, supplies and parts. On this money, the company pays rather then collects interest. Inventory is "money" whose appearance as well as its value-negotiability are ever changing. Hence, it is always in danger of devaluation.

Inventory ties up money which represents roughly up to 25 percent of a corporations assets, and about 35 percent of the gross national product. Most companies figure that it costs 20 percent or more of the inventory value to carry them for a year.

A company's profits, its competitive standing and its potential for continued expansion are conditioned by the manner in which it controls its inventories. The control of inventories is one of the most complex and far reaching of all business activities. Its planning and execution involve participation by most of the functional segments of a business; e.g. sales, production, purchasing, finance and accounting.

The main functions of inventory control are to keep track of inventories and to maintain minimum but adequate inventory commensurate with company needs and available finance at a minimum total cost, and with a minimum number of controls that are again commensurate with company needs. But arrival at the happy medium between too much and too little stock is a tremendous feat in itself.

Inventory control can cover the following classes of inventory:

1) Raw materials.

2) Work in process.

3) Finished component parts.

4) Finished and purchased goods.

5) Packing and packaging goods.

6) Toolings and supplies.

This report is concerned with the study of type of inventory as of class 6 above. This type is known by a variety of names including "general stores," "maintenance and operating supplies" and the like. It includes all the nonproduct items regularly stocked by company and either consumed in the operation of a plant or office or needed to maintain its building and equipment. In manufacturing or processing, supplies are those items which are not included in the final product except in a minor way. They are indirect cost items on a product or a process.

0.5 OBJECTIVE

The objective of this report is to undertake a preliminary study of the general stores inventory. This study was chosen to see how the theories of inventory control interact with the practice and to what extent they are applicable.

The approach taken in this study is that of System Analysis. There are two phases of this study: the analysis of the operating structure of the inventory control system and the study of some of the inventory decisions.

This study is mainly based on its educational importance. No attempt has been made to design or recommend a new system or procedure. To stores personnel, however, it would give some insight of the use of analytical techniques to inventory situation.

The most important part in such an organization or system study is to review the existing paperwork and other related procedures. This analysis is necessary if any system improvement is desired in these areas.

It was necessary to collect the past history of items to study some inventory decisions. A sampling technique was used to gather the necessary data.

This study has a wide scope and it can cover the whole subject of Inventory Management. Hence in the beginning,

it was not possible to define the boundries of this report. "A boundry in the systems sense restricts the scope of a problem in a size commensurate with the cost and time available for solution and the amount of detail necessary to understand the process (8)." It was desired to study some fundamental concepts such as:

i. The study of the system's operating structure and related procedures, the objectives and relevant costs.
ii. To learn the sampling technique.
iii. The value analysis of this inventory.
iv. To determine the turnover of inventories per year.
v. To study the ordering policy of the system.
vi. The study of lead time distributions for the various ordering procedures of the system.

Situation Studied:

This report is concerned with a study of the general stores inventory belonging to Kansas State University. It consists of approximately 8,500 different items with an investment level of $250,000. It includes the necessary materials for various job orders and maintenance supplies for the various departments of the university. The various catagories of items that consist of great many diversified materials were named as contract items, hardware items, small tools, plumbing materials, steel, paint and auto supplies, electricals and custodian items, etc.

Plan of Study:

This study is divided into two parts.

Part I: Study of operating structure and procedures of the inventory control system.

Part II: Study of the control signals of the present inventory system and to try application of mathematical theories of inventory control to a present system.

PART I: ANALYSIS OF THE PRESENT INVENTORY SYSTEM

1.1 General Discussion of Systems Analysis

A system may be defined as anything in motion, in process or in a state of change (8), p. 26. This defination would not include communication systems as they lack "motion" in a conventional sense. Hence a more complete defination would be that "a system (often called as a total system) is a complex unity formed of a set of many diverse objects to achieve a common plan or serving a common purpose, subject to a given set of constraints, through a given set of relationships between the objects and their attributes (8), p. 26. Objects are parameters of systems such as input, process, output, feedback control, and a restriction. Attributes are the properties of object parameters. A property is the external manifestation of the way in which an object is known, observed or introduced in a process. Relationships are the

bonds that link objects and attributes in the system process. They are postulated among all elements, among systems and subsystems, and between two or more subsystems. The "system malfunction" occures due to changes in the desired relationships between objects and attributes.

The term "process" used above is defined as the totality of components encompassed by all objects, attributes and relationships to produce a given result. Processes may be mental (thinking, planning, learning), mental motor (testing, writing, constructing) or mechanical (operating, functioning). Processes may apply to men and machines and their combined activities. Even the simplest system does not exist without process which transforms input into output.

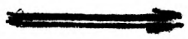
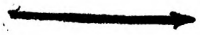
"Feedback" is defined as the subsystem function that compares output with a criterion (i.e. objective). In the "feedback control" state, subsystem operations are maintained by correcting for difference between output and criteria. Control may function internally (as a part of physical design of an equipment) or externally (as an inspection) to the processor.

The system restriction is supplied by an agency designated as the purchaser of the system output. The criterion or standard of performance is conditioned by the purchaser's restriction. In an operative sense, the criterion is conceived in terms of the objective of the system.

Let us take one simple example of an inspection subsystem to understand the above discussion. Here the process is to check the diameter. The input to this system would consist of an inspector, work place set-up, micrometer, engineering drawing and the part to be inspected. The output would also consist of all the above items but with the decision to accept or reject the part. The purchaser of the part has provided a restriction which is translated into an engineering drawing and thus forms criteria for the inspector. There is also a feed back of information to the manufacturing subsystem regarding the acceptance of the part.

System analysis is a "systematic" approach towards analysis of several different levels of systems and their integrated procedures, beginning at first with the overall system views and then moving into the final details required for decisions making. The means used for representing these details are flow charts. There is no specific criterion with respect to the amount of detail which should be shown in any flow diagram. It must be sufficient for its intended purpose. Thus, in case of computer oriented system, the computer program flow charts must be very detailed. On the other hand a master block flow diagram emphasizes scope rather than depth of the total system. It is called a master block flow diagram because complex components are not detailed but are pictured simply as boxes. Large scale or master block flow charts, thus, indicate a sweeping view of the

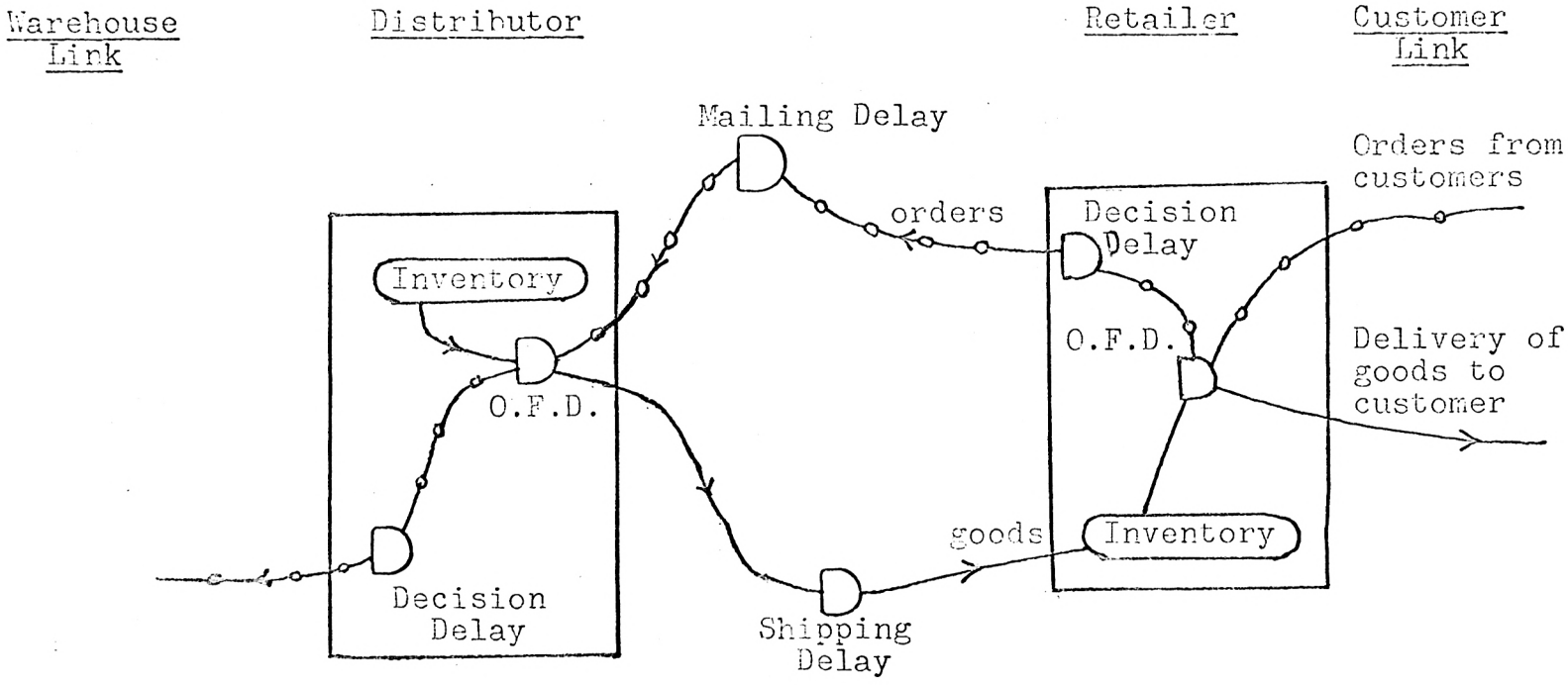
system and help to prevent overlooking some components which might be affecting the system to be studied. The links connecting the various kinds of boxes (levels of activities) may represent six different type of flows: information, materials, orders (decisions), money, personnel, and capital equipment. These various flows may be represented in a chart as follows:

Information	- - - - -
Material	———————
Orders	-0-0-0-
Money	-$-$-$-
Personnel and Population changes	
Capital equipment, Tools & factories	

Thus, all of the elements of a system have their respective channels. The flow in any one channel can be affected by the flow in an another channel even though the channels transmit different kinds of things. Associated with these flows are various types of delays such as: mailing delay, shipping delay, order filling delay, decision making delay, etc.

For example, let us take a subsystem link between retailer and distributor see Figure 1. The retailer receives orders at some rate from the customers. After some

Figure 1: RETAILER-DISTRIBUTOR SUBSYSTEM



O.F.D. = Order filling delay.

delay in filling, goods are shipped to the customer. To make up the inventory level the retailer decides to place an order with the distributor. This in turn generates a finished goods flow from distributor to the customer.

The transmission in each channel is seldom continuous. Usually it is either sporadic or regularly repeated at intervals. Thus when production requests raw materials from purchasing:

1. Link transmits sporadically if a fixed-quantity (re-order point) inventory system is used.
2. Link transmits periodically on a fixed cycle if a fixed review period inventory system is used.
3. The link may transmit continuously in a continuous process industry; e.g., the supply of crude petroleum from oil field to the refinery through pipelines.

The master flow chart and its detail charts require patience to detect and incorporate all details of an existing system, while ingenuity is required in designing a new system to rearrange the links, change the frequency and quality of transmissions, add new components, etc., so as to remove duplications, reduce critical delays associated with various flows, and to achieve improved operation with respect to the management's measure of effectiveness. The output of a system consists of several components. Each component is a different measure of effectiveness which should be compared with the

corresponding criteria which is conceived in terms of the management's objective. With respect to the inventory problem, the measures of effectiveness would include the service level obtained, the average investment in inventory, the number of orders which were required, and the cost of running the system.

The actual operating system may not be congruent with the proposed system. This is because the system gradually adapts to the changes imposed by the "human" processor.

The broad application of system theory now covers the business problems of all kinds including inventory studies. Systems analysis in inventory studies is used for two different purposes.

1. For choosing the best possible decision rules for the system as a whole.
2. For increasing the processing and operating efficiency of the system, once an appropriate and satisfactory set of rules have been selected.

Both these areas (these relates parts II and I of this report) cannot be treated as independent of each other, as a variety of systemic costs tie these study phases together. Since both the decision rules and operating system represent a single functional entity, the system approach is the only approach which can be trusted when a non-theoretical inventory study is being undertaken. The importance of systems theory to inventory analysis should not be predicated on the

use of computers. The benefits which can be derived even when the electronic data processing is not involved are substantial.

1.2 The Present System.

The present inventory system under study is a manual system, adapted to the handling of a large number of items of varying importance and with a widely different pattern of usage.

The first step in such a study is to determine the general scheme of the system, who are involved, where they are located, and what forms are used. At this point it is helpful to review, if they exist, the organization charts, the procedure instructions, reports and data from the control records. In this study, through personal interview and observations, the attempt was made to find out what each person does, and when, how and why. Thus, if sufficiently detailed and accurate notes were made it would be possible to construct from this person by person data a complete picture of the following:

1. Organization and personnel.
2. Policies, objectives, and terminologies.
3. Procedures--information flow and sequence of events related to storekeeping, recordkeeping and ordering procedures of the existing system.
4. Cost structure of the system.

In the analysis of several different levels of the system, one starts with the overall system views and work down to the finer details. Thus it is proper and efficient to arrange interviews starting at the top and moving down the organizational level. But as a matter of convenience, this sequence was not strictly followed in this study. In contacting the persons to be interviewed, it was kept in mind that the only person who is upto date about what is done, and how it is done, is the person who is doing that job everyday. Also, it would be interesting to contrast the views of various people on what the other person does in the system.

The following sections are based on information obtained from various persons.

1.3 Organization and Personnel of the System.

Organization of the general stores inventory under this study involves personnel from following three segments:

(i) Storekeeping

(ii) Recordkeeping

(iii) Plant maintenance office controlling purchases.

Both the stores and the record keeping sections employ classified personnel and parttime students. One supervisor has been employed recently to supervise both of these functions. The purchases of stores are controlled through the central physical plant and maintenance offices. The clerical

and administrative charges of the first two sections amounts to approximately $4,200 per month.

The storekeeping section has one storekeeper of class 3 (highest rank), two of class 2, one of class 1 and one part time student. The duties of the class 3 storekeeper are to look after material requisitions, specifications, new item initialization, etc. The other storekeepers have been assigned different segments of the inventory.

The recordkeeping section has three full time women and two part time girl students. Two women work mainly on the posting of stock cards, and one is at the switch board. The part time girls type list of job orders, and inventory reports, and may do some posting work in their spare time.

1.4 Objectives of Management.

To understand and appreciate the existing system of this stores inventory it would be necessary to explore the objectives of the present organization. In a business situation, materials management has the following typical objectives (13):

Primary Materials Objective.

1. Low operating costs i.e. low costs of acquisition, possesion, transportation and low payroll costs.
2. Low prices of purchases materials.
3. Continuity of supply to production and maintenance.
4. Consistency of quality.

5. Minimum investment in inventory i.e., high turnover of inventories.
6. Superior supplier performance i.e., adequate quality of purchased materials, prompt delivery and in general favorable vendor relations.
7. Development of personnel.
8. Good records.

Secondary Objectives.

These represent the materials department's contribution to the achievement of the objectives of other departments. They are not so limited in scope as the primary ones, and vary from industry to industry. The following are generally found in common:

1. Favorable reciprocal relations: deliberately buying from one's own customers.
2. New materials and products.
3. Economic make or buy decisions.
4. Standardization.
5. Product improvement.
6. Interdepartmental harmony.
7. Forecasts for prices, costs, and general business activity.

It is obvious that this government sponsered activity would differ considerably from a business activity. Here, the state government makes provision for a fixed amount of

capital to be spent in inventories in any fiscal year. The unspent capital would not be carried over in the next year. There is no interest on capital nor any scheme for alternate investment. The existing inventory system has been developed in the course of time, and it is based on the ideas of several different people. For economical buying, the state government requires most of the purchases through the state purchasing division. The following seems to be the reasonable objectives of this stores inventory.

1. Low prices of purchased materials by using a competitive bidding procedure and trying for quantity discounts.
2. Low payroll costs as to operate within the available budget.
3. Continuity of supply.
4. Assurance of quality.
5. Standardization.
6. Inter-departmental harmony (with various university departments).
7. Good records.

1.5 The Relevent Costs of the System.

As said above, the usual objective of an inventory system would be the minimization of the total costs of the system. There are three major classes of the various costs associated with any inventory situation:

1. Cost of Possession.
2. Cost of Acquisition.
3. Systemic Costs.

Cost of Possession.

This class includes various costs of carrying inventories. Many companies estimate that it costs as much as 15-25 percent per year to carry inventories. The following breakdown shows the major components of this class of costs with their typical percentages of value of stock:

Interest on capital tied up in inventory .	6-7%
Taxes.	.5-2.5%
Insurance.	.25- .5%
Storage: Housing & repairs.	.75-1.25%
Handling & Miscellaneous	2-3%
Clerical	1.5-3%
Deterioration.	1-3%
Obsolescence	3-5%
Totals	15-25%

A second kind of costs associated with carrying inventories may also exist in some inventory situations. These are out of stock cost and overstock cost. The out of stock cost would include cost due to the loss of goodwill of customer (it is difficult to determine and one has to rely on executive estimates of the cost; it can be imputed from

permissible stockouts in some period of time), and cost of rush order may be at a higher price. The overstock cost would include cost of carrying the extra stock and obsolescence costs in some situations.

Cost of Acquisition.

This is the cost of processing a purchase order (set up cost in case of a self supplier). It is composed of the following:

1. Cost of making and sending the purchase order.
2. Cost of expediting.
3. Cost of issue and receipt transaction.
4. Cost of updating.
5. Administrative and overhead costs.

The cost of possession is opposing in nature to the cost of acquisition and out of stock cost is opposing to the overstock cost. Over and above these costs, there are systemic costs.

Systemic Costs.

These are the costs associated with the particular inventory control system. They depend on the amount of inspection required of the existing inventory level and the amount of data processing necessary. They also differ with regard to the flexibility of systems in achieving savings which might result from the amalgamation of orders for

several items into one order from a supplier or central warehouse. Systemic costs also covers the costs of installation and implementation of a system.

