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Discrepancies between Historical Accounting Data and the Theoretical Data Requirements for Economical Order Quantity Application

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DISCREPANCIES BETWEEN HISTORICAL ACCOUNTING DATA AND THE THEORETICAL DATA REQUIREMENTS FOR ECONOMICAL ORDER QUANTITY APPLICATION

by

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The basis for this thesis was conceived over a period of years, while employed in several different occupations. Whether in electronics, heavy industry, light sheet metal operations, etc., a gap always seemed to exist between the lanquage of the accountant and the day to day operating decisions being made in the manufacturing operations. It is hoped that the results of this thesis will draw to the attention of accountants and business managers alike, a better understanding of each other's problems.

Although, the writing of this thesis has taken approximately five years, I am most indebted to those individuals at Western Michigan University who have assisted me in its final draft. My appreciation goes to the members of my committee, Dr. Alan Leader, Mr. William Morris and Mr. James Henricks for the many hours of editing and points of clarification to which they contributed.

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THE PROBLEM AND ITS BACKGROUND

Statement of the Problem

This study will investigate the accuracy of present accounting data as used in a specific business application. The particular business application is the quantative decision technique of economical order quantities. Other methods of accumulating cost information which may better suit the requirements of economical order quantity application will be suggested. A comparison of the results using historical accounting data and theoretically defined data will be made.

Reason for Analyzing the Problem

Many problems are encountered when the business manager attempts to apply historical accounting data to decision making techniques. Comparing the difference in results between the historical accounting data used and the theoretical requirements of economical order quantity calculations, it can be pointed out how changes in the economical order quantity effect production scheduling, machine utilization and inventory control.

Great strides in quantitative analysis of business decisions have been made in the last twenty-five years.[1] The early impetus from the military and the federal government have carried over into private enterprise.[2] Universities offer concentrated curriculums concerned with statistical analysis, operations research, market research and other specialized managerial sciences. Specialized journals and professional associations have been formed and have gained acceptance in the field. Management consultants in "Management Science", "Operations Research", and "Systems Analysis" have instructed business firms in the use of a wide range of modern business management techniques. Although all of these tools are now available to investigate managerial problems on a quantative basis, the results obtained through these techniques are derived from historical accounting data. Although we have had the introduction of entire new fields of management science, no comparable innovation

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[1]Sheele, Evan D., Westerman, William L., Wimmert, Robert J., Principles and Design of Production Control Systems, Englewood Cliffs, New Jersey, Prentice Hall, Inc., 1960 Pp. 109-30. Churchman, West C., Ackoff, Russell L., and Arnoff, Leonard E., Introduction to Operations, New York, New York: John Wiley and Sons, Inc., 1961 Pp. x & 640. Williams, J. D., The Compleat Strategist, New York, New York, McGraw Hill Book Company, 1954 Pp. xiii & 232. Spencer, Milton H., Ph. D., Siegelman, Louis, Ph.D., Managerial Economics, Homewood, Illinois, Richard D. Irwin, Inc., 1959 Pp. xiv & 445. Dooher, M.J., Successful Production Planning and Control, New York, New York: American Management Association, 1955 Pp. 202. Saaty, Thomas L., Mathematical Methods of Operations Research, New York, New York: McGraw Hill Book Company, 1959 Pp. xi & 421. Spurr, William A., Ph.D., Kellogg, Lester S., M. A., and Smith, John H., Ph.D., Business and Economics Statistics, Homewood, Illinois, Richard D. Irwin, Inc., 1955 Pp. xi & 579.

[2]Williams, J.D., The Compleat Strategist, New York, New York, McGraw Hill Book Company, 1954 Pp. xiii & 233.

has taken place in the field of accounting. This study will attempt to partially investigate and establish cost accounting techniques more in line with the theoretical data required to provide management with accurate costing for decision making application.

Specifically, this paper will provide methods for measuring some of the significant costs involved in economical order quantity determination.