It was not easy to estimate the various costs of this stores inventory. As being a government sponsered activity, it had no tax, space rent or utility charges, no capital cost, and no insurance charges. Thus carrying cost would include handling, clerical, freight and miscellaneous expenses. Deterioration and obsolescence costs were also negligible. As will be seen later, for purchasing at low price through the state purchasing division necessitates a lot of processing of an order. Thus carrying cost seems to be low and ordering cost high. In the second part of this report it has been shown that the present ordering practice implies the ratio of cost per order to the percentage carrying cost as 29.68. At present the sales price of an item is kept 15 percent above the unit cost to cover the operating expenses of this warehouse. No further attempt was made to estimate these costs.

Recordkeeping and accounting.

Under the existing procedure, one perpetual inventory stock card is used per item stocked. See form no. 1 in Appendix A. This form is designed for recording issue, receipt and credit transactions and for maintaining an upto date inventory balance. The "DATE" column in this form is the

date of the transaction; "AUTH'Y" designates job order number or departmental requisitioning authority number; "REC'D" column is only used for receipt entries and "ISSUED" for the quantity issued; "TOTAL TO DATE" gives the running total of the quantity issued from the beginning of a financial year and "BAL." is the expected balance of the physical count. "UNIT COST" and "TOTAL COST" were entered to account for the purchase price of the goods received. The unused material received back from a job order was credited in "REC'D" column and the necessary adjustment made in "TOTAL TO DATE" and "BAL." columns. This credit entry was made in red ink to distinguish from purchase receipts. At the beginning of a fiscal year the previous year ending balance of the item and its total cost were noted in green ink.

Other entries on this card are "UNIT COST", "SELL PRICE", "MINIMUM", "MAXIMUM", "VENDORS" list and sale of item in each month during two years. Unit cost is the price at which the item was generally available and sales price is 115 percent of the unit cost. "Minimum" is used as a signal of reorder. "Maximum" is used as a guide in deciding order quantity. The suggested order quantity is "Maximum" minus "Balance" at the time of reorder. The list of Vendors and the summary of sales during each month are generally not entered on a stock card.

During the collection of the historical data for the items sampled (see ABC analysis in part II of this report),

some discrepencies were noted in some records. In some instances "Balance" was shown as less than the actual physical stock, while it was more in some others. The variation was even as great as a thousand units, though it was mostly found in records for low cost items. Such errors are usually possible in manual record keeping. However, they could result in stockouts, especially for high usage items. In some cases, the physical count of an item was not correct and at times the physical counts of an item taken twice within a few days were different. This is normal and the latter number would be selected as the count. Sometimes the record showed that more could be issued than the balance shown, even though this balance was verified by a recent physical count. Some of the errors can be attributed to the compact design of the recordkeeping form, but such a design is necessary for an immediate review of perpetual inventory cards. Records also vary from actual physical inventory due to pilferage or unreported damage to materials. Thus there must be some sort of physical inventory to guard against error, dis-honesty or disinterest. The verification of stockcard "balance" by the physical count of an item would prevent the accumulation of the above errors. It was observed that the frequency of checking the physical count of an item was low. For some items the count was made once in two to four years. One reason was that enough man hours could not be spared for this work. At present the inventory is taken in a continuous

fashion. Some items are checked daily and by part numbers. Two persons work together to make a count. The continuous physical inventory does not disrupt operations of a warehouse as a whole, but it should be so planned that all items are covered once a year. Also instead of checking the items by part numbers, it would be easy if the inventory is taken at the time of the receipt of materials, when the stock has been depleted to a minimum. But this method would lead to the low usage items being checked rarely.

In another plan, the physical inventory is taken periodically e.g. yearly or at the end of accounting period. This plan assures that all items are checked once and also gives the overall picture of stock on hand. But the stores personnel would be overloaded during this period, and it may be necessary to shut down the activities of a warehouse for a day or two. Hence, this activity may be carried out during vacation shut down period.

The accounting procedure used in this system is last in first out, i.e., "LIFO". Other methods available are first in first out, i.e., "FIFO" and average unit cost price method. Suppose a warehouse had 6,000 pounds of zinc in its inventory purchased at 10 cents a pound. Also suppose that 4,000 pounds are bought at a price of 14 cents a pound at some later date. Now suppose that the warehouse gets an order for finished die-castings in which 1,000 pounds of metal will be used. The order price is based on the current market price for zinc, 11 cents a pound, so the total cost of metal will be as follows:

At the market price: 1,000 pounds at 11¢/lb = $110

Cost on FIFO basis: 1,000 pounds at 14¢/lb = $140

Cost on LIFO basis: 1,000 pounds at 10¢/lb = $100

Cost on average price basis: 1,000 pounds at 11.6¢/lb = $116

The unit average price is arrived at by dividing the cost of the most recent receipts, to the extent of inventory quantity by the inventory quantity. Thus in above case,

$$\text{Average cost} = \frac{10\ (6{,}000) + 14\ (4{,}000)}{10{,}000} = 11.6¢/\text{lb}$$

The above average unit cost method is commonly called the moving average method and requires the average cost to be computed after each new shipment.

With the "LIFO" method, changing prices for raw materials has a smaller effect on the stated profits than with the "FIFO" method. This takes some of the pressure off of the material manager to time purchases properly. However, even with LIFO, profits over a long term will be affected just as much by timing of purchases as with FIFO, and the average cost method, though costlier in operation is superior in swinging market situation than the other methods.

1.7 Storekeeping.

The smooth working of stores depends on efficient parts storage system. In the present warehouse, materials and

parts are stored according to size. The whole warehouse is divided into sections and at the end of each section the master list of standing job orders is posted. It is desirable to have a master list of items by storage location. No such list was available. This requires each person to be conversant with an item at any place in the warehouse.

A good storage system ensures the smooth operation of storekeeping. Some systematic storage procedures found in practice are as under:

1. Storage by part number.
2. Storage by co-ordinate index number.
3. Storage by serial index numbers, usually called the simple section bin system.
4. Storage by frequency of use.

The first method is only suitable for small parts. The co-ordinate index system is suitable for a nearly rectangular area. One way of setting the index is to number the storage spaces, thus aisles are numbered in sequence, as are rows and levels of bins. A number 2-4-3 would indicate the bin in second aisle, fourth column and third level from bottom.

If the storage area is not rectangular, then storage spaces can be divided into sections numbered serially. Location symbol may consist of a few letters and a few numbers. Thus the bin racks in each section is numbered serially by aisle, each row of shelves may be lettered from

the bottom up and within each row each shelf may be numbered.

The second and third procedures require a list for providing the cross-reference between the part number and the location symbol but it permits greater flexibility and more utilization of space. The third method does not require the area to be rectangular or bins to be of uniform size. It is also suitable for the frequency-of-use storage procedure.

Storage by frequency of use method is used in some organizations. The high usage items are located near storage exits. This method is applicable if an ABC analysis (see part II of this report) of inventory is done previously.

1.7.1 Issuing items.

The paper work of receipts and issue transactions is done by all of the storekeepers of class 2 and 1. Materials and parts for a particular job order are issued on "PHYSICAL PLANT M & R" form (see form no. 2, Appendix A). This form is filled out (except price information) in duplicate by a storekeeper. One copy is sent to the posting section and the other copy to the foreman of maintenance. The posting clerk adds the price information as she posts it to the stock card and then sends it to the accounting department for charging the materials to the job order.

The temporary needs of any department for various items can be checked out on a "CHECK TICKET" (see form no. 3, Appendix A). If these items are not returned within 30 days,

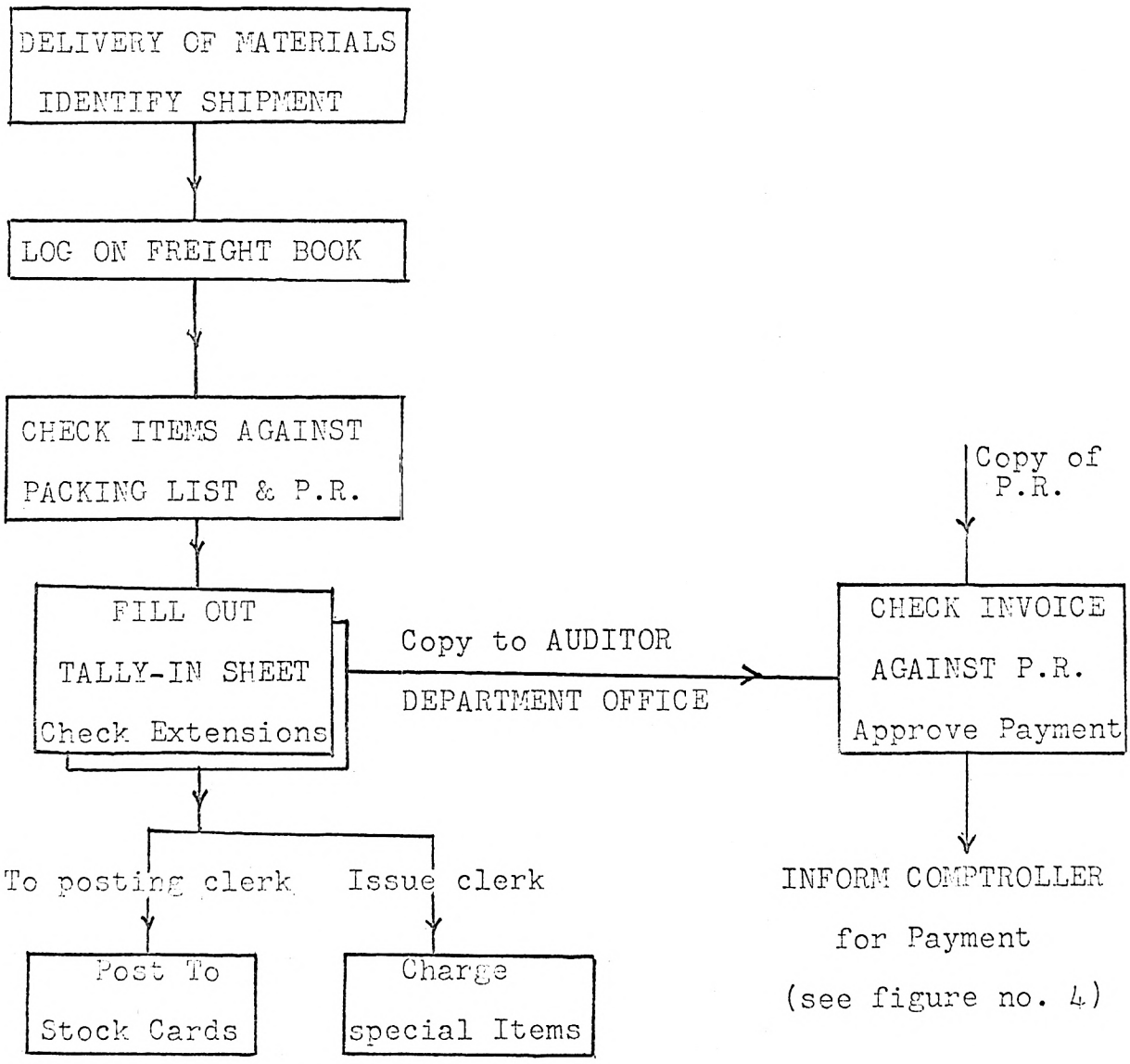
they are charged to that department.

1.7.2 Receiving Items.

Figure number 2 shows the flow chart of the receiving procedure. When a shipment of goods is received from the vendor, the package identification is made with reference to the receiving department name and purchase order voucher or invoice (refer to the ordering procedure) number. The freight is paid if it is not prepaid, and the payment is logged on the freight book. Then the items received are checked against the packing list and against Purchase Request or Purchase Order Invoice form (see ordering procedure). If there is a partial delivery, it is recorded in the above form. Then the "TALLY IN" Sheet (see form no. 4, Appendix A) is filled out for items received with respect to item numbers, quantity, description, invoice value, etc. Also some extensions such as the discount, freight etc. are checked. One copy of the "Tally in Sheet" is sent to the posting section for posting on the stock cards of the items received. The goods for construction and other special job orders are also received by the stores and are checked directly without posting.

The other copy of the "Tally in Sheet" is sent to the auditor who checks the invoice against the Purchase request and approves the payment. Then it is sent to the Comptroller's office for the necessary payment.

Figure 2: PROCEDURE FOR RECEIPT OF MATERIALS



1.8 The Inventory Control System.

One of the most important phases of the whole inventory control program is to develop a sound procedure for determining when and how much to buy. The beginning point in this process is to determine the probable rate of usage. In case of a supplies inventory or for items having a steady demand the usage can be anticipated from historical records.

The procedure of when and how much to buy requires one to determine the reorder point and the reorder quantity of each item. The present store has a widely used "maximum minimum" method of inventory control, whereby a quantity of material is requisitioned each time the balance on hand (or balance available) has declined to the reorder quantity set by a "minimum". The suggested order quantity is the difference between "maximum" quantity and stock on hand at the time of reorder, modified by the anticipated usage in the coming period and standard package amounts.

The "Minimum" and "Maximum" were arbitarily set by the storekeeper, class 3 (say, S.K.3) based on his judgement of the past usage and lead time during the past three to four years. They are not systematically reviewed and updated. The "Minimum" quantity was generally set for an 8 to 9 months supply and the "Maximum" quantity was approximately 1½ times that of the minimum.

The "Minimum-Maximum" control system is simple and has a low cost of operation. This method is suitable for a supplies type inventory where:

1. The items are of small value and size, which therefore can be ordered infrequently and in large quantities.
2. The usage of items is such that the timing and quantities of future issues cannot be predicted, but which must be available at all times.

The method may cause shortages or surpluses of an item if the lead time is long and the rate of usage varies considerably from time to time. Thus "Minimum" and Maximum" points should be reviewed periodically for such items.

1.8.1 The Ordering Procedure.

The persons connected with this procedure consists of personnel from the stores, the maintenance office, the physical plant (say P.P.) office, the comptroller office, the purchasing division of state of Kansas and vendors.

The objectives of the ordering procedure are as follows:

1. To buy at low prices. Similar quantities are consolidated and ordered from a single vendor to take advantage of price discounts. The quotations from vendors are requested and the most competitive bids are accepted.

2. As many of the orders as possible are to be processed through the state purchase office. The requirements for other government sponsered activities are amalgamated in a single quotation to achieve further savings.
3. The ordering procedure is centralized in nature. The forms used in this procedure are also used for other type of orders of various university departments (e.g. the construction orders and other special job orders).
4. To ensure that the procedure is self starting. The procedure is initiated if a material shortage is noted as a result of stock check. Certain cards are supposed to be checked every day such that each card is checked once a year.
5. The government allocates funds for spending during a fiscal year. Generally, the items are ordered once a year (The turnover of the inventory was found to be nearly one in part II of this report).

The ordering procedure can be divided into two steps.

1. The procedure for materials requisition.
2. The procedures for ordering.

There are 2 alternative procedures for ordering named as follows:

1. The P.R.-P.O.V. procedure.
2. The local ordering procedure.

In the P.R.-P.O.V. procedure the orders are processed by the state purchase office. The state government requires that except in case of emergency, orders of a value greater than $50 should be placed through its central purchase office. In an emergency, orders up to $200 worth can be placed through the Physical Plant office. Thus the orders placed by the Physical Plant office follow the local ordering procedure. Orders of any amount and regardless of price for certain state sponsored Kansas industries are also handled through the local ordering procedure.

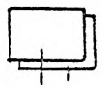
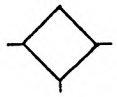
In the local ordering procedure bids are requested. The selected vendor is then sent the Purchase Order Invoice (say P.O.I.). The orders for Kansas Industries are not amenable to the bidding procedure, and the P.O.I. is sent directly to such a vendor. The other variation of this P.O.I. procedure is followed in the case of emergency purchases, where the materials are purchased directly from the local market and then the P.O.I. is sent to the vendor.

1.8.2 A Graphical Description of the Procedures.

If the procedure is lengthy, it is difficult to understand all of the details. So the better method is to describe the graphical paper flow chart of the procedure with explanation of details. To understand such chart, its language should be predefined. Figure 3 shows the symbols used in charting the above ordering procedures.

FIGURE 3

PAPER-FLOW CHARTING SYMBOLS

SYMBOL	NAME	DESCRIPTION
	Operation	Work being done on a form.
	Reference	Form is pulled out of filing cabinet to refer standard or past information.
	Form-origin	More than one copies of a form are originated.
	Operation take-off	Operation when information is transcribed to another form.
	Cross over	Vertical flow line crosses a horizontal flow.
	Inspection	Determination of the correctness of information and approval.
	Move	Form is moved from one location to another.
	Delay	Form awaiting for further action.
	File	Form is placed in an organized filing system.
	Disposal	Form is destroyed.
	Re-origin	The form is duplicated--copied at some place other than that of origin.
	Break	Break in procedure analysis indicating something that is not pertinent to the study.