Significance of the Study

The expressed purpose of applying economical order quantity theory to manufacturing operations is the maximization of profits through the optimization of the inventory costs and operating costs.[1] The successful application of economical order quantity theory to practical business problems depends on the accurate determination and categorization of the relevant costs. It is expected that an analysis and accurate determination of the cost factors will then provide a basis for other types of decisions to be made in the manufacturing and marketing of a product. These other fields of decision

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[1]Churchman, West C., Ackoff, Russell L., and Arnoff, Leonard E., Introduction to Operations Research, New York, New York: John Wiley and Sons, Inc., 1961 Pp. 199-200. Marks, Lionel S., Mechanical Engineer's Handbook, New York, New York; McGraw Hill Book Company, Inc., 1958 Pp. 17-7, 17-8. Dooher, M. J. Successful Production Planning and Control, New York, New York ; American Management Association, 1955 Pp. 182. Sheele, Evan D., Westerman, William L., Wimmert, Robert J., Principles and Design of Production Control Systems, Englewood Pp. 109-30. Churchman, West C., Ackoff, Russell L., and Arnoff, Leonard E., Introduction to Operations Research, New York, New York: John Wiley and Sons, Inc., 1961 Pp. 199-232. Welsch, Everet W., Tested Scientific Inventory Control, Greenwich, Conn., Management Publishing Corp., 1959 Pp. 57-70. Konn, Harry, "Get Your Money Off the Shelf", Machine and Tool Blue Book, January, 1961 Pp. 74-78.

will not be explained further in this study, but will be discussed briefly in the last chapter entitled, "Implications and Inferences".

Anticipated Results

Upon completion of the analysis of the problem, a comparison of the economical order quantity results using historical accounting data and the new data will be made. The case for using the new data will be established based on the methods by which the new data was obtained. The study will then recommend continuing analysis of other related costs to increase the accuracy of economical order quantity application.

The formula[1] to be used in comparing the economical order quantity results is:

$$q_o = \sqrt{\frac{2}{T}\ \frac{RC_s}{C_1}}$$

A detailed analysis[2] of the formula and assumptions regarding the formula will be presented in Chapter II. A majority of the cost factors to be analyzed are now represented through present accounting methods in the formula factor C_1. These costs in the formula factor C_1 are grouped in the burden rate multiplier. The burden rate multiplier is a current cost accounting technique to prorate other manufacturing expenses based on the amount of direct labor

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[1]Churchman, West C., Ackoff, Russell L., and Arnoff, Leonard E., Introduction to Operations Research, New York, New York: John Wiley & Sons, Inc., 1961 Pp. 203-4.

[2]Formula definitions and explanation on page 12 of this paper.

required to manufacture the product.[1] It is anticipated that a more accurate determination and measurement of these cost factors will considerably affect the resultant economical order quantity. The economical order quantity will be affected because many of the costs now appearing in the denominator C_I factor of the formula as burden rate percentages will be shown to be setup costs as represented by C_s in the numerator of the formula.

Field of Application

Within limitations, the results of this study should be applicable to a wide range of manufacturing operations. It is expected that the method used to establish the new cost data can be further refined and applied to a wide spectrum of cost analysis. Therefore, managers in many different types of corporations should be interested in the focus of this thesis; specifically in the sensitivity of economical order quantity formulations to errors in cost data. These errors arise out of and are inherent in historical accounting systems.

The problem has been stated and its significance given. The next chapter will establish the theoretical foundation for the economical order quantity formula to be used. A brief history of the development and application of economical order quantity theory will be presented as an aid to clarification of the concept. The

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[1]Matz, Adolph, Ph.D., Curry, Othel J., Ph.D., Frank, George W., M.B.A., C.P.A., Cost Accounting, New Rochelle, New York, Southwestern Publishing Company 1954 Pp. 223-8

assumptions underlying economical order quantity theory and its application will be stated explicitly and discussed.

ECONOMICAL ORDER QUANTITY THEORY

This capter of the thesis will establish the definition of economical order quantities, relate briefly the history of economical order quantity theory, establish the formula to be tested and state the assumptions necessary for application of the formula.

Economical order quantity calculations are used in this study for testing the relevance of historical accounting data. The application of economical order quantity theory is applied to manufactured and purchased parts to maximize profitability. In its broadest sense, economical order quantity theory is one of many inventory control techniques.

In analyzing the theory of economical order quantities, it will be recognized that it can be a complicated solution to inventory control. Mathematicians and operations research personnel have spent many years refining the theory and devising practical formulas for different inventory control problems. The formulas are based on certain rational assumptions which will be discussed in this chapter. However, it must be pointed out that the results of the formula-application are no better than the validity of the data applied to the formula.

Definition of Economical Order Quantity

A general definition of economical order quantities is obtaining that quantity of parts which result in the lowest total cost. A more detailed, concise definition would be:

"In general, the greater the quantity of units produced at a time, the lower will be the fixed cost incurred for each unit. The cost of processing the individual order through the planning function and the setup changes for machines are fixed costs and may not vary with the number of units in the order or load; therefore, spreading these costs over the largest possible number of units is desirable. However, while these unit costs are declining while load size increases, others are rising. For instance, the costs of storage and insurance and the carrying charges for capital invested are rising as load size increases. The most economical load size is that point at which the declining cost and the rising cost provide a minimum total unit cost." [1]

There are even more sophisticated definitions of economical quantities.[2,3] The various definitions of economical order quantity basically state that the main problem to be solved is to minimize cost by establishing the correct relationship between the cost of carrying parts in inventory and the cost of producing or purchasing parts. Although the theory was developed over 40 years ago, practical application has not been widely adopted.

History of Economical Order Quantity Theory

Most companies[4] follow either the accountant or production-oriented methods of inventory control. These two methods of

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[1]Marks, Lionel S., Mechanical Engineer's Handbook, New York, New York: McGraw Hill Book Company, Inc., 1958 Pp. 17-7, 17-8.

[2]Churchman, West C., Ackoff, Russell L., and Arnoff, Leonard E., Introduction to Operations Research, New York: John Wiley and Sons, Inc. 1961 Pp. 232-4.

[3]Welch, Everet W., Tested Scientific Inventory Control, Connecticut Management Publishing Corp., 1959 P. 15.

[4]Scheele, Evan D., Wimmert, Robert J., and Westerman, William L., Principles and Design of Production Control Systems, Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1960 Pp. 109-10.

inventory control are pointed out as being in use through 1960, even though economical order quantity formulas were developed in the early 1900's, little progress has been made since the early 1940's. In Principles and Design of Production Control Systems, Scheele, Wimmert and Westerman[1] describe two extreme methods of inventory control.

> "The mathematical determination of the quantity of an item to be ordered at any one time was one of the first subjects of investigation by the pioneers of scientific management. By the early 1900's many formulas had been developed, but until after World War II the application of these formulas was very limited.
>
> The production-oriented solution: 'Produce in very large lots in order to minimize setup and procurement costs.'
>
> The treasurer-, comptroller-, or accountant-oriented solution: 'Produce in very small lots in order to minimize the investment in stock' "

In Alford's[2] Laws of Management Applied to Manufacturing, additional history of economical order quantities is given. Much has been written about economical order quantities. Churchman, Ackoff, and Arnoff[3] list thirty-three texts (not cited elsewhere in this paper) dealing with some phase of economical order quantities. However, in the texts cited, very little if any attempt is made to

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[1]Scheele, Evan D., Wimmert, Robert J., and Westerman, William L., Principles and Design of Production Control Systems, Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1960 Pp. 109-10.

[2]Alford, L.P., Laws of Management Applied to Manufacturing, Ronald Press Company, 1928 P. 225.

[3]Churchman, West C., Ackoff, Russell L., and Arnoff, Leonard E., Introduction to Operations Research, New York: John Wiley and Sons, Inc. 1961 Pp. 232-4.

analyze and measure setup costs, unit costs and inventory costs.