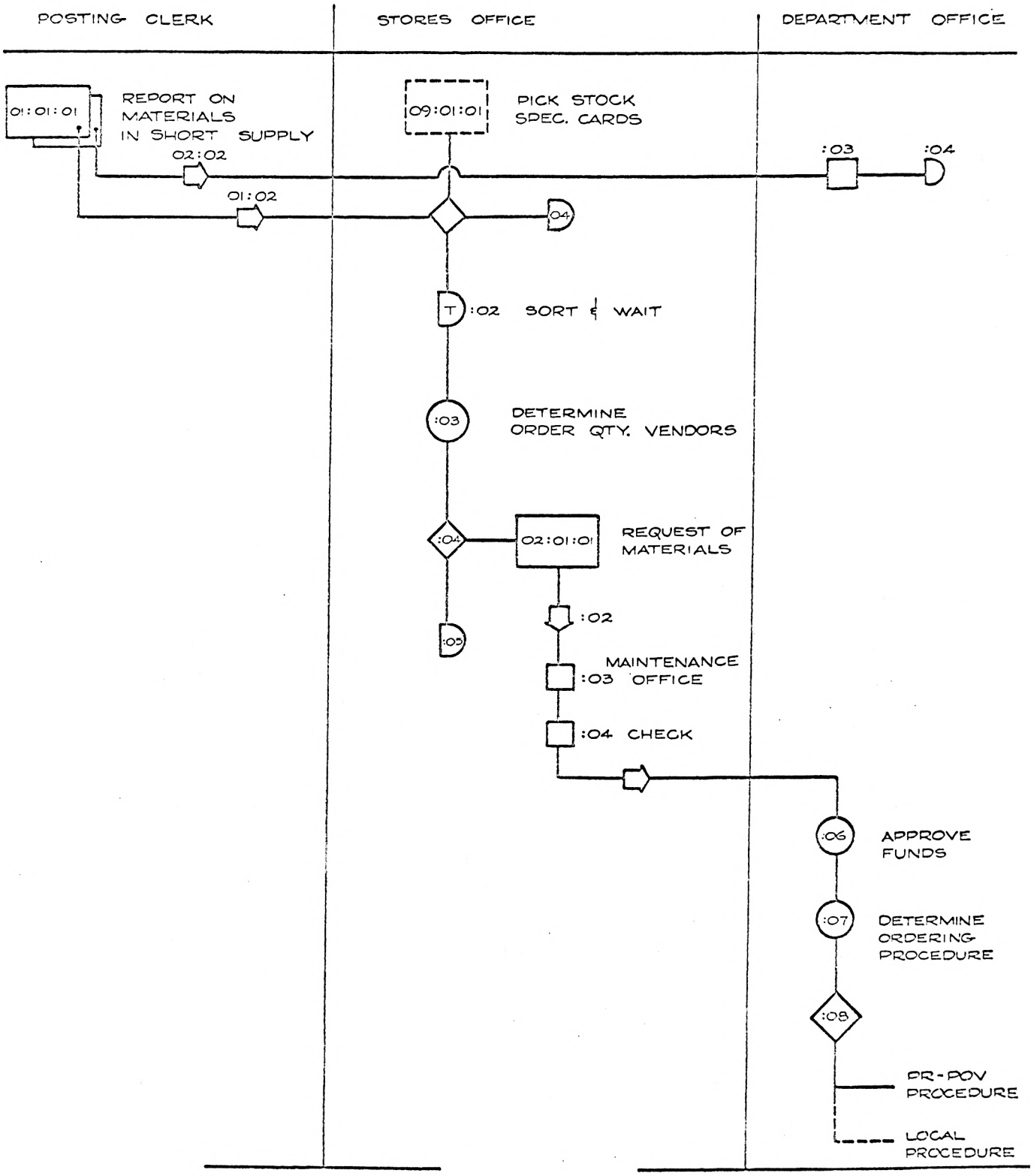


FIG. 4. : FLOW CHART FOR MATERIALS REQUISTION

01 : REPORT ON MATERIALS IN SHORT SUPPLY
09: STANDARD STOCK SPECIFICATION CARD
02: REQUEST FOR MATERIALS

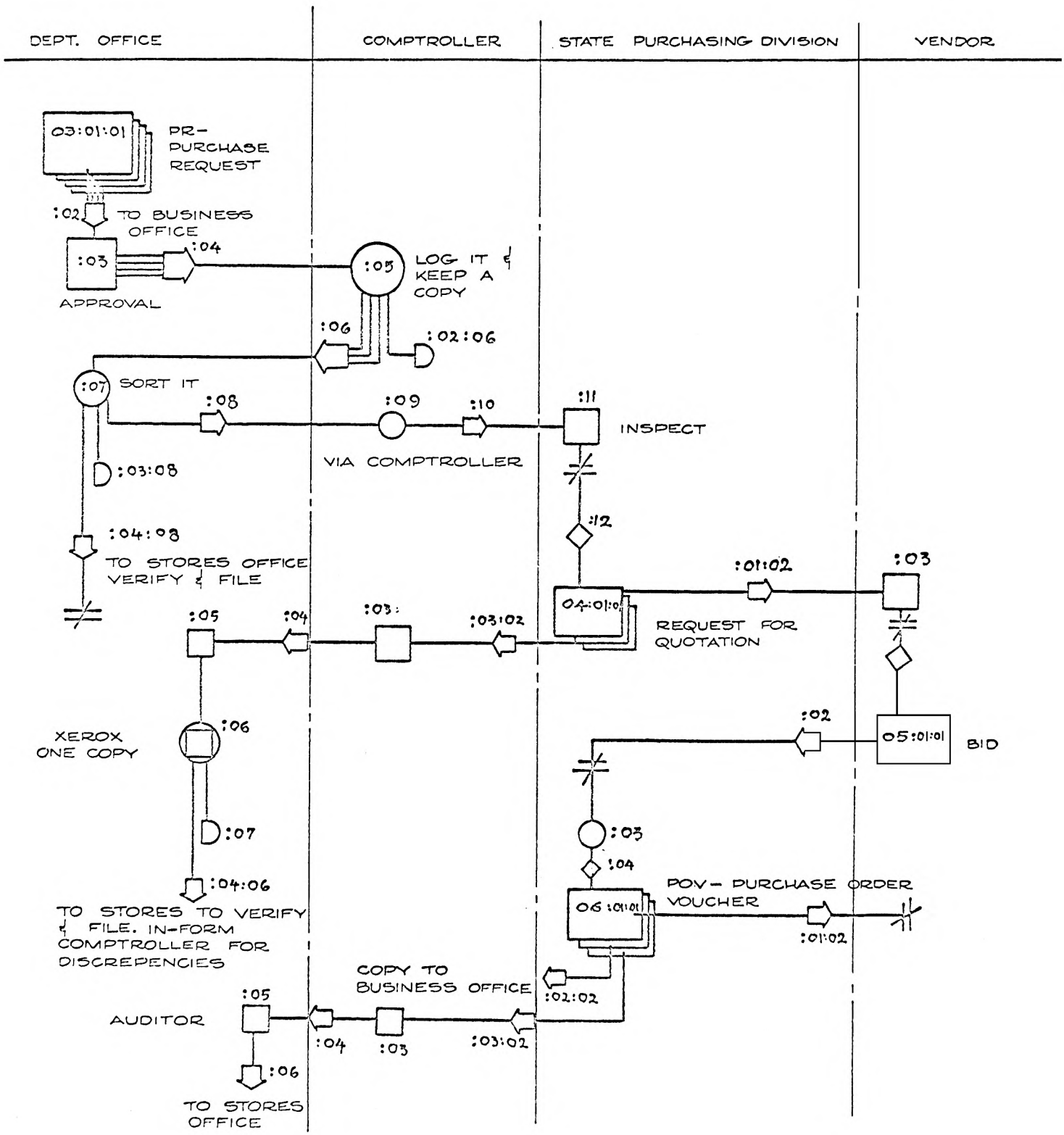


FIG. 5.: ORDERING PROCEDURE 1 (PR-POV PROCEDURE)

03 : PURCHASE REQUEST (P.R.) FORM
04 : REQUEST FOR QUOTATION
05 : VENDOR'S BID
06 : PURCHASE ORDER VOUCHER (P.O.V.)

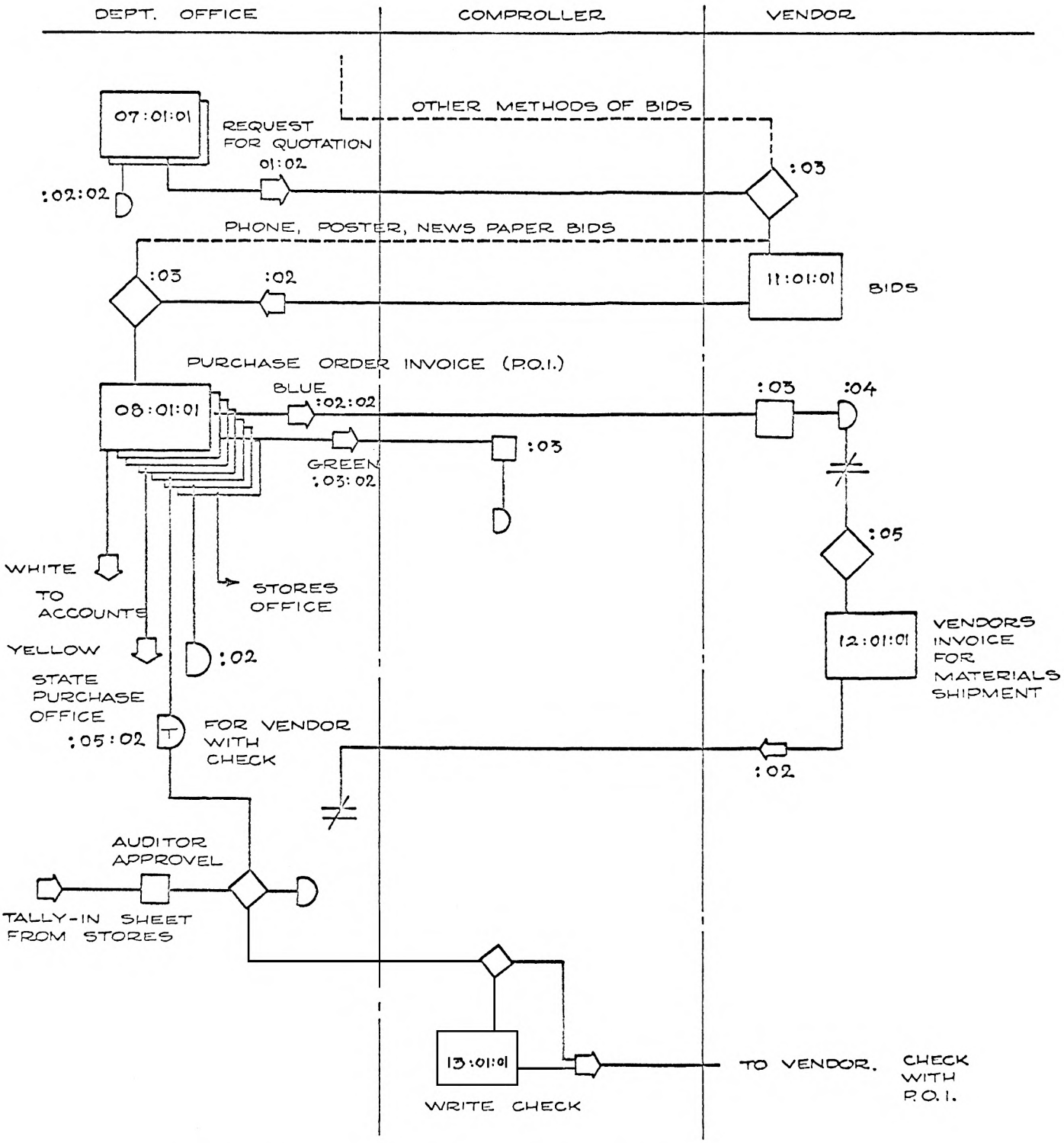


FIG. 6.: LOCAL ORDERING PROCEDURE

07: DEPARTMENTAL REQUEST OF QUOTATION FORM
08: PURCHASE ORDER INVOICE (P.O.I.)
11: VENDORS' BIDS
12: VENDOR'S INVOICE ON MATERIALS SHIPMENT

Figures 4, 5 and 6 show the flow charts for Materials Requisition, P.R.-P.O.V. procedure and local ordering procedure respectively. For each symbol in a chart there is a sequence of numbers 01:03:05.

The first set of two digits (i.e. 01) may represent the form number, while the second set (03) refers to the copy of this form and third set (05) would refer to the step in the procedure. The first set of digit would serve as an index for the form and should be printed on it.

In the following, the previous ordering procedures are described with the help of flow charts, keying the explanations if necessary, to the various symbols.

1.8.3 Figure 4: Flow Chart for Materials Requisition Procedure.

01: :01 The posting clerk originates a "Report on Materials in short supply," as a result of a stock check of some cards. This form (see no. 5 Appendix A) is prepared in duplicate.

: :02 When the form is filled (or every Monday, which ever is earlier) one copy is sent to the department (Physical Plant) office and other copy to the storekeeper, class 3.

:02:03 Inspect.

:02:04 File for future reference.

01:01:03 S.K.3. checks the form and picks up the stock specification cards for the listed items. He

attaches a slip of paper to each card (see form no. 6 Appendix A) to note the quantity on hand and needed for each item.

01:01:04 He files the form.

09:01:02 He sorts out the stock specification cards in various catagories mentioned previously. He then waits for enough items that can be processed in a single order (approximately $200).

09:01:03 He consolidates items. Determine the quantities to be ordered as to suit the packaging and shipping requirements and to get the price discounts.

09:01:04 & 02:01:01 The "Request for Material" form (see no. 7 Appendix A) is prepared for a group of like items.

09:01:05 Filing back.

02:01:02 Move to the superintendent of maintenance office.

02:01:03 Inspection by two officials.

: :04

: :05 Moved to the auditor in Physical Plant Office.

: :06 The auditor approves the funds for various items. Checks the format and coding.

: :07 The form is passed on to another officer. He checks the items needed, their total value and

the urgency of need. He then determines the ordering procedure to be followed.

: :08 The information is transcribed to another form which originates either the P.R./P.O.V. procedure or the local ordering procedure.

1.8.4 Figure 5: Flow Chart for P.R./P.O.V. Procedure.

03: :01 "Purchase Request" is prepared in four copies.
White copy - to the purchasing division.
Pink - to the comptroller.
Yellow - for the department file.
Additional white - for the stores office.

: :02 Move to the business office for approval and

: :03 return.

: :04 Move to the comptroller office.

: :05 Log it and keep a copy.

:02:06 File.

: :06 Other copies returned back.

: :07 Sort the 3 copies.

:03:08 File in a departmental file.

:04:08 Sent to stores office to verify and file for future reference.

:01:08 Send to the State purchasing division, Topeka,

to : :10 through the comptroller's office.

: :11 Inspect.

: :12 Information is transcribed into another form.

04: :01 Request for quotation is prepared for similar material requirements of various organizations.

04: :02 One copy of quotation to interested vendor.

04:03:02 One copy of quotation is sent to the comptroller

to : :05 office which is passed on to the Physical Plant Office.

04:03:06 The copy of the request of quotation form is xeroxed.

04:04:06 The xerox copy is sent to the storekeeper, class 3 for verification and file. In case of discrepency, the Comptroller office should be informed.

05:01:01 Vendor prepares the bid on the request of quotation.

: :02 Move on to the purchase office.

: :03 Selection of a vendor.

05:01:04 The purchase order voucher, say P.O.V. is

06:01:01 written.

06:01:02 Copy to the vendor.

:02:02 One copy to the business office.

:03:02 One copy is sent to the Physical Plant Office,

to : :06 through the comptroller office. The auditor verifies it and passes on to the stores office. The storekeeper, class 3 notes the P.O.V. member on his copy of P.R. and then returns the P.O.V. to the Physical Plant.

1.8.5 Figure 6: Flow Chart for Local Ordering Procedure.

07: :01 Request for quotation form is originated. Other methods of inviting bids are by phone, poster, or newspapers.

:01:02 Send to a vendor.

11:01:01 The vendor prepares the bid and send to the

: :02 Physical Plant office.

: :03 The vendor is selected.

08: :01 The Purchase order Invoice (P.O.I.) is prepared in seven copies as follows:

White copy - sent to accounts.

Blue copy - sent to vendor.

Green copy - moved on to the comptroller.

Yellow copy - to the State purchase office.

Pink copy - to be sent to vendor with payment after receipt of materials. File temporarily.

White copy - for the department file.

White copy - to the stores office.

12:01:01 Vendor prepares his invoice and sends to the

: :02 stores on shipment of materials.

The stockout situation in this warehouse would not generally create any serious problem. If the stockout of any item occurs, the posting on the stock card is verified and the necessary correction is made. Then the item is included

in the report on materials in short supply. If the item is needed badly, then it will be purchased on a retail price.

2.0 PART II: STUDY OF THE INVENTORY DECISIONS

This part of the study is concerned with the analysis of some decisions of the Inventory Control System and looks for the feasibility of applying the mathematical theories of Inventory Control. For this it was necessary to analyze the relevant data of the items in the inventory. Since this was not a full scale study, it was decided to resort to a sampling technique for the purpose of this report. The major elements of the analytical part of this study are as follows:

1. A representative sample of items was selected to obtain data about usage, cost, lead time, investment level etc. necessary for further analysis.
2. An ABC analysis of the items selected.
3. To determine the optimal ordering policy for the present situation.
4. To determine typical lead time distributions for this stores inventory.
5. To determine the inventory turnover ratio.

2.1 Selection of a Sample.

Control over the cost and time required for an inventory study is in part vested in deciding the size of a sample, the selection and grouping of items and the amount of past history to be collected.

The size of the sample may be decided on the basis of the desired accuracy of the results to be obtained for a given confidence level. From the literature survey of case studies in Inventory Control (2), it was first decided to take a 2% sample. The method used was to draw a random sample from a master list of stock numbers. Unfortunately no such up-to-date list was available. It was found that the stock card numbers used to refer to the items run from 1 up to 11,900, with more than 25 percent blank cards. These items were roughly arranged by catagory, but they were not quite distinct. Items of some categories were mixed with items of another catagory. Roughly the stock card numbers for different catagories ran as follows:

Hardware items:	1- 2,495
Plumbing items:	2,496- 5,533
Plumbing, glass & paints:	5,534- 6,450
Steel products, small tools:	6,451- 7,600
Electricals:	7,601-10,000

Some items such as pipe fittings, nipples, valves, large lamps etc., were ordered by the state purchasing division through special contracts made with various suppliers. This catagory of contract items was mixed up in other catagories. Thus it was impractical to stratify the sample by major catagories. The sample was taken at random. This was accomplished with the use of Fischer & Yates' Random number tables. The random numbers drawn were assigned

as stock numbers of items selected. Thus if the random number drawn is "5201" then the item having the stock number of 5201 was selected. The sample was divided into 10 subsamples such that 20 numbers were drawn for every 1,000 items. If the number drawn corresponded to a blank card, this was simply noted in order to have the estimate of percentage of blank cards. These numbers drawn were arranged serially to facilitate data collection. After collecting the necessary data, this sample size seemed to be inadequate and the sample size was doubled by repeating the above procedure.