Welch[1] in his book Tested Scientific Inventory Control stated the following:

> "The 'New Approach' to Inventory Control
>
> Today's business magazines are devoting much space, and our management seminars are devoting much time, to this 'new approach' to inventory control. The 'economic order quantity' and the 'statistical reorder point' formulas are being treated as new discoveries in the techniques of management of goods.
>
> The facts are that a few far sighted experts were writing about inventory formulas in such magazines as the Harvard Business Review as far back as 1926. Several companies have been known to have been applying them for as long as twenty-five years.
>
> Yet for some reason, acceptance of the application of formulas is just beginning to come into its own in modern business."

Landy[2] further states that the accuracy of economical order quantities is no better than the cost data used in determining them.

> "Volumes have been written concerning economic quantities, order points, etc., by men more capable than the author; hence, no attempt is going to be made here to influence anyone in the use of economical lot quantity or to explain how to arrive at the quantity in the first place. However, let it be said that the inventory condition of any company will be only as good as the major data upon which decisions are being based plus common sense used by those making the decisions."

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[1] Welch, Everet W., Tested Scientific Inventory Control, Connecticut Management Publishing Corp., 1959 P. 15.

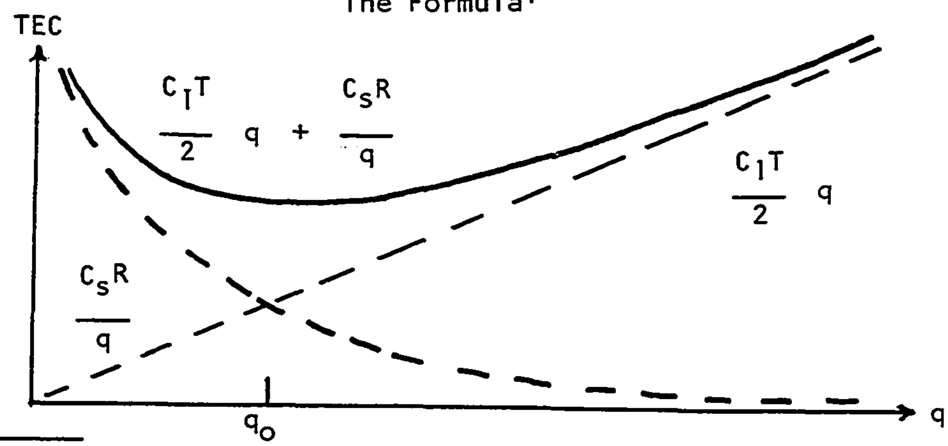
[2] Landy, Thomas M., Production Planning and Control, New York: McGraw-Hill Book Company, Inc., 1950 P. 212.

It appears from the literature and the writer's contacts with others in industrial management that use of economical order quantity theory has not been widely accepted by management. It is the author's opinion that this condition is due to several factors. These factors include management's uncertainty in applying mathematical formulas, ignorance, lack of accurate measurement techniques and proper overhead allocations.

This paper will examine the major cost factors used in economical order quantity application. The analysis will then center on a particular part used in the manufacture of industrial fork lift trucks. It is suggested that comparable analysis could be made of other industries and products with similar results.

It can be seen from the history of economical order quantities that most businesses have not taken advantage of the theory. The formulas themselves have been available for some time. The formula used in this paper is a standard one.

The Formula[1]



[1]Churchman, West C., Ackoff, Russell L., and Arnoff, Leonard E., Introduction to Operations Research, New York: John Wiley and Sons, Inc., 1961 Pp. 201-4.

$$q_o = \sqrt{2 \frac{R}{T} \frac{C_s}{C_1}}$$

On the preceding page is the graph and formula for one type of inventory problem governed by the assumptions on the following pages. Following is a list of symbols used above.

q = Input, or quantity ordered.
q_o = Optimum order quantity.
T = Period for which a policy is being established.
R = Total requirement for period T.
C_1 = Holding cost per unit of goods for a unit of time.
C_s = Setup Cost per production run.

TEC= Total expected relevant cost (In this chapter TEC is sometimes called the total expected cost. Actually, inasmuch as such costs as the price of the item are not affected by the size of run and hence are not included in Models I through VI, we really mean total expected relevant costs.)