It was found that there were approximately 17.5% blank cards (77 out of 439) among stock cards 1 to 10,500. Between 10,500 - 11,900 there were mostly blank cards. The actual sample thus turned out to be of 362 items representing 3.45 percent of 10,500 items.

At first the one year of past history was considered adequate. But since most of the stock items were job order supplies type and much variation was found in usage during year to year, it was found desirable to have the amount of data for the past two years in order to show these variations and trends (6), p. 200.

2.1.1 Collection of Data of the Past History of the Items.

For the above purpose a tabular form was designed denoted by TABLE 1, in Appendix B, Historical Data of Items

Sampled" in this report. There are 9 columns in this form. The first column is the serial number, second is the stock number of the item, columns three, four and nine designate respectively the receipts, issues and stock outs in the fiscal years 1964 to 1966. These columns have two subdivisions: "No." means the total number of respective entries to an item in the year and "Qty" in columns 3 and 4 means the total quantity received of an item in a year; length in column 9 means total length in weeks in which the item was out of stock. Entries in column nine were made only if a stock out had occured. Otherwise it was left blank. The "no." and "qty" entries in column 3 and 4 were made to read entries for fiscal years 1964-65 and 1965-66, separated by a + sign. Thus say, item stock number "039" has total receipts of 440 units by 3 orders in the year 1964-65 but no receipt in year 1965-66. Column 5 is the 1966 fiscal year end balance. Column 6 is the unit cost (average if there was any small variation) of the item. Columns 8 and 7 read maximum and minimum fixed for the item.

The source of this data was the stock cards of the items (form No. 1, Appendix A) housed in trays of recordkeeping cabinets. This data was then punched on data processing cards so that the computer could be used for further computations. This data is shown in TABLE 1A in Appendix B.

2.2 A.B.C. or Value Analysis for Selective Control.

In any inventory control program, where scientific control is desired, the value analysis of the inventory is the first step after collecting the necessary data. An ABC analysis yields a measure of the importance of each item and helps to put "first things first." It is not a system, nor a procedure, but it is an analytical approach to get the most control for the least amount of details needed.

It is worthwhile to give a historical background to this subject. H. F. Dickie advanced this concept and first put it to use in actual inventory management at General Electric Co. Dickie quotes that "A,B,C inventory analysis shoots for dollars, not for pennies. By applying the knowledge of true parts values from such product analysis, G. E. switched over from penny chasing and inventory confusion to apple pie order and important dollar savings." (3) Since then many industries utilize this analytical technique advantageously. In nearly any type of inventory there are "Blue and red chip items" or say "Vital few and Trivial many" items. Dickie classifies the different items carried in any inventory as under (3):

A items: These are few major items that tie up the most of inventory dollars.

C items: They are very numerous but inexpensive ones that make a minor part of the total dollar demand for the whole inventory.

B items: Sometimes it is desirable to form a third class of items, intermediate between the above two classes. These items are not as important as "A" class items, but are worth some attention. These items should also be given consideration in long range planning.

2.2.1 How to Make an ABC Analysis.

First obtain the usage per year and unit cost for each item in a sample. Arrange the items in descending order of total usage in dollars. Unit cost is the unit purchase price in case of purchase item. If the item has been self manufactured this cost would include material, labor and overhead cost of the unit. Extend the value of each piece into given product times number of such identical pieces. The assembly labor cost should not be included in the above. Construct a table of cumulative percentage of the total number of items and the total cost of the items.

In a warehousing problem such as the one in this study this evaluation is simply done by extending the value of each item times its sale quantity in the period under consideration. Similarly in a nonrepetitive manufacturing problem, multiply the usage for a month by the unit value.

The naming of the ABC classes is some what flexible but this affects the required sample size for specified

levels of accuracy and confidence in percentage of these classes or the probability of drawing an A, B, or C item.

In this study, the cumulative distribution of percentage of the total dollar usage versus cumulative percentage of the number of items was found by writing a small computer program. The results are plotted in figure 7.

Let us denote P_i = cumulative percent of total items and T_{zc} = Total dollar demand. Then following are notable points of this distribution.

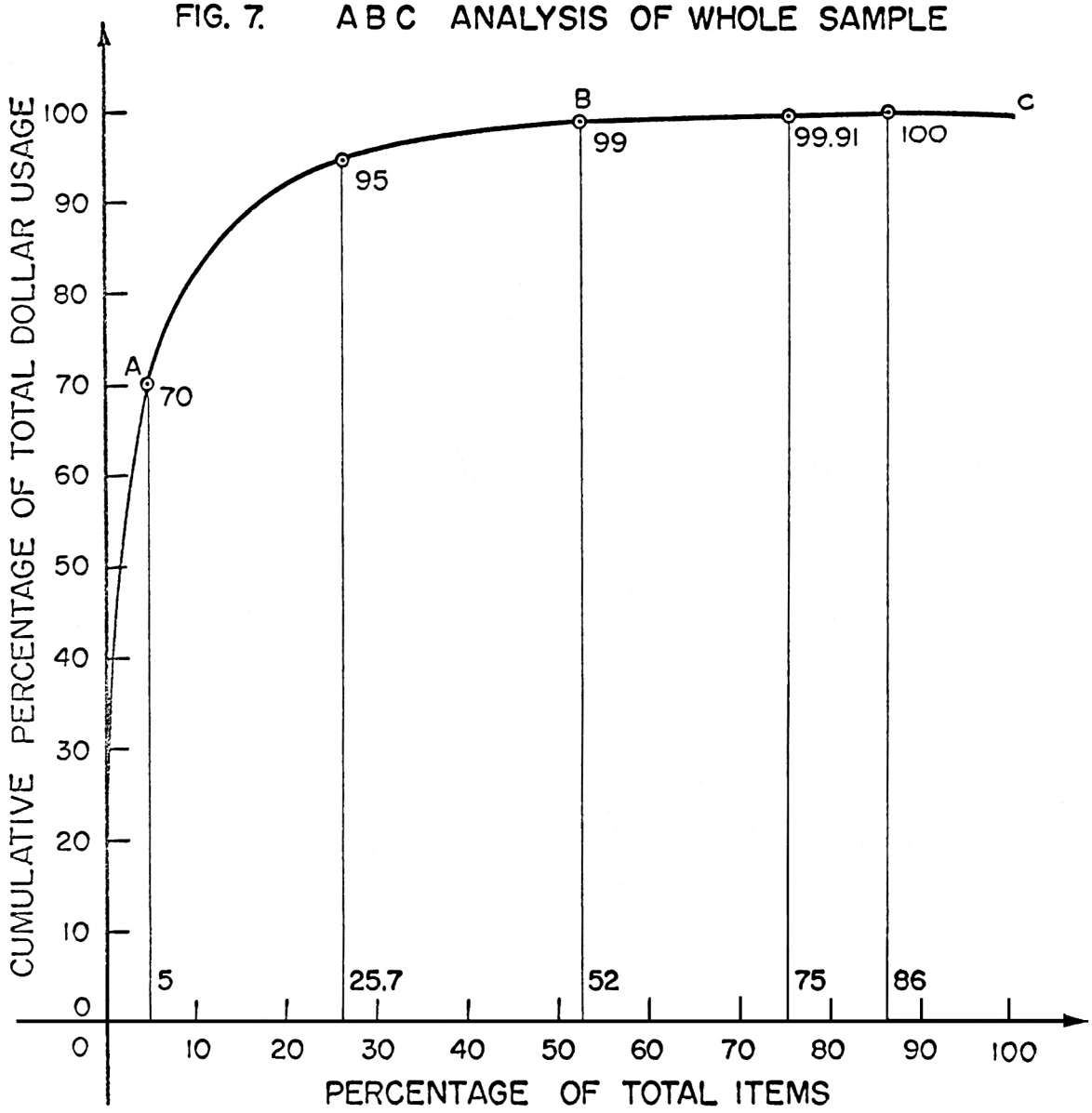
TABLE 2

P_i %	Cumulative percent of T_{zc}	* Cumulative percent of total average inventory
6	75	--
25.7	95	71.0
52	99	--
86	100	88.3
100	100	100

The three part division of above inventory situation curve may be:

A items: The first 6% of items accounting for 75% of total dollar demand. There are 22 items in this class out of 362.

FIG. 7. A B C ANALYSIS OF WHOLE SAMPLE



B items: 19.7% of the items accounted for 20% of total dollar demand. There are 71 items in this class.

C items: Remaining 74.3% of the items have 5% of the total dollar demand. There are 269 such items.

In the above table there is a column with an asterisk (*) mark, showing the cumulative percent of the total average inventory. This would also aid in further inventory control. It can be seen that 14% of the items have had no usage in the past two years and have tied up 11.7 percent of the inventory money, which is quite high.

We need the greatest control for A items. Careful attention should be paid to the following aspects.

a. Estimates of requirements.

b. Standby and protective stocks should be at a minimum.

c. Careful and prompt receiving and inspection.

d. In case of an inventory maintained for production purposes, A items must be given the greatest care in shop scheduling so that a rapid flow is maintained through the factory.

A items consumes most of the inventory dollars, hence its safety stock must be held at minimum. If the item is a purchase item, A item orders must have a very close follow up by the purchasing department. In case the item is manufactured the in process time of the A items must be kept at

a minimum. However, A items are also used readily and since they carry a fewer days supply, they require a very vigilant recordkeeping to prevent stock outs. For each A item, compute its requirements, check the quantities on hand and on order and set reorder quantities carefully and time reorders so that the inventory will be held at a minimum.

B items are also important enough to justify recordkeeping. Its use may be permitted on requisitions only. Maximum and minimum stock quantity controls may be adopted for most of the B items.

C items are general use items and their usage does not justify recordkeeping. Its stock should be kept ample all the time. C items may be kept in enclosed storerooms or may be kept out next to the workmen to allow them use as they need. C items do not cost much and to prevent its stockouts its safety stock should be large. Also due to loose control, it may be used wastefully. It should be ordered about 2 percent more than the predicted demand to allow for normal shrinkage.

For C items a Bin reserve system should be used instead of recordkeeping since:

1. Upon receipt of a new order, the reserve quantity should be sealed, a tag is attached to it carrying the necessary information.
2. When the stock is down to the reserve quantity seal is broken and the bin reserve tag is sent to the ordering clerk.

3. The order clerk calculates the past usage and places his order. He determines a new reserve quantity and sends a new tag to the stockroom.
4. When the new order arrives the reserve quantity is sealed.

Merits of ABC Analysis.

ABC analysis may be adopted by large or small businesses with the following advantages (3):

1. Improved Inventory Control. Direct inventory reductions are obtainable. Thus it creates new enthusiasm.
2. Increased turnover due to reduction in lead time on high value purchase parts.
3. Lower clerical costs by proper emphasis on A items and proper evaluation of less important C items.
4. Better planning of production.

However, ABC Analysis is not free from pitfalls (3):

1) Serious stock deficits may result in case of purchased A item even if there is close follow up because a normally reliable vendor is overloaded or he is also up against material shortages.
2) Watch out for the string savers too. Guard against closer control and more detail records on small insignificant items.

3) Orders for B and C items tend to become fill-ins. If B or C item is self made in the factory its reorder takes a backseat.

4) If the bin reserve quantity for C item is not reviewed frequently or if procurement time increases substantially, the sealed reserve may be inadequate.

5) The practice of holding A items to a minimum makes their reorders very sensitive to the changing demand.

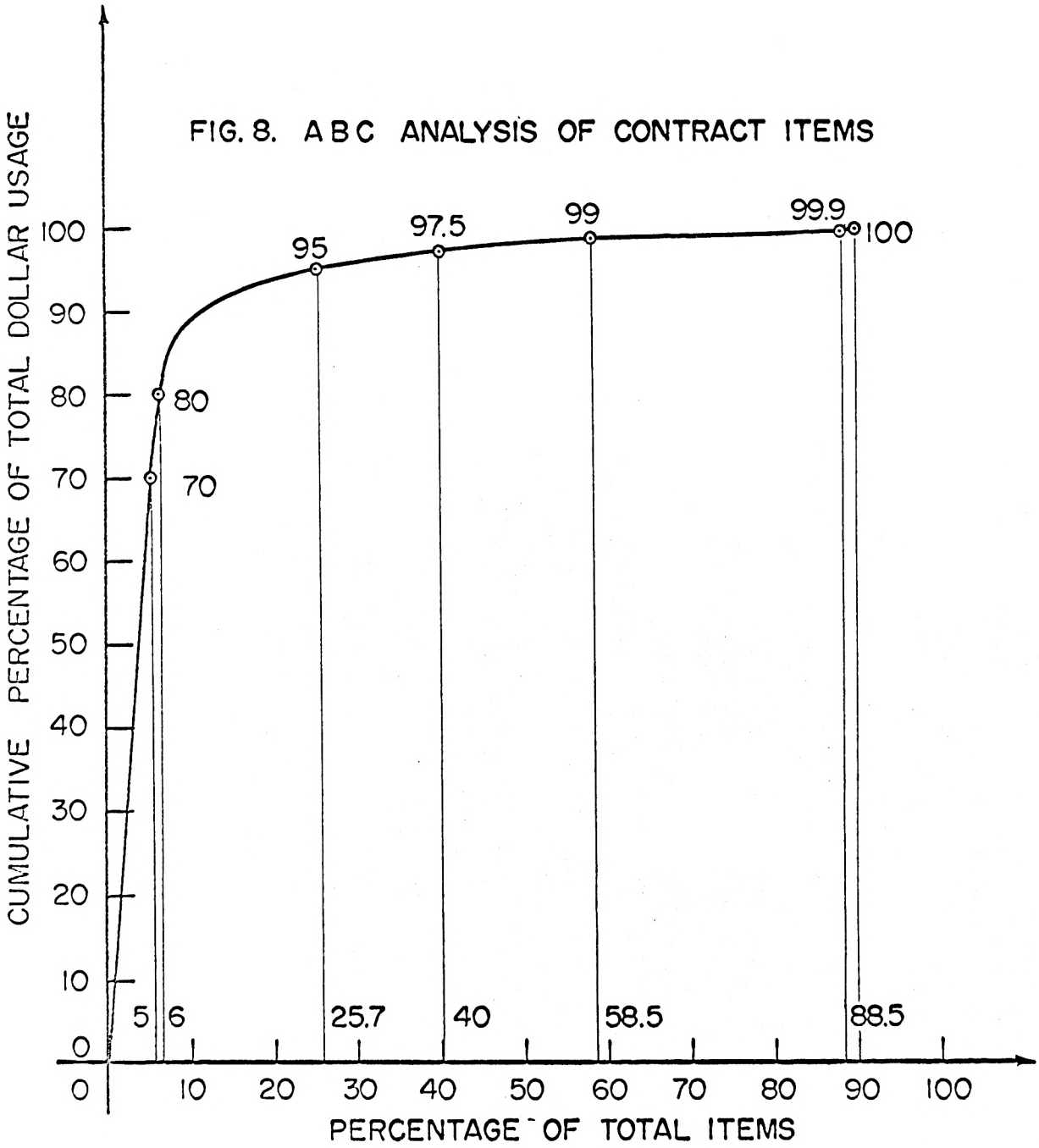
In the situation under study, since it is a maintenance store, the division into only 2 classes (AB and C) is more suitable for administration. Management can decide how many items should be in class AB which are under control similar to items in A and B classes. For the remaining items no recordkeeping should be adopted, and may be maintained as in the "C" class of items. Thus for the present study following 2 divisions are suggested.

AB class: First 52% of the items having 99% of total dollar usage.

C class: Remaining 48% of items having only 1% of total dollar demand.

It was thought that A-B-C curve for contract items would be different than that for overall situation. The sample of 362 items contained 35 contract items. The ABC Analysis of these 35 items is shown in figure 8. It is apparent that this distribution is very much similar to that of overall

FIG. 8. A B C ANALYSIS OF CONTRACT ITEMS



situation. The significant points of this distribution are as follows:

TABLE NO. 3

$P_{\%i}$	Cumulative percent of T_{zc}
5.71	78.6
25.7	95.0
40.00	97.5
51.43	98.6
88.57	100

Though the sample of contract items is small, it was not considered necessary to check for a bigger sample as the ABC curve for this catagory doesn't differ significantly from the curve of overall inventory.

2.3 Optimal Ordering Policy When System Costs are Unpredictable.

When demand for an item is known for a given period of time, and the estimates of carrying cost and ordering cost are available, then an economic order quantity can be determined by the following formula.

$$X_0\# = \sqrt{\frac{2C_r}{C_c}} \qquad \sqrt{Z/C} \qquad (1)$$

where,

$X_0^{\#}$ = economic order quantity

C_r = Cost per order

C_c = Percentage cost per dollar in inventory for a given period of time.

Z = Demand of an item in a given period of time, in units.

C = Unit cost of the item.

This formula is derived by balancing the two opposing costs: the total carrying costs against the total ordering cost. It is also applicable to economic lot size model for production inventory where Cr is the set up cost of a lot (7). However, for the supplies inventory under this study, it was difficult to get the estimates of these costs. Fortunately there exists one method for the optimal ordering policy for the total inventory. Thus it is possible to develop a consistent ordering policy such that it minimizes the total average inventory keeping the same total number of orders as in a present situation. Thus, let

TI = Total average inventory

TO = Total number of orders

N_i = Number of orders to satisfy demand Z_i for an item in a unit period, usually a year.

Other previously defined symbols would also have subscript i for different items in this discussion.