Assumptions Used in the Application of the Formula

It should be understood at this point that the formula is a model based on certain assumptions. These assumptions establish a workable model by simplifying actual conditions:

Direct labor and material costs per unit do not appreciably change with small changes in volume production.

Setup costs are fixed regardless of quantity because the method of operation does not change.

The inventory cost factor is a pre-determined, fixed percentage of unit cost for all part numbers. Later in the paper a more accurate method of measuring inventory costs will be described.

The amount of inventory on hand for a particular part is a maximum at the beginning of its inventory period and is zero immediately before replenishment, the depletion occuring at a constant rate. The average amount of inventory on hand over the entire period can be represented by $\frac{q}{2}$ where q is the original lot size.

The first assumption states that direct labor and material cost per unit do not change with small changes in volume. It should then be recognized that the outcome of the formula may cause large changes in volume of product. At this new production level the original direct labor and material cost may be involved. If orders were being run every month for a quantity of ten units each, the tendency would be to use the present material cost and direct labor cost of the part in the formula. The results of the formula might then show that it is more economical to make one run a year of one hundred twenty parts. This, of course, could precipitate a change in method and / or permit the operator to perform at a higher level of efficiency. Also, if special materials were used in the manufacture of the part, the cost of the material might be reduced because of larger volume purchases. This reduction in direct labor and material costs would have no effect on the quantity predicted by the E.O.Q. formula, as long as the economical order quantity recommended a single year's run at one time.

Should the results of the formula show that the parts should be run one time a month, it might then be necessary to re-evaluate the material cost for larger quantities as well as an increase in efficiency so that these costs changes could be introduced into the formula, resulting in a different value for the economical order quantity.

The second assumption states that the setup costs are fixed, regardless of quantity. If a particular part analyzed by E.O.Q. formula showed that it should be run in much higher quantities, it might prove advantageous to investigate a change of method to improve the operation and this, of course, would then affect the setup costs.

The third assumption is that the inventory cost factor is predetermined and a fixed percentage of unit cost for all parts. This is a misleading assumption in the application of economical order quantity theory. (Inventory investment cost and certain taxes are directly related to the unit cost of the part stored in inventory.) The other costs which make up the inventory cost factor are related to such things as the weight, size and obsolescence factor of the particular part. The inventory cost factor analysis will be stated in much more detail in a later portion of this paper.

The fourth and last major assumption is the basis for choosing the particular economical order quantity formula shown on Page 12. This economical order quantity formula was developed on the basis of a constant rate of decline of the inventory on hand for a particular part number. This means that any part number to be used with this formula should basically be of maximum quantity when placed in inventory and withdrawn from inventory for use on a regular basis, and normally the quantity usage does not vary. When the usage of a part varies over a short period and is withdrawn from stock at random intervals, other economical order quantity formulas[1] should be used.

Regardless of the particular economical order quantity formula, the same problem of measuring the cost factors exists. As stated earlier, the formulas are usually based on historical accounting data which could generate incorrect economical order quantities because historical accounting data is used in the formula calculations. In the next chapter of this thesis, historical accounting practices will be summarized. It will be shown how these accounting practices are used to arrive at the dollar value of the cost factors in the economical order quantity formula. The chapter will then discuss the problems encountered in using historical accounting data.

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[1]Churchman, West. C., Ackoff, Russell L., and Arnoff, Leonard E., Introduction to Operations Research, New York: John Wiley and Sons, Inc., 1961 Pp. 205-34.

PURPOSE OF MEASURING THE COST FACTORS

> "Let it be said that the inventory condition of any company will be only as good as the major data on which decisions are being based plus common sense used by those making the decisions." [1]

Having economical order quantity formulas available did not necessarily mean that practical inventory solutions could be reached.[2] Accurate costs must be used in the formulas. There are at least three historical accounting methods by which costs are accumulated for use in economical order quantity formulas. Two of these methods are given extensive treatment in the text, "Cost Accounting".[3]

Matz refers to a quotation by Theordore Lang[4] to describe an actual cost system as "a cost system, which records and summarizes costs as they occur, and which determines costs only after manufacturing operations have been performed or services rendered." Matz goes on to explain that, even though actual costs of material and labor were used, the overhead or burden was applied on some fixed

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[1]Landy, Thomas M., Production Planning and Control. New York McGraw-Hill Book Co., Inc., 1950 P. 212.