Thus we want to minimize

$$\text{Total average inventory } TI = \sum_i \frac{X_i C_i}{2} \tag{2}$$

subject to the restriction that

$$\sum_i Z_i/X_i = TO \quad \text{or} \quad \Sigma Z_i/X_i - TO = 0 \tag{3}$$

To solve this we use the mathematical technique of Langrangian multiplier. Thus let us form the Lagrangian, denoted by L, by adding λ , the multiplier times the given restriction equation to the expression to be minimized. Thus

$$L = \sum \frac{X_i C_i}{2} + \lambda \left(\Sigma \ Z_i/X_i - TO \right) \tag{4}$$

The solution to the given problem can be found by minimizing "L", i.e. taking the derivatives of L with respect to X_i and λ and setting them equal to zero we get

$$X_i = \sqrt{2\lambda} \quad \sqrt{Z_i/C_i} \tag{5}$$

and

$$\lambda = \frac{\left(\sum Z_i C_i \right)^2}{2(TO)^2} \tag{6}$$

Let us denote

$$\sum_i \sqrt{Z_i C_i} = S_{zc}$$

$$X^{\#}_{iO} = K_1 \sqrt{Z_i/C_i} \quad \text{where } K_1 = \frac{S_{zc}}{TO} \tag{7}$$

The above equations do not require knowledge of the system costs, but still the company is incurring ordering and

carrying costs. These costs are generally a function of the company rather than of the individual inventory item, i.e. these cost factors tend to be a constant for all items in a particular inventory.

The above formula can also be derived by another approach which considers implicit inventory costs for a company operating at a particular reorder level. These implied costs can be used to review the reorder rules for individual items in order to reset these rules if they are not consitent for all items. Such a procedure would not necessarily result in the most economic ordering policy, but it does yield a consistent policy for items under consideration. It would ensure that the total number of orders placed remains constant and always reduces the total average inventory. Thus assuming that the inventory costs tend to be a constant for all items in a particular inventory, the economic order quantity for any item is $X_{iO}^{\#} = K_1 \sqrt{Z_i/C_i}$ (1)

where $K_1 = \sqrt{2C_r/C_c}$ is an unknown constant depending on the implied ordering and carrying costs based on the present overall average level of inventory orders.

Also $X_{iO} = Z_i/N_i$ (8)

From the above two equations, the number of orders for an item can be defined as

$$N_i = \frac{1}{K_1} \sqrt{Z_i C_i}$$

Since K_1 is constant for all items,

$$TO = \text{Total no. of orders} = \sum_i N_i = \frac{\sum \sqrt{Z_i C_i}}{K_1}$$

from this $$K_1 = \frac{\sum \sqrt{Z_i C_i}}{\sum N_i} = \frac{S_{zc}}{TO} \qquad (9)$$

Thus implied ratio of ordering cost to carrying cost is

$$\text{Ratio} = \frac{C_r}{C_c} = \frac{K_1^2}{2} = \frac{(\sum \sqrt{Z_i C_i})^2}{2(TO)} \qquad (10)$$

The costs implied by this value of K_1 based on the existing volume of orders are not necessarily correct or may not seem reasonable to management. The management can then set other acceptable ranges for each cost from which new value of K may be estimated.

To study the ordering policy of the inventory of this store, and to seek for a consistent policy, a computor program was written. Only the A and B items (91 in number) were studied. The averages of the 2 years data were used. A new ordering policy (keeping the total number of orders for above 91 items constant) was found by using the above formula. See Appendix C.

For the purpose of this analysis, an order was defined as the purchase of material for one stock item. Even though several items might be ordered from a single vendor on the same purchase order, each unit has to be handled seperately in the remaining part of the purchasing, receipt and stocking functions. Thus, the volume of orders was defined as

the total receipts for all items and not as the number of purchase orders.

It was found that present policy was not consistent. The maximum and minimum of the present system were set arbitarily approximately four years ago (based on memory and feeling of the past usage), and no systematic updating or review is being carried out. The minimum quantity was generally taken as 8-9 months supply. The maximum quantity was set at about $1\frac{1}{2}$ times that of the minimum. This control signal had virtually no significance because in many cases order quantities were such that the stock went above the maximum. There were no standard order quantities used for any catagories of items. Thus order sizes fluctuated for any particular item. Some items having high usage were ordered in large quantities with phased deliveries. This is a good practice. However, some items with low usage were ordered too frequently.

For a new ordering policy for the A and B items the ratio of ordering cost to carrying cost is found as

Ratio = C_r/C_c = 29.68 or, C_r = 29.68 C_c. (See "Ratio" in the results of computor program in Appendix C).

Assuming the carrying cost to be 10 percent for this particular situation, ordering cost turns out to be $2.97 per orders. It seems that the costs of the system are

underestimated in the present practice of ordering. The ratio would be larger for an optimal policy.

One mathematical result of the above derivations can be stated as follows:

For optimal ordering policy

$$\frac{C_r}{C_c} = \frac{TI}{TO} \tag{11}$$

but, $K = \sqrt{\frac{2TI}{TO}} = \frac{\sum \sqrt{Z_i C_i}}{TO}$, as discussed before

or $(TI)(TO) = \frac{1}{2} \left(\sum_i \sqrt{Z_i C_i} \right)^2 = \text{Constant}$ (12)

Thus for an optimal ordering policy the total average inventory multiplied by the total number of orders should remain constant. This constant is one half of the sum of the square root of the usage in dollars of the items under consideration.

2.4 Study of Inventory Turnover Ratios.

One convenient measure of the efficiency of materials control is the "turnover ratio," i.e. the number of times the inventory is used within a year or other suitable period. When inventories are low in relation to sales, less capital is tied up in inventories, this in turn increases the return of investment. The storage and carrying costs are lower when turnover is high. On the other hand there is a great danger in over emphasizing this factor, it is said that too high turnover increases the cost of acquisition. A high inventory turnover is not necessarily indicative of a

well controlled inventory. A high average may reflect a high rate of turnover in a few classifications of large value. Every item in stores must stand on its own merit with respect to turnover. However, it is impractical to evaluate each item and inventory control should be based on the turnover for each classification.

Turnover is subject to the law of diminishing returns. The curve of total costs of possession and acquisition against inventory turnover is a parabolic type (10), p. 112. As the number of annual stock turns increases, the cost of possession decreases but the cost of acquisition increases. Initially however, the rate of increase in the latter cost is lower than the rate of decrease in the former cost until at some value total costs are minimum. After this higher value of inventory turnover increases the total costs.

For the sample of the general stores inventory studied in this report it was desired to have an idea of the operating investment turnover or the number of times the class of materials used and replaced in a year. The inventory turnover ratio may be defined as the sales income of the materials sold divided by the average investment in an inventory of materials in a period usually taken as a year. It was management policy of the store under study to sell the item at 15 percent premium over its unit cost to cover the operating expenses. The average investment in inventory was difficult to find exactly. The reason being that the

rate of ordering was not consistent with the rate of usage. Many items were overstocked and hence it was not necessary to place a single order in 2 years for some items that were active in usage. Also the rate of usage was irregular. Hence for the purpose of getting an idea of the flow of inventories and its costs, the average of the beginning and closing value of the inventory of an item was used as an average investment in a financial year. The following results were obtained for different classes of items sampled and for different years.

TABLE 4

Class of Inventory	Turnover Ratio in 1964-65	1965-66	A Financial year Average for 1964-66
1. A & B class items	1.11	1.28	1.22
2. 277 items having activity in 2 years	.95	1.09	1.04
3. All 362 items	.814	.936	.910

Thus we see that inventory turnover ratio is less than one for overall situation. Since this is a maintenance store, the objective of management is not a high inventory turnover and optimum costs but rather good services to the consumer departments, continuity of supply, good supplier relations etc. It may be remembered that the sales price is only 15 percent higher than the unit cost for provision of operating costs of the stores. Instead of a turnover ratio control,

there is a "dollar limits" by budgets available for investment in each catagory of materials. Order quantities were based on judgement of the "time limits", i.e. the number of months of supply allowed.

Inventory turnover may not be set as in an inventory control program. However, it is desirable to have the figure of turnover ratio in the annual report of the inventory control activity. The comparison of this figures with figures from the same type of industries and the figures of previous years would give an idea for further control modifications. To increase the turnover level, the materials manager might institute a program to reduce the number of items carried in stock, to persuade vendors to carry special stock available for early deliveries, to work on tighter lead times, etc.

2.5 Study of Typical Lead Time Distributions.

There is always some interval between the time that the need for material is determined and the time when the material is actually received. This period is called the lead time. The total lead time has two components, administrative lead time and supplier lead time. The shortest lead time items are those furnished by a local supplier for immediate delivery from his stock. Even in such a case three to seven days lead time is necessary. Much longer lead times are necessary for items made to order by out of town suppliers,

and the more complex the item, longer the lead time.

Lead time for an item may vary with different suppliers, or with the same supplier but at various stages of the business cycle. In a manufacturing operation lead time increases with an increase in demand. Changing lead times is one of the most difficult problems of material management. The decrease in lead time is not as bad in its effect as the rather sudden increase in lead time which would result in stock outs. Thus lead time and the usage rate during lead time affects the money blocked in safety stock of an inventory. If the lead time is long, the safety stock would be high. It may be necessary for items having high usage to forecast the length of the lead time by inference from past data. If lead times do vary substantially then it is usually worth some appreciable effort to try to find the cause of the variation and eliminate it.

Administrative lead time includes time for the information to flow, time to accumulate enough work to make it worthwhile to process the files, and a lapse of time while the orders are reviewed and released. If total elapsed time is more than five times the active time (the active time for above activities has to be determined experimentally), then there are opportunities for improvement in tightening up the scheduling procedures, elimination of unnecessary waiting time, or even unnecessary steps in the process (11). The length of the minimum lead time is the natural measure of

a system being controlled. Thus in designing a control system the steps should be taken to shorten the lead time and the items having long lead times should be planned in advance.

In this study an attempt was made to determine lead time distributions for two catagories of items. The first catagory is the hardware and miscellaneous item. The orders for this catagory were handled through the Purchasing Division of the State of Kansas. The lead time estimated includes the period of time from the writing of the purchase request till the time the material is received. Minimum order size was found to be 50 dollars. The practice is to consolidate requirements of various items (that can be delivered by a single supplier) in a single purchase request. About half of the purchase requests were written to procure materials for job orders and remaining were to build up the stock of the items to provide for future usage. All the information necessary in this analysis were available in the purchase request file. It was also felt that the delivery time estimated by the suppliers used was on the low side.

211 observations of the orders for a year period were taken. About 95 percent of the observation had lead times of 21 to 140 days. To find the frequency distribution of the lead time, the observations were divided into certain classes. According to the Sturges rule (12) the number of

classes $K = 1 + 3.3 \log_{10} (N)$, Where N is the total number of observations.

This specifies about 9 classes. Hence class interval was taken as $\frac{140 - 21}{9}$ say 12.

TABLE No. 5 gives the statistically processed data and results.

TABLE 5

Class Interval	Mean Value of class X_i	Frequency f_i	$f_i \cdot X_i$	$(X_i-\bar{X})^2$	$f_i(X_i-\bar{X})^2$
9-20	14	2	28	2,401	4,802
21-32	26	31	806	1,369	42,439
33-44	38	39	1,482	625	24,375
45-56	50	36	1,800	169	6,084
57-68	62	29	1,794	1	29
69-80	74	25	1,850	121	3,025
81-92	86	14	1,204	529	7,406
93-104	98	12	1,176	1,225	14,700
105-116	110	3	330	2,209	6,627
117-128	122	6	732	3,481	20,886
129-140	134	5	670	5,041	25,205
141-152	146	3	438	6,889	20,667
153-165	158	2	316	9,025	18,050
166-176	170	2	340	11,449	22,898
177-188	182	2	364	14,161	28,322
Totals		211	13,332		245,515

$$\text{Mean} = \frac{\sum f_i X_i}{\sum f_i} = \frac{13,332}{211} = 63.2 = \bar{X}. \qquad \text{Variance} = \frac{\sum f_i (X_i - \bar{X})^2}{\sum f_i} = 1169$$

Figure no. 9 is the plot of the frequency distribution of lead times. It can be seen that this distribution is a skewed one having a long tail on the right hand side. The

FIG. 10

A. LOCAL ORDERING PROCEDURE

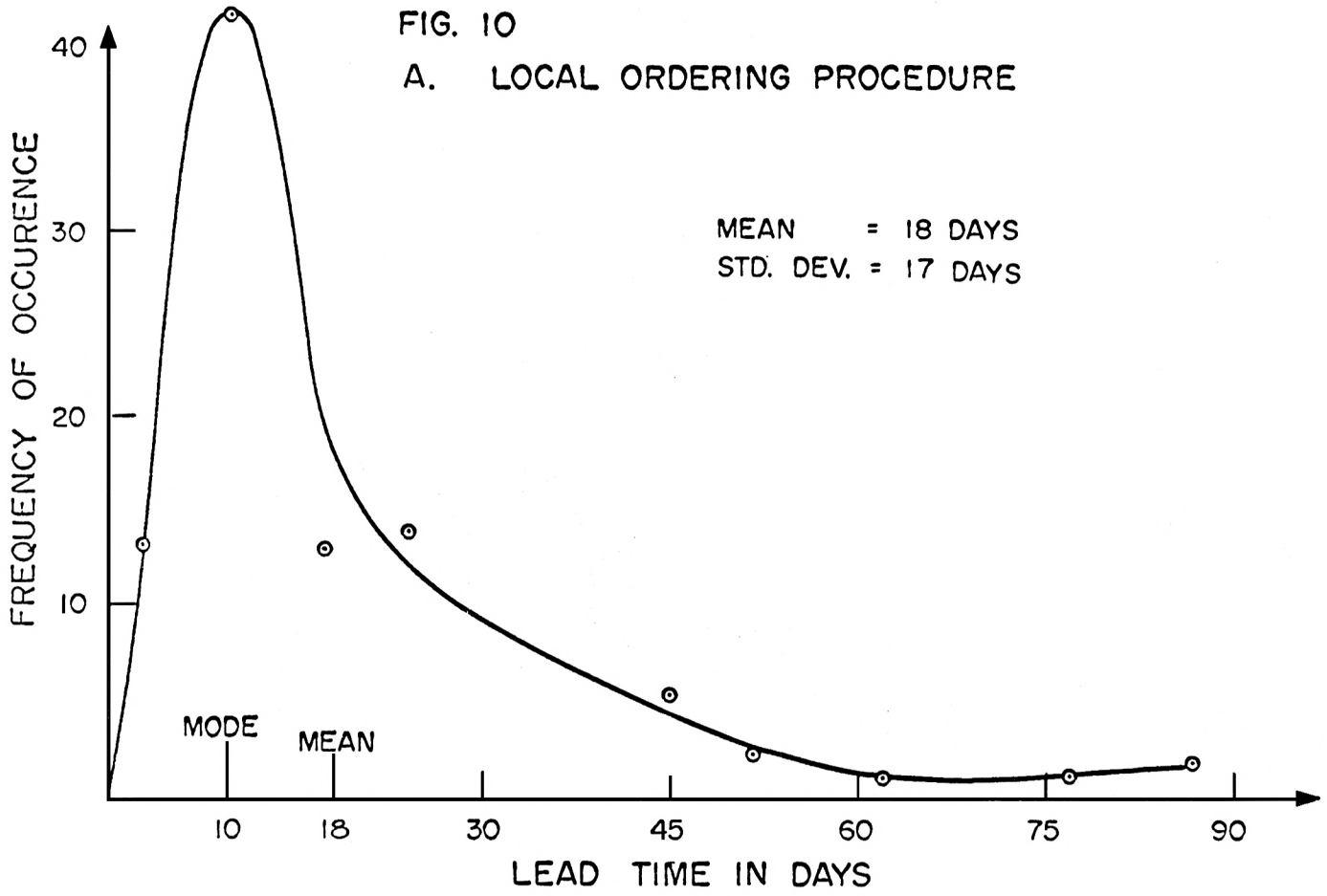
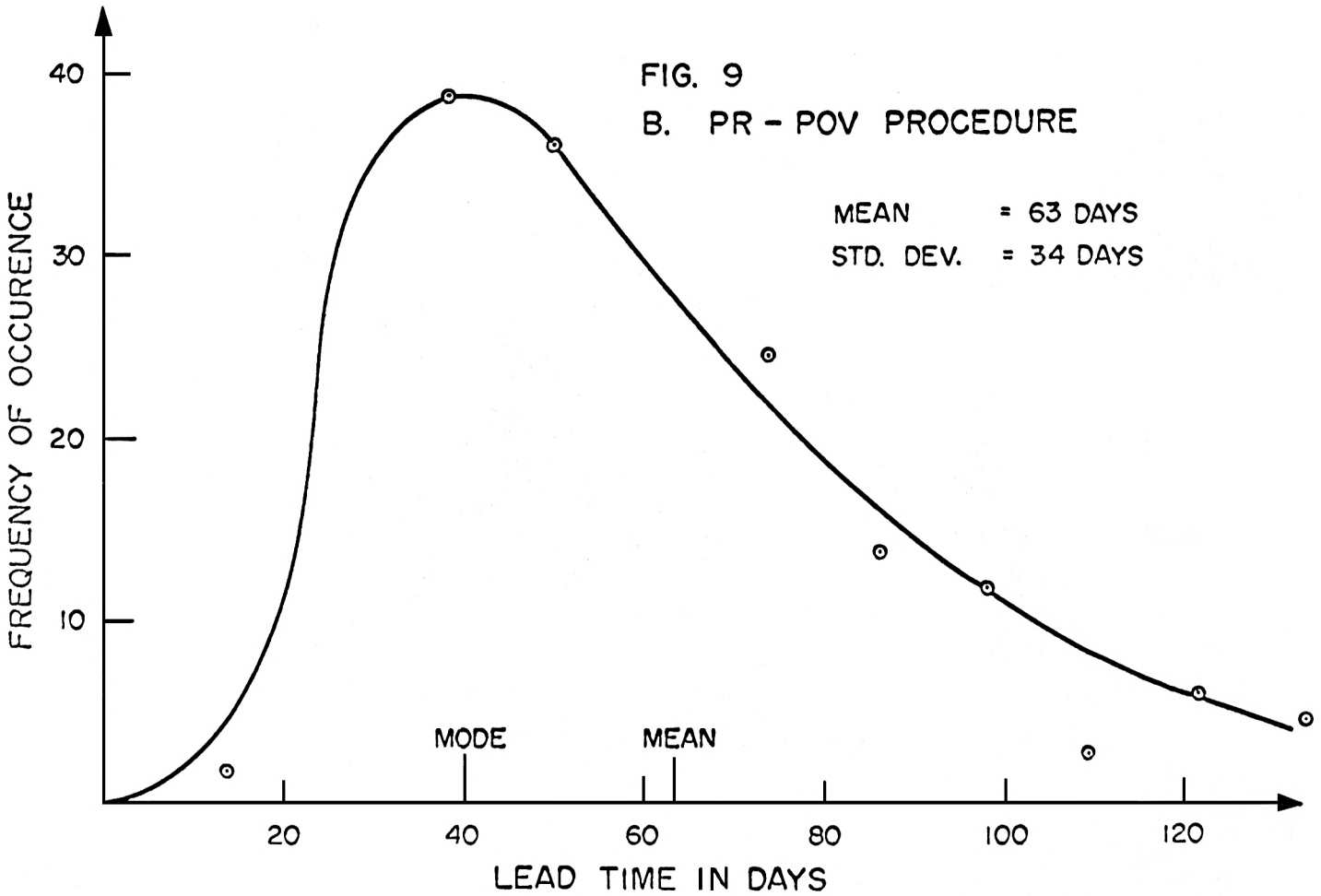


FIG. 9

B. PR - POV PROCEDURE



mean and standard deviation of this distribution are 63.2 and 34.1 respectively.

There is another lead time distribution for items which were ordered through the purchase order invoice procedure. Here lead time was shorter because the orders were not processed through the purchasing division of the State of Kansas. Many of the contract items also fall in this group. The data for this analysis was taken from purchase order invoice (P.O.I.) file. In some urgent cases material was ordered by the phone calls and the P.O.I. was sent after the material was received. Such invoices were not considered for this analysis. A total of 97 observations were taken. As before, the number of classes by Sturge's rule turns out to be 8. Ninety-five percent observations are distributed in the range of 3 to 55. This gives class intervals of 7 days. Proceeding as above this analysis also gives a skewed distribution of lead time with a mean of 18 days and standard deviation of 17 days. It is plotted on Figure no. 10.

The duration of time between the item is found in short supply to the time the purchase request is written was roughly estimated to be varying between 13 to 23 days. Thus the average total lead time for an item is 81 days for the PR -POV ordering procedure and 36 days for the local ordering procedure.

3.0 CONCLUSIONS

This preliminary study is found to be interesting and educational. It is a system description and has revealed the following areas of improvement:

1. It would be worthwhile to extend the ABC analysis to the whole inventory. A bin reserve system can be used instead of recordkeeping for about half of the items.
2. Attention should be given to the problems of taking the physical inventory. A stock check may be made at the time of receipt of materials, when the stock has been depleted to a minimum.
3. A master list of items providing cross reference between a part number and its storage location should be maintained in the store.
4. A list of active and inactive items should be prepared. Accordingly, the minimum and maximum values may be updated.
5. It would be worth some effort to simplify the ordering procedure and to check for the improvement in areas of forms control.

This study also illustrates how the objectives and procedures of the governmental organization can differ from an industrial or business situation. The aim of the present

management is thus to ensure a clean and smooth working inventory system, providing for the needs of various departments within the available budgets and operating under the rules of the university and government.

The outlook of the present management is also progressive. Thus some improvements are being undertaken and others are proposed in the present system which are not discussed in this report.

This study would not be complete in all respects. However, the important topics under the scope of the subject have been included.

4.0 ACKNOWLEDGEMENTS

I am deeply grateful to my major advisor, Dr. Louis E. Grosh, Associate Professor, Department of Industrial Engineering, Kansas State University. Not only has he arranged with the stores personnel to get this study originated, but offered his counsel and help from time to time during its development. He thus helped in arranging and accompanying some meetings with stores personnel. Finally his critical review of this report refined the editing of it.

The author wishes to express his appreciation to the stores executives to allow for using their facilities with the spirit of being a part of an educational institution. Many thanks to all the persons of the store who were courteous and patient to provide necessary information during various meetings and for helping in gathering other datas necessary in this study.

5.0 APPENDIX A

DESCRIPTION

FORM #	
1	STOCK (RECORDKEEPING) CARD
2	PHYSICAL PLANT M & R
3	CHECK TICKET
4	TALLY IN SHEET
5	RAW MATERIALS IN SHORT SUPPLY
6	STOCK SPECIFICATION CARD
7	MATERIALS FOR REQUISITION FORM

#1

DATE	AUTH'Y	REC'D	ISSUED	TOTAL TO DATE	BAL.	UNIT COST	TOTAL COST	SELL PRICE	DATE	AUTH'Y	REC'D	ISSUED	TOTAL TO DATE	BAL.	UNIT COST	TOTAL COST	SELL PRICE

UNIT COST	MINIMUM
SELL PRICE	MAXIMUM

#1

DATE	AUTH'Y	REC'D	ISSUED	TOTAL TO DATE	BAL.	UNIT COST	TOTAL COST	SELL PRICE	DATE	AUTH'Y	REC'D	ISSUED	TOTAL TO DATE	BAL.	UNIT COST	TOTAL COST	SELL PRICE

VENDORS	UNIT COST	MINIMUM	SOLD	J	F	M	A	M	J	J	A	S	O	N	D
1			19____												
2	SELL PRICE	MAXIMUM	SOLD	J	F	M	A	M	J	J	A	S	O	N	D
3			19____												

PHYSICAL PLANT M & R

Job No. ..... **Date**.....

Name .....

Material	Unit Price	Amount

#3

Received by_____ Date_____

Department_____ S.Cl. Cust. H.&P. Grnd.

CHECK TICKET

To be returned_____

I have received the following in good order from Physical Plant Department.
All items not returned in 30 days will be charged to your department.

_____

_____

_____

_____

_____

_____

_____

_____

% of Discount_____

TALLY-IN

#4

Freight

Prepaid_____

Collect_____

Order No._____

Date_____

Freight and Express Record

From_____

Carrier_____

Freight Bill No._____

Weight_____ No. of Pieces_____

Quant.	ITEM	DESCRIPTION	INVOICE		EXTENSIONS			
			Unit Cost	Total Cost	Less Discount	Freight	Unit Cost	Total Cost

REPORT ON MATERIAL IN SHORT SUPPLY

Sheet No.

Date______________________________

Card No.	Article or Material Size Color Finish	On Hand	Unit Cost	Need	Card No.	Article or Material Size Color Finish	On Hand	Unit Cost	Need

Card No.		#6	ORDER WITH CARD

ARTICLE AND DESCRIPTION - SIZE - MATERIAL - PLATING - FINISH - COLOR - MFG. & CAT. NO.

Est. Cost	Unit of Measure	Std. Package	Use One Year	Min.	Max.

Model	Type	Form	Style	Frame	HP	Volt	Amp	PH	CYC	CFM

Vendor	Address	Town	State

Date	Ordered							

#7

K. S. U. OFFICE OF SUPERINTENDENT OF MAINTENANCE
REQUEST FOR MATERIAL

Department of P.P. M&R Fund ______ Date 10-31-66

vendors (2) Richards Auto Parts, 210 Poyntz Ave, Manhattan, Ks
(3)
(4)

Invoice #06385 Date 10-28-66

Card No.	Used One Year	On Hand	Need	Unit	ARTICLE	Brought Forward	ESTIMATE	
	*	yes.	yes					
				1	CS-724 A Echlin Points		1	60
				1	AL869 Echlin condenser		0	68
					Job # 66-1027 Yellow tractor			

TOTAL 2 28

Requested by ______

6.0 APPENDIX B

TABLE 1

HISTORICAL DATA OF ITEMS SAMPLED

1	2	3		4		5	6	7	8	9	
Sr No.	Stock no.	Receipts no.	qty	Issues no.	qty.	65 Inv. Balance	Unit Cost	Minimum	Maximum	Stock Outs no.	Length (weeks)
-	9027	0+1	0+200	0+9	0+175	210	.09	20	40		
	9096	--	--	9+3	34+12	29	.07	20	40		
	9097		--		--	40	.06	5	15		no Items since 7/61
	9226	0+1	0+100	516	78+72	77	.10	24	72		
	9370	--	--	0+5	0+17	35	3.00	20	40		
	9435	1+0	3+0	1+1	1+1	3	58.00	2	4		
	9469	11	1440+1500	28+47	1271+1956	1519	.0046	1000	2000		
	9550	0+1	0+25	3+5	3+7	29	.13	4	14		
	9647	2+1	2+1	3+0	3+0	2	2.11	1	2		
	9774	1+0	1+0	1+0	1+0	3	4.00	2	3		
	9893	1+1	12+16	16+18	26+21	32	.162	24	40		
	9949	1+0	200+0	4+6	68+31	281	.0661	150	350		
	9972	0+1	0+10	2+1	12+4	10	.75	0	0		
	10052	2+2	60+70	25+20	45+29	41	.73	6	24		
	10168	--	--		--	4	2.32	2	4		
	10193	-	--	4+3	5+7	56	.80	30	70		
	10239	--	--	2+3	2+3	1	2.03	2	6		

TABLE 1A. PUNCHED DATA OF PAST HISTORY OF ITEMS IN SAMPLE

(1) STOCK NO.	(2) RECEIPTS NUMBER 1ST YEAR	2ND YEAR	64-66 QUANTITY 1ST YEAR	2ND YEAR	(3) ISSUES NUMBER 1ST YEAR	2ND YEAR	64 66 QUANTITY 1ST YEAR	2ND YEAR	(4) 1966 INV.	(5) UNIT COST	(6) AVE. USAGE PER	(7) MIN-IMUM	(8) MAX-IMUM
39	3	0	440	0	13	3	177	16	298	.1450	13.99	100	200
91	3	1	3000	2000	127	91	2525	1733	1620	.0465	99.00	1000	2000
97	0	0	0	0	1	1	1	2	3	1.7000	2.55	0	2
129	0	0	0	0	6	8	100	137	203	.0170	2.01	200	400
150	0	0	0	0	4	1	19	1	372	.0320	.32	50	150
153	0	0	0	0	2	3	6	188	194	.0500	4.85	150	250
167	0	0	0	0	1	1	12	36	199	.0450	1.08	10	60
188	0	0	0	0	1	1	2	2	171	.0750	.15	25	75
193	0	0	0	0	0	0	0	0	100	.1400	0.00	25	75
221	3	3	900	800	30	46	669	819	192	.0100	7.44	300	500
226	0	0	0	0	5	8	10	104	332	.0187	1.06	100	200
279	0	0	0	0	1	3	12	12	78	.0660	.79	50	100
347	0	0	0	0	0	0	0	0	17	.2786	0.00	10	25
369	1	1	24	8	0	0	0	0	32	.1000	0.00	10	20
386	0	1	0	500	16	25	499	356	341	.0145	6.20	300	500
405	2	0	2100	0	62	57	1336	998	744	.0090	10.50	600	1100
449	1	1	150	100	10	5	174	27	180	.1000	10.05	100	200
485	1	0	7	4	3	5	5	8	0	3.0000	20.25	8	526
571	0	0	0	0	2	1	10	2	10	.2170	1.30	3	15
573	0	0	0	0	0	0	0	0	12	.3000	0.00	6	15
587	0	0	0	0	1	3	8	14	142	.0180	.20	72	216
590	0	0	0	0	0	0	0	0	2	25.5000	0.00	0	2
606	1	2	3	76	8	15	39	60	18	1.4200	70.29	20	40
615	0	0	0	0	3	5	24	10	69	.0670	1.14	20	40
619	0	0	0	0	0	0	0	0	9	.0900	0.00	6	18
689	0	0	0	0	4	1	51	17	654	.1660	5.64	600	900
782	1	1	20	20	9	18	10	29	15	.2800	5.46	20	40
784	0	2	0	20	3	6	5	13	10	.5400	4.86	3	9
787	1	0	4	0	1	2	1	1	1	5.1500	6.44	0	2
792	0	0	0	0	1	3	2	4	11	.1000	.30	4	16
830	1	1	10	300	2	3	8	220	279	.0110	1.25	150	250
859	0	0	0	0	1	1	6	12	288	.0100	.09	25	125
885	0	0	0	0	0	0	0	0	11	.8100	0.00	6	16
919	0	0	0	0	0	1	0	50	115	.2300	5.75	25	125
932	0	2	0	450	38	50	220	332	327	.1200	33.12	200	400
978	1	0	600	0	7	4	324	122	381	.0230	5.13	300	900
1008	0	0	0	0	0	0	0	0	3	.2000	0.00	0	1
1016	1	1	1000	2000	71	76	1319	2203	2080	.0036	6.34	800	1800
1063	0	0	0	0	0	0	0	0	9	.1200	0.00	3	7
1084	0	0	0	0	3	2	24	9	49	.0050	.08	40	140
1124	0	2		66	2	6	1	35	62	.3500	7.88	24	48
1164	0	0	0	0	0	2	0	1	2	.2600	.23	2	4

													4
1183	0	0	0	0	0	0	0	0	5	2.1200	0.00	1	6
1234	0	0	0	0	0	6	0	73	661	.0080	.29	288	370
1257	0	0	0	0	0	2	0	18	26	.0410	.37	100	244
1283	0	0	0	0	0	0	0	0	414	.0070	0.00	288	432
1303	0	0	0	0	2	3	42	68	102	.0311	1.71	144	288
1337	0	0	0	0	9	4	68	9	163	.0430	1.66	50	150
1356	0	1	0	100	1	1	100	1	152	.0234	1.18	60	160
1359	0	0	0	0	1	1	8	4	54	.0220	.13	30	130
1369	0	0	0	0	2	5	20	50	321	.0209	.73	288	432
1369	0	1	0	200	14	3	104	112	235	.0073	.79	160	360
1432	0	0	0	0	4	6	38	59	275	.0220	1.07	200	300
1477	1	0	288	0	1	0	2	0	335	.0063	.00	144	288
1490	0	0	0	0	4	4	146	51	381	.0056	.55	288	432
1504	0	0	0	0	0	0	0	0	62	.0040	0.00	0	
1533	1	1	720	1008	42	98	635	1048	808	.0062	5.22	720	1440
1569	0	0	0	0	4	0	324	0	1377	.0013	.21	288	576
1589	1	1	1440	1500	25	33	1017	1711	1508	.0042	5.73	1440	2880
1606	1	0	500	0	12	4	183	260	452	.0066	1.46	288	576
1608	0	1	0	432	5	7	164	274	302	.0098	2.15	288	576
1622	0	0	0	0	6	13	406	324	756	.0070	2.56	600	1320
1676	0	0	0	0	0	2	0	18	363	.0038	.03	288	576
1692	0	1	0	1000	12	16	343	650	1150	.0050	2.48	1000	1720
1721	0	0	0	0	16	14	271	252	743	.0060	1.57	432	1008
1732	0	0	0	0	3	6	60	174	490	.0050	.59	144	576
1753	0	0	0	0	2	0	26	0	33	.0030	.04	0	
1786	0	0	0	0	7	9	61	67	1452	.0153	.98	432	864
1804	1	0	144	0	1	1	144	4	395	.0150	1.11	288	432
1859	0	0	0	0	4	7	40	39	639	.0035	.14	432	720
1969	1	0	2	0	1	0	1	0	4	1.5300	.77	1	3
1987	0	1	0	1000	1	32	577	1372	860	.0220	21.44	1000	2000
2046	0	0	0	0	64	39	232	224	926	.0180	4.10	250	500
2063	3	0	2200	0	59	65	850	1262	1598	.1398	147.63	800	1400
2099	1	3	75	240	10	12	118	220	82	.2640	44.62	40	88
2114	0	1	0	12	2	4	8	6	18	.2300	1.61	12	24
2157	0	1	0	300	12	10	145	114	571	.0049	.63	300	600
2174	1	0	300	0	4	4	58	14	454	.0230	.83	200	400
2196	0	0	0	0	1	0	4	0	22	.0690	.14	10	30
2224	1	1	48	24	1	1	15	12	50	.2000	2.70	48	72
2242	0	0	0	0	0	0	0	0	147	.0080	0.00	0	
2259	0	1	0	100	11	18	27	32	179	.1454	4.29	100	200
2291	2	2	5000	3500	26	35	1789	3920	2671	.0500	142.73	2000	3500
2302	0	0	0	0	10	6	520	57	677	.0172	4.96	300	800
2315	0	0	0	0	2	4	286	179	1557	.0125	2.91	500	1500
2342	1	3	1000	4000	9	7	956	2133	4180	.0500	77.23	500	15
2369	1	0	1000	0	15	6	1800	204	1080	.0160	16.03	500	1000
2418	0	1	0	300	2	2	130	821	300	1.4396	684.53	100	300
2449	0	0	0	0	0	0	0	0	18	.1800	0.00	10	20
2467	3	0	36	0	13	10	22	22	16	.7800	17.16	20	35
2468	0	1	0	15	10	7	15	8	16	.6500	7.48	12	24
2570	0	0	0	0	0	0	0	0	4	.2800	0.00	2	6
2591	2	3	16	41	6	11	7	16	35	.2000	2.30	4	10
2662	0	0	0	0	2	3	3	9	20	1.2000	7.20	25	45