[2]ibid.

[3]Matz, Adolph, Ph. D., Curry, Othel J., Ph. D., Frank, George W., M.B.A., C.P.A., Cost Accounting. New Rochelle, New York: Southwestern Publishing Company, 1954 Pp. 33-5.

[4]Lang, Theodore (Ed.), Cost Accountants' Handbook. New York, New York: The Ronald Press Co., 1947 P. 210. As reported in Matz.

rate basis; thus showing that even the "actual cost system" doesn't live up to its name.

Matz[1] then begins to explain the standard cost system which is widely used in this country today. In a standard cost system all costs are pre-determined in advance of production. Accounts are designed to collect actual costs and the difference between actual costs and standard costs are collected in separate accounts termed variances.

The third accepted accounting method is known as direct costing. Direct costing is not a widely accepted technique in the United States at the present time. The differences between the standard costs absorption technique and direct costing are well expressed in an article "Direct Costing to the Rescue" in Business Week magazine in March of 1962. The essential argument presented for direct costing is repeated here:

> "The Widgitronics plant is operating at a pre-determined 'normal' or standard rate. But this assumption doesn't hold up in practice. The result was that in January, when production was high and sales low, the company showed a 'profit'; in February, when conditions were reversed, there was a 'loss'."[2]

The article goes on to state that the figures given by the

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[1]Matz, Adolph, Ph. D., Curry, Othel J., Ph. D., Frank, George W., M.B.A., C.P.A., Cost Accounting. New Rochelle, New York: South-Western Publishing Company, 1954 Pp. X-800.

[2]Business Week, "Direct Costing to the Rescue." Finance Dept., New York, New York: McGraw-Hill Publishing Company, (Bell, Elliott V. Ed.), March, 1962, Pp. 45-8.

standard absorption costing technique didn't make sense to anyone trying to control costs. The figures were then reappraised under direct costing rules. The direct costing rules as stated were "only costs directly associated with production went into the value of the inventory. The overhead, rather than being allocated to the product lines, was simply charged to the monthly profit and loss statement." The results in comparing the two systems reversed the profit and loss portions of the two months being compared.

Any of the three aforementioned account methods is acceptable in the field of accounting.[1] For the purpose of this study, the standard cost absorption method represents present accounting practices, and in this study will be referred to as historical accounting.

Historical Accounting Practices

There are many variations of the standard cost system. For the purposes of this study, the variation used will be that of the Clark Equipment Company. Machine setup cost is treated as another segment of direct labor. The main elements of this standard cost system are direct material, direct labor, machine setup and overhead costs. This system is only concerned with the manufacturing costs and does not consider selling expense or general administrative expenses. The overhead costs are the manufacturing expenses and represent one

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[1]The direct cost method is not accepted by the Federal Government for income tax purposes and the American Institute of Certified Public Accounts does not consider it acceptable for public documents. Therefore, direct costing is not widely used.

portion of the chart of accounts.[1] The chart of accounts of the manufacturing expenses are the cost factors to be analyzed, consisting of forty-eight major cost factors (excluding direct labor, direct material and machine setup).

Except for direct labor, machine setup and material, the other cost factors are treated as overhead by the accounting department.

To compute an overhead rate based on direct labor dollars, the accounting department[2] establishes an overhead rate for each direct labor department. The overhead rate for the machining department is not necessarily the overhead rate for the welding department. Not only does each direct labor department have different manufacturing expenses for setup, materials handling, lighting, supplies, etc., but each direct labor department uses a different percentage of assistance from the general service departments. The general service departments are cost accounting, engineering, purchasing, industrial engineering, etc.

Some manufacturing expenses are collected by the accounting department through the use of special charge