												45
2699	0	0	0	0	2	1	2	1	78	.0800	.12	4	14
2714	1	0	50	0	23	8	36	13	37	.0955	2.34	30	60
2731	1	0	10	0	4	2	5	3	13	.4000	1.60	10	20
2733	0	0	0	0	2	1	3	3	5	.4900	1.47	4	10
2742	0	0	0	0	5	0	5	0	9	.2200	.55	5	10
2759	0	0	0	0	0	0	0	0	6	.2000	0.00	1	3
2789	0	0	0	0	1	2	1	3	7	1.2800	2.56	6	12
2820	0	1	0	16	8	1	17	1	17	.4800	4.32	6	16
2826	0	1	0	10	1	5	2	7	11	.1200	.54	10	20
2897	2	2	43	61	9	12	48	40	37	3.4000	149.60	15	35
2942	0	0	0	0	0	0	0	0	19	1.7000	0.00	12	24
2978	0	1	0	50	12	8	28	9	92	.1500	2.78	50	100
2994	0	0	0	0	2	0	3	0	20	.2200	.33	10	25
3116	0	0	0	0	1	0	2	0	15	.8200	.82	8	18
3159	0	1	0	15	3	3	4	3	16	.4200	1.47	8	18
3196	0	0	0	0	0	2	0	84	279	.8200	34.44	0	
3224	0	2	0	22	26	31	29	32	19	1.2600	38.43	15	35
3251	0	1	0	30	6	7	27	18	37	.1700	3.83	10	30
3264	0	0	0	0	0	2	0	3	63	.1200	.18	10	20
3312	1	0	2	0	2	0	2	0	2	8.4500	8.45	1	2
3320	0	1	0	10	0	7	0	9	12	.6500	2.93	4	10
3321	0	1	0	10	1	4	1	8	11	.4680	2.11	4	10
3572	0	0	0	0	0	1	0	3	7	1.0760	1.61	4	8
3585	5	0	1	0	2	1	2	2	9	7.3500	14.70	5	10
3596	0	0	0	0	2	0	2	0	21	3.3000	3.30	8	18
3640	2	1	48	46	5	4	11	9	83	.2300	2.30	15	30
3674	1	2	12	18	7	7	13	9	17	29.7700	327.47	6	16
3732	2	2	50	60	18	16	46	63	37	.4000	21.80	40	60
3755	0	1	0	2	0	2	0	2	4	.7400	.74	1	3
3783	0	0	0	0	1	0	6	0	12	.7500	2.25	4	10
3787	1	0	36	0	9	9	15	10	35	.1400	1.75	25	50
3798	0	0	0	0	0	0	0	0	6	2.7100	0.00	2	6
3805	1	0	3	0	1	1	1	2	1	2.6900	4.04	1	3
3823	0	0	0	0	1	2	1	5	2	15.8600	47.58	2	8
3876	0	0	0	0	0	0	0	0	55	.1400	0.00	0	7
3897	1	1	10	8	7	7	11	8	12	11.7500	111.63	10	18
3907	0	1	0	3	1	1	1	1	2	3.7600	3.76	1	3
3949	0	1	0	10	4	6	5	7	3	.3700	2.22	1	4
3950	0	1	0	5	2	3	2	5	7	.3700	1.30	2	4
4123	1	0	10	0	3	1	6	1	11	.0560	.20	6	16
4131	1	0	5	0	3	0	5	0	5	.1300	.33	2	6
4136	0	0	0	0	0	1	0	1	5	.2300	.12	2	6
4295	0	0	0	0	0	0	0	0	68	.0700	0.00	30	80
4301	1	0	10	0	4	3	4	4	14	.4100	1.64	10	20
4359	0	0	0	0	5	2	98	7	217	.1630	8.56	80	240
4373	1	1	500	300	42	45	209	2087	309	.2760	316.85	300	500
4379	0	1	0	1360	13	17	688	953	871	.0488	40.04	480	1280
4409	1	0	48	0	2	1	22	24	26	.3015	6.93	4	16
4480	0	1	0	105	10	5	86	36	180	.1100	6.71	80	185
4490	0	2	0	210	3	8	71	238	135	1.4300	220.94	130	214
4499	0	0	0	0	0	0	0	0	497	1.6000	0.00	100	300
4572	1	0	6	0	3	2	3	2	4	.3700	.93	2	4

												4
4573	0	1	0	4	2	1	2	1	5	.5100	.77	0	
4613	0	0	0	0	0	0	0	0	1	3.8300	0.00	1	2
4623	1	0	4	0	1	0	1	0	3	1.4500	.73	0	
4646	0	0	0	0	1	2	1	2	11	.1300	.20	10	20
4698	0	0	0	0	2	1	49	3	182	.4036	10.49	100	200
4727	0	0	0	0	6	3	25	10	60	.0200	.35	10	20
4764	0	0	0	0	0	1	0	1	8	12.7300	6.37	2	6
4790	0	0	0	0	0	1	0	1	7	1.9500	.98	3	9
4822	1	0	72	0	1	2	4	4	94	.4600	1.84	20	30
4874	0	1	0	15	12	5	18	11	15	.1500	2.18	10	20
4913	0	0	0	0	1	1	1	2	10	.9120	1.37	2	6
5021	0	0	0	0	0	1	0	1	4	1.3800	.69	1	3
5084	0	0	0	0	1	0	1	0	5	.5000	.25	3	6
5096	0	0	0	0	3	1	9	1	35	.7500	3.75	5	10
5113	1	1	12	8	9	9	9	10	3	21.3500	202.83	0	
5118	0	0	0	0	0	0	0	0	3	63.2500	0.00	1	3
5167	4	2	80	62	12	16	71	38	53	.1700	9.27	10	20
5235	0	0	0	0	1	0	1	0	8	4.9500	2.48	3	6
5255	2	3	43	41	33	18	44	22	41	4.7000	155.10	20	38
5268	1	2	12	22	6	4	10	7	28	3.4600	29.41	10	20
5291	0	0	0	0	0	0	0	0	2	14.5100	0.00	1	2
5327	0	0	0	0	0	0	0	0	0	18.2900	0.00	1	3
5345	0	0	0	0	0	0	0	0	1	227.0000	0.00	0	1
5358	1	2	6	6	5	5	6	6	10	7.6000	45.60	6	12
5382	0	2	0	3	0	0	0	0	4	26.0000	0.00	1	3
5384	0	1	0	2	2	0	2	0	3	16.5000	16.50	1	2
5444	0	0	0	0	5	4	1	14	30	.0568	.68	12	32
5482	0	0	0	0	2	2	2	2	23	.0263	.05	15	35
5553	0	1	0	144	3	2	144	24	120	.4800	40.32	72	144
5596	0	0	0	0	3	2	3	2	20	1.4100	3.53	5	15
5610	2	1	75	10	27	10	204	50	100	.6600	83.82	50	150
5637	0	0	0	0	1	0	1	0	4	4.6700	2.34	5	30
5662	2	0	69	0	9	9	36	23	10	.4348	12.83	40	63
5702	0	1	0	11	1	1	1	2	13	1.0820	1.62	2	13
5722	0	0	0	0	1	0	3	0	0	1.9400	2.91	2	3
5724	0	0	0	0	3	1	5	3	7	1.7100	6.84	3	10
5758	0	0	0	0	1	0	2	0	3	5.0680	5.07	2	11
5821	0	0	0	0	0	0	0	0	24	3.0000	0.00	12	24
5854	0	0	0	0	0	0	0	0	397	.1300	0.00	100	300
5897	3	3	22500	19270	320	330	17311	20456	4217	.11952	256.58	3000	6000
5917	14	9	104	62	14	9	104	62	0	.3560	29.55	0	
5923	2	1	1239	1011	2	41	47	884	2169	.3140	146.17	0	
5933	4	3	19860	12620	288	250	1460	13812	8009	.1300	1846.78	0	
5986	2	1	150	100	16	11	149	51	93	.0650	6.50	30	80
6020	2	1	2240	1600	28	32	908	1559	1775	.1530	188.73	300	940
6106	0	0	0	0	0	0	0	0	5	2.6300	0.00	0	
6128	0	1	0	100	40	46	66	90	25	2.7800	216.84	25	
6165	1	0	6	0	4	2	9	3	13	2.7400	16.44	20	28
6166	3	1	34	6	4	1	8	3	53	2.7000	14.85	24	38
6187	0	0	0	0	0	0	0	0	11	.9000	0.00	0	
6226	0	0	0	0	6	6	13	5	1	15.0000	138.75	65	65
6270	2	2	140	200	9	11	189	121	97	.3400	52.70	50	150

													150
6301	0	0	0	0	3	1	19	2	124	.0600	1.17	100	180
6351	2	1	100	60	8	5	47	33	160	.2900	11.60	80	140
6359	0	1	0	20	1	1	5	2	37	.4590	1.61	10	30
6408	0	0	0	0	2	3	9	14	127	.0457	.53	50	150
6438	0	0	0	0	3	3	2	3	6	9.5350	26.22	2	7
6511	1	1	8	16	3	4	6	9	10	1.8000	13.77	8	24
6572	0	0	0	0	2	3	2	3	10	.7500	1.88	8	20
6581	2	2	50	30	16	27	33	49	16	.4900	20.09	15	25
6626	0	0	0	0	0	1	0	1	4	.2000	.10	2	4
6649	0	1	0	35	10	21	16	41	21	2.4200	68.97	30	60
6667	0	1	0	100	3	13	13	53	99	.1111	3.67	50	100
6672	2	1	100	100	15	12	58	30	155	.4690	20.64	50	100
6731	0	0	0	0	0	6	0	6	1	.7700	2.31	4	8
6763	1	1	120	60	35	42	143	78	88	.3500	38.68	80	140
6780	0	0	0	0	1	0	8	0	10	.3700	1.48	6	16
6805	0	2	0	50	18	18	23	22	43	1.2000	27.00	24	48
6829	0	0	0	0	3	2	3	2	17	1.6000	4.00	6	12
6849	2	1	13	36	16	23	19	31	20	.6000	15.00	24	36
6860	2	4	24	56	26	33	30	46	13	1.5500	58.90	12	24
6865	0	1	0	3	1	2	1	2	6	3.0000	4.50	3	6
6932	0	0	0	0	1	1	1	1	3	1.4000	1.40	1	
6992	0	0	0	0	1	0	5	0	3	3.0600	7.65	3	7
6996	1	1	48	42	25	20	49	44	26	2.7500	127.88	30	72
7029	0	1	0	6	1	0	2	0	8	1.2000	1.20	2	6
7055	3	1	15	6	5	6	5	7	11	1.5000	9.00	6	12
7074	2	0	300	0	14	10	35	32	432	.1605	5.38	100	250
7083	0	0	0	0	0	0	0	0	2700	.0400	0.00	50	200
7107	1	2	12	37	18	23	38	25	25	2.4700	77.81	8	20
7154	0	0	0	0	2	0	4	0	38	.6000	1.20	20	40
7194	2	1	48	12	38	18	40	21	27	1.6400	50.02	20	36
7233	0	0	0	0	0	1	0	1	4	3.5100	1.76	2	4
7252	1	0	12	0	5	4	17	4	6	.7500	7.88	0	
7388	0	0	0	0	0	1	0	1	15	.0400	.02	12	36
7399	0	0	0	0	0	1	0	1	4	6.1800	3.09	2	4
7430	0	0	0	0	10	5	10	6	89	.0300	.24	36	60
7457	1	2	3	6	3	5	3	5	5	1.9700	7.88	3	6
7466	0	0	0	0	0	0	0	0	5	1.4000	0.00	3	6
7482	1	0	3	0	0	0	0	0	3	1.4800	0.00	1	2
7523	0	0	0	0	1	0	1	0	29	2.4000	1.20	10	16
7584	1	2	34	112	22	46	44	121	48	.2500	20.63	30	70
7587	0	0	0	0	2	3	4	6	66	.6252	3.13	20	50
7704	2	2	72	48	37	44	64	57	19	.1700	10.29	15	24
7709	0	1	0	40	1		55	0	40	1.2660	34.82	0	
7758	1	0	25	0	1	0	1	0	65	.1900	.10	12	25
7762	1	2	330	220	240	105	276	143	446	1.5400	322.63	100	300
7780	1	0	14	0	9	5	9	5	0	5.9800	41.86	7	14
8070	1	0	4	0	1	2	1	3	2	3.0000	6.00	2	6
8076	0	0	0	0	1	0	4	0	92	.0120	.02	10	
8087	0	0	0	0	0	0	0	0	36	.9900	0.00	12	36
8114	1	1	1	2	1	2	1	3	2	.6000	1.20	1	2
8153	1	1	1	1	1	1	1	1	3	.9700	.97	2	3
8206	0	1	0	12	2	2	5	8	17	.7700	5.01	10	20

												20
8232	0	0	0	0	0	1	0	6	17	.0350	.11	20	
8266	1	2	100	150	95	90	128	194	5	.2300	37.03	50	150
8278	2	2	5	4	8	6	10	6	5	1.8000	14.40	2	4
8297	1	1	30	20	5	5	11	31	45	1.4500	30.45	40	60
8313	0	0	0	0	0	1	0	1	0	46.5000	23.25	0	1
8387	0	0	0	0	0	0	0	0	5	.1600	0.00	2	4
8445	3	2	200	72	77	62	98	63	278	.8300	66.82	150	200
8457	1	0	100	0	10	7	99	60	98	.3600	28.62	40	100
8468	0	0	0	0	4	4	156	60	784	.2900	31.32	300	800
8522	0	0	0	0	3	2	5	2	14	.4880	1.71	5	15
8549	1	0	1000	0	2	9	18	82	1877	.0230	1.15	1000	1600
8554	1	2	25	110	19	12	40	24	128	.7400	23.68	40	90
8586	1	0	6	0	1	1	1	1	5	7.3800	7.38	3	6
8593	0	0	0	0	0	0	0	0	2	7.7400	0.00	0	
8599	0	0	0	0	0	0	0	0	887	.0450	0.00	100	600
8635	0	0	0	0	0	0	0	0	3	.1560	0.00	0	
8636	0	0	0	0	1	0	1	0	4	5.3000	2.65	0	
8652	1	0	20	0	0	1	0	6	20	2.1700	6.51	10	30
8654	0	0	0	0	1	0	1	0	19	4.0000	2.00	4	8
8702	1	1	1	10	6	9	6	13	11	.1800	1.71	5	15
8703	0	1	0	6	4	6	4	8	9	.1672	1.00	5	10
8708	0	0	0	0	2	0	3	0	7	2.2700	3.41	0	
8714	0	1	0	2	1	2	2	2	2	10.0000	20.00	1	3
8774	1	0	24	0	14	5	25	7	19	.6500	10.40	18	30
8817	0	0	0	0	0	0	0	0	46	1.0300	0.00	2	6
8872	1	0	12	0	4	4	5	8	18	3.3500	21.78	8	18
8875	1	0	5	0	0	1	0	3	4	14.0000	21.00	3	7
8941	0	1	0	3	1	0	1	0	3	3.5000	1.75	2	4
8978	0	0	0	0	3	2	9	16	41	.3300	4.13	40	80
9016	0	3	0	90	0	6	0	26	58	.0900	1.17	15	30
9027	0	1	0	200	0	9	0	75	210	.0900	3.38	20	40
9049	1	1	50	30	7	10	23	38	27	.0700	2.14	15	30
9096	0	0	0	0	9	3	34	12	29	.0700	1.61	20	40
9097	0	0	0	0	0	0	0	0	40	.0600	0.00	5	15
9188	0	2	0	7	0	3	0	7	6	3.9000	13.65	3	6
9226	0	1	0	100	5	6	78	72	77	.1000	7.50	24	72
9266	0	0	0	0	0	0	0	0	37	.2200	0.00	6	16
9296	0	1	0	10	5	3	9	8	12	.6000	5.10	10	15
9347	0	1	0	200	26	19	117	71	363	.0275	2.59	200	400
9370	0	0	0	0	0	5	0	17	35	3.0000	25.50	20	40
9435	1	0	3	0	1	1	1	1	3	58.0000	58.00	2	4
9469	1	1	1440	1500	28	47	1271	1956	1519	.0046	7.42	1000	2000
9516	1	1	5	4	2	0	3	0	9	71.6000	107.40	3	6
9520	2	3	4	6	2	3	2	4	5	15.7500	47.25	2	4
9523	1	0	36	0	22	16	30	20	26	.1833	4.58	24	60
9550	0	1		25	3	5	3	7	29	.1300	.65	4	14
9584	0	0	0	0	2	5	2	5	13	.1470	.51	3	12
9616	2	0	3	0	1	0	1	0	3	1.3300	.67	0	1
9647	2	1	2	1	3	0	3	0	2	2.1100	3.17	1	2
9727	2	1	90	50	54	60	86	71	72	.3000	23.55	50	90
9774	1	1	1	1	1	1	1	1	3	4.0000	4.00	2	3
9786	0	0	0	0	3	0	6		1	7.6500	22.95	1	3

9803	0	0	0	0	0	0	0	0	5	.8800	0.00	2	5
9883	0	0	0	0	0	1	0	15	92	.1500	1.13	0	
9893	1	1	12	16	16	18	28	21	32	.1620	3.97	24	40
9898	0	1	0	20	5	1	8	6	16	.1200	.84	10	20
9911	1	0	16	0	3	5	3	7	8	.7050	3.53	8	16
9947	0	0	0	0	5	6	64	78	225	.0410	2.91	200	300
9949	1	0	200	0	4	6	68	31	281	.0661	3.27	150	350
9972	0	1	0	10	2	1	12	4	10	.7500	6.00	0	
9999	0	0	0	0	8	8	49	65	398	.0800	4.56	300	500
10052	2	2	60	70	25	20	45	29	41	.7300	27.01	6	24
10168	0	0	0	0	0	0	0	0	4	2.3800	0.00	2	4
10189	1	0	15	0	11	4	13	8	11	2.0000	21.00	12	24
10193	0	0	0	0	4	3	5	7	56	.8000	4.80	30	70
10195	0	0	0	0	2	1	4	2	30	.6000	1.80	30	50
10239	0	0	0	0	2	3	2	3	1	2.0300	5.08	2	6
10243	1	2	4	4	3	2	3	2	4	12.0000	30.00	2	4
10451	0	0	0	0	1	0	1	0	6	1.1800	.59	2	4
10466	1	0	33	0	7	2	40	6	30	.0600	1.38	20	50
10530	0	0	0	0	0	2	0	3	2	.4100	.62	2	6
10593	0	3	0	90	19	15	46	39	52	3.1900	135.58	10	30
10601	1	0	6	0	0	1	0	1	5	12.7500	6.38	2	6
10679	0	0	0	0	1	0	1		24	.4000	.20	0	

CONTRACT ITEMS

2627	0	0	0	0	10	11	12	12	21	.1870	2.24	15	30
2762	0	1	0	18	4	1	8	1	29	.0945	.43	15	30
3006	2	2	70	54	22	9	54	43	32	.1040	5.04	30	50
3013	0	0	0	0	2	2	4	3	135	.2500	.88	25	50
3418	0	0	0	0	3	2	3	2	7	.4200	1.05	6	12
3427	0	0	0	0	0	0	0		3	.8800	0.00	1	3
3479	2	1	40	12	11	5	17	5	70	.4400	4.84	35	55
3524	0	0	0	0	2	2	7	7	15	.1660	1.16	4	
3526	0	0	0	0	1	5	1	5	38	.1985	.60	15	25
3991	0	0	0	0	8	4	8	5	41	.0753	.49	15	30
4041	0	1	0	20	6	7	7	8	31	.1910	1.43	20	40
4067	1	0	4	0	0	0	0	0	6	.5863	0.00	1	2
4076	0	0	0	0	0	1	0	1	2	1.0000	.50	1	3
4161	0	0	0	0	4	2	5	3	26	.0700	.28	20	40
4185	1	1	35	30	27	19	40	26	44	.0680	2.24	40	70
4186	1	2	40	80	47	30	65	54	82	.0740	4.40	50	90
4249	0	1	0	4	2	0	2	0	11	.5080	.51	2	4
4895	0	1	0	1	3	7	3	10	6	.1880	1.22	6	16
4969	2	0	80	0	11	12	19	26	94	.2520	5.67	40	80
4997	0	0	0	0	0	2	0	3	11	.7500	1.13	6	16
6964	1	0	6	0	3	1	4	3	6	6.2100	21.74	2	6
7659	1	1	10	20	2	2	4	6	26	.1100	.55	6	16
7671	0	0	0	0	0	2	0	6	17	.2000	.60	10	20
7740	0	1	0	10	1	2	6	12	17	.3990	3.59	15	25
7915	5	2	312	120	14	16	172	108	49	.4000	56.00	48	96
7918	4	5	2040	2160	45	38	2075	1971	681	.1310	265.01	250	610
7979	0	3	0	128	3	7	28	100	67	3.9636	253.67	32	72

												72
7983	1	1	24	96	1	8	3	109	108	.1280	0.0	40	120
7985	0	1	0	10	1	2	1	4	17	.7700	1.93	4	20
7993	0	0	0	0	0	0	0	0	8	3.6000	0.00	2	10
8018	0	0	0	0	0	0	0	0	20	1.5100	0.00	0	
8033	0	0	0	0	1	5	2	15	34	.3700	3.15	12	72
10336	3	2	8	4	8	3	11	3	4	.5500	3.85	2	4
10393	4	3	14	21	8	15	1	19	9	.4900	7.11	6	16
10395	0	0	0	0	1	1	1	1	6	1.2300	1.23	3	7
10939	0	0	0	0	0	2	0	2	4	19.5800	19.58	0	

7.0 APPENDIX C

APPENDIX C. SAMPLE COMPUTER PROGRAM

```
MONSS     JOB  DINKAR K NAIK  I E DEPT
MONSS     COMT 15MINUTES,5  PAGES
MONSS     ASGN MJB,12
MONSS     ASGN MGO,16
MONSS     MODE GO,TEST
MONSS     EXEQ FORTRAN,,,,,,,FMAT
C      PROGRAM FOR CALCULATING TURN OVER RATIO AND OPTIMAL ORDER QUANTITY
       DIMENSIONIN( 91),M1( 91),M2( 91),R1( 91),R2( 91),I1( 91),I2( 91),Q
      11( 91),Q2( 91),B2( 91),C( 91)
       DIMENSIONB( 91),B0( 91),B1( 91),R( 91),TI( 91),ZC( 91),ICQ( 91),RZ
      1( 91),S(91),Z(91)
    2 FORMAT(I6,2I4,2F7.0,2I4,2F7.0,F6. ,F8.4)
    5 FORMAT (3F20.8)
    7 FORMAT  (I6,F5.1,F8.1,F5.1,F8.1,F7.1,2F9.4,F10.4,I5)
    9 FORMAT(4H K1=,F12.6,7H RATIO=,F14.6)
      J=91
      SS1=0
      SS2=0
      SS=0
      SI1=0
      SI2=0
      SI=0
      SRZ=0
      SM=0.
      DO 100 K=1,J
    1 READ (1,2)IN(K),M1(K),M2(K),R1(K),R2(K),I1(K),I2(K),Q1(K),Q2(K),B
      12(K),C(K)
      B1(K)=B2(K)+Q2(K)-R2(K)
      B0(K)=B1(K)+Q1(K)-R1(K)
      B(K)=(B0(K)+B1(K)+B2(K))*C(K)/3.
      Z(K)=(Q1(K)+Q2(K))/2.
      ZC(K)=Z(K)*C(K)
      TI(K)=(I1(K)+I2(K))/2
      R(K)=(R2(K)+R1(K))/2.
      SS =SS +ZC(K)*1.15
      SS1=SS1+Q1(K)*C(K)*1.15
      SS2=SS2+Q2(K)*C(K)*1.15
      SI=SI+B(K)
      SI1=SI1+(B0(K)+B1(K))/2.*C(K)
      SI2=SI2+(B2(K)+B1(K))/2.*C(K)
      RZ(K)=ZC(K)**.5
   50 SRZ=SRZ+RZ(K)
      S(K)=(M1(K)+M2(K))/2
      SM=SM+S(K)
  100 CONTINUE
      TRIN=SS/SI
      TRIN1=SS1/SI1
      TRIN2=SS2/SI2
      WRITE(2,5)SS1,SS2,SS
```

```
      WRITE(3,5)SS1,SS2,SS
      WRITE(2,5)SI1,SI2,SI
      WRITE(3,5)SI1,SI2,SI
      WRITE(2,5)TRIN1,TRIN2,TRIN
      WRITE(3,5)TRIN1,TRIN2,TRIN
      F1=SRZ/SM
      RATIO=F1*F1/2.
      WRITE(2,9)F1,RATIO
      WRITE(3,9)F1,RATIO
      DO  60 K=1,J
      ICQ(K)=F1*RZ(K)/C(K)
      WRITE(2,7)IN(K),S(K),R(K),TI(K),Z(K),B2(K),C(K),B(K),ZC(K),ICQ(K)
   60 WRITE(3,7)IN(K),S(K),R(K),TI(K),Z(K),B2(K),C(K),B(K),ZC(K),ICQ(K)
      STOP
      END
     MONS$      EXEQ LINKLOAD
                CALL FMAT
     MONS$      EXEQ FMAT,MJB
     MONS$      JOB  ACT$$DINKAR K. NAIK      I E       0313C40409

C      RESULT FOLLOWS

C      AVG. INVENTORY AND USAGE IN DOLLARS PER YEAR AND TURN OVER RATIOS
       1964-65 BASIS      1965-66 BASIS        AVG. OF TWO YEARS
       11223.82600000      13433.51300000      12328.66200000 - USAGE IN $
       10155.83400000      10544.29300000      10168.11400000 - AVG. INV. IN
           1.10516040          1.27400790          1.21248260 - TURN OVER RA

 K1=     7.704815, RATIO=      29.682090

C      OPTIMAL ORDERING QUANTITY AND OTHER DATA ON TWO YEARS AVERAGE. A,B IT

STOCK AVG. RECEIPT AVG. ISSUE    1966      UNIT      AVG.      AVG.    OPTIMAL
NUMBER  NO.  QTY.   NO.  QTY.   INVEN.    COST    INVENTORY USAGE  ORDERING
                                BALANCE           $ INVEST.   $     QUANTITY

  5897  3.0 20885.0325.0 18883.5 4217.0    .1195 391.7210 2256.5782 3062
  5897  3.0 20885.0325.0 18883.5 4217.0    .1195 391.7210 2256.5782 3062
  5933  3.0 16240.0269.0 14206.0 8009.0    .1300 916.5433 1846.7800 2546
  2418   .0   150.0  2.0   475.5  300.0   1.4396 994.2837  684.5298  140
  3674  1.0    15.0  7.0    11.0   17.0  29.7700 337.3933  327.4700    4
  7762  1.0   275.0172.0   209.5  446.0   1.5400 580.0666  322.6300   89
  4373  1.0   400.0 43.0  1148.0  309.0    .2760 387.3200  316.8480  496
  7918  4.0  2100.0 41.0  2023.0  681.0    .1310  74.2333  265.0130  957
  7979  1.0    64.0  5.0    64.0   67.0   3.9636 228.5676  253.6704   30
  4490  1.0   105.0  5.0   154.5  135.0   1.4300 253.5866  220.9350   80
  6128   .0    50.0 43.0    78.0   25.0   2.7800 112.1266  216.8400   40
  5113  1.0    10.0  9.0     9.5    3.0  21.3500  71.1666  202.8250    5
  6020  1.0  1920.0 30.0  1233.5 1775.0    .1530 199.4610  188.7255  691
  5255  2.0    42.0 25.0    33.0   41.0   4.7000 134.7333  155.1000   20
  2897  2.0    52.0 10.0    44.0   37.0   3.4000  83.8666  149.6000   27
  2063  1.0  1100.0 62.0  1056.0 1598.0    .1398 278.1088  147.6288  669
  5923  1.0  1125.0 21.0   465.5 2169.0    .3140 529.7180  146.1670  296
```

2291	2.0	4250.0	30.0	2854.5	2671.0	.0500	94.0333	142.7250	1840
6226	.0	.0	6.0	9.5	1.0	15.0	135.0000	142.5000	6
10693	1.0	45.0	17.0	42.5	52.0	3.1900	106.3333	135.5750	28
6996	1.0	45.0	22.0	46.5	26.0	2.7500	76.0833	127.8750	31
3897	1.0	9.0	7.0	9.5	12.0	11.7500	144.9166	111.6250	6
9516	1.0	4.5	1.0	1.5	9.0	71.6	405.7333	107.4000	1
91	2.0	2500.0	109.0	2129.0	1620.0	.0465	59.6905	98.9985	1648
5510	1.0	87.5	18.0	127.0	100.0	.6600	72.3800	83.8200	106
7107	1.0	24.5	20.0	31.5	25.0	2.4700	63.3966	77.8050	27
2342	2.0	2500.0	8.0	1544.5	4180.0	.0500	146.0333	77.2250	1354
606	1.0	53.0	11.0	49.5	18.0	1.4200	14.6733	70.2900	45
6649	.0	17.5	15.0	28.5	21.0	2.4200	73.4066	68.9700	26
8445	2.0	136.0	69.0	8 .5	278.0	.8300	197.5400	66.8150	75
3860	3.0	40.0	29.0	38.0	13.0	1.5500	12.9166	58.9000	38
9435	.0	1.5	1.0	1.0	3.0	58.0	174.0000	58.0000	1
7915	3.0	216.0	15.0	14 .0	152.0	.4	38.9333	56.0000	144
6270	2.0	170.0	10.0	155.0	97.0	.3400	20.6266	52.7000	164
7194	1.0	30.0	28.0	3 .5	27.0	1.6400	49.7466	50.0200	33
3823	.0	.0	1.0	3.0	2.0	15.8600	89.8733	47.5800	3
9520	2.0	5.0	2.0	3.0	5.0	15.7500	47.2500	47.2500	3
5358	1.0	6.0	5.0	6.0	10.0	7.6	76.0000	45.6000	6
2099	2.0	157.5	11.0	169.0	82.0	.2640	21.9120	44.6160	194
526	1.0	12.0	15.0	22.5	19.0	1.9700	50.5633	44.3250	26
7780	.0	7.0	7.0	7.0	.0	5.9800	9.9666	41.8600	8
5553	.0	72.0	2.0	84.0	120.0	.4800	42.2400	40.3200	101
4379	.0	680.0	15.0	82 .5	871.0	.0488	40.4552	40.0404	999
6763	1.0	90.0	38.0	11 .5	88.0	.3500	37.6833	38.6750	136
3224	1.0	11.0	28.0	3 .5	19.0	1.2600	44.5200	38.4300	37
8266	1.0	125.0	92.0	161.0	5.0	.2300	10.0433	37.0300	203
7709	.0	20.0	.0	27.5	40.0	1.2660	40.0900	34.8150	35
3196	.0	.0	1.0	42.0	279.0	.8200	274.7000	34.4400	55
932	1.0	225.0	44.0	276.0	327.0	.1200	38.6000	33.1200	369
8468	.0	.0	4.0	108.0	784.0	.2900	254.0400	31.3200	148
8297	1.0	25.0	5.0	21.0	45.0	1.4500	66.7000	30.4500	29
10243	1.0	4.0	2.0	2.5	4.0	12.0	28.0000	30.0000	3
5917	11.0	83.0	11.0	83.0	.0	.3560	.0000	29.5480	117
5268	1.0	17.0	5.0	8.5	28.0	3.4600	59.9733	29.4100	12
8457	.0	50.0	8.0	79.5	98.0	.3600	49.5600	28.6200	114
10052	2.0	65.0	22.0	37.0	41.0	.7300	6.3266	27.0100	54
6805	1.0	25.0	18.0	22.5	43.0	1.2	38.4000	27.0000	33
6438	.0	.0	3.0	3.0	6.0	9.5350	85.8150	28.6050	4
9370	.0	.0	2.0	8.5	35.0	3.0	139.0000	25.5000	12
8554	1.0	67.5	15.0	32.0	128.0	.7400	55.9933	23.6800	50
9727	1.0	70.0	57.0	78.5	72.0	.3	25.4000	23.5500	124
8313	.0	.0	.0	.5	.0	46.5	31.0000	23.2500	0
9786	.0	.0	1.0	3.0	1.0	7.6500	22.9500	22.9500	4
3732	2.0	55.0	17.0	54.5	37.0	.4	15.0666	21.8000	89
8872	.0	6.0	4.0	6.5	18.0	3.3500	70.3500	21.7750	10
6964	.0	3.0	2.0	3.5	6.0	6.2100	45.5400	21.7350	5
1987	.0	500.0	21.0	974.5	860.0	.0220	28.6073	21.4390	1621
8875	.0	2.5	.0	1.5	4.0	14.0	60.6666	21.0000	2
10189	.0	7.5	7.0	1 .5	11.0	2.0	31.3333	21.0000	17
3672	1.0	100.0	13.0	44.0	155.0	.4690	44.2423	20.6360	74

7584	1.0	73.0	34.0	82.5	48.0	.2500	14.3333	20.6250	139
485	.0	6.0	4.0	7.0	.0	3.0	7.0000	21.0000	11
6581	2.0	40.0	21.0	41.0	16.0	.4900	11.2700	20.0900	70
8714	.0	1.0	1.0	2.0	2.0	10.0	26.6666	20.0000	3
10939	.0	.0	1.0	1.0	4.0	19.5800	104.4266	19.5800	1
2467	1.0	18.0	11.0	22.0	16.0	.7800	20.2800	17.1600	40
5384	.0	1.0	1.0	1.0	3.0	16.5	38.5000	16.5000	1
6165	.0	3.0	3.0	6.0	13.0	2.7400	43.8400	16.4400	11
2369	.0	500.0	10.0	1002.0	1080.0	.0160	23.7226	16.0320	1928
6849	1.0	24.5	19.0	25.0	20.0	.6	11.2000	15.0000	49
6166	2.0	20.0	2.0	5.5	53.0	2.7	114.3000	14.8500	10
3585	2.0	.5	1.0	2.0	9.0	7.3500	78.4000	14.7000	4
8278	2.0	4.5	7.0	8.0	5.0	1.8	14.4000	14.4000	16
39	1.0	220.0	8.0	96.5	298.0	.1450	32.0450	13.9925	198
6511	1.0	12.0	3.0	7.5	11.0	1.8	10.2000	13.5000	15
9188	1.0	3.5	1.0	3.5	6.0	3.9	23.4000	13.6500	7
5662	1.0	34.5	9.0	29.5	10.0	.4348	6.2321	12.8266	63
6351	1.0	80.0	6.0	4 .0	160.0	.2900	36.0566	11.6000	90
405	1.0	1050.0	59.0	1167.0	744.0	.0090	10.3920	10.5030	2774
4698	.0	.0	1.0	26.0	182.0	.4036	80.8545	10.4936	61
8774	.0	12.0	9.0	16.0	19.0	.6500	15.6000	10.4000	38
7704	2.0	60.0	40.0	6 .5	19.0	.1700	3.7966	10.2850	145

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A PRELIMINARY INVENTORY STUDY OF A STORES INVENTORY

by

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B. E. (Mech. Engg.), Maharaja Sayajirao University, Baroda, India, 1963

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Industrial Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1967

ABSTRACT

This report is concerned with the preliminary inventory study of the general stores inventory belonging to Kansas State University. The scope of this study covers the overall inventory system with respect to its objectives, organization, procedures and decisions. This study was chosen to see how the theories of Inventory Control interacts with the practice and to what extent they are applicable.

The approach taken in this study is that of System Analysis. There are two parts of the study: the analysis of the operating structure of the inventory control system and the study of some of the inventory decision procedures. It was necessary to collect the past history of items to study some inventory decisions. A sampling technique was used to collect the necessary data. In the first part, flow charts are used to illustrate the existing ordering procedures. This is a system description and has revealed some areas of improvement. It also illustrates how the objective and procedures of the government supported organization can differ from an industrial or business situation. This study would give some insight to the stores personnel, of the use of analytical techniques to inventory problems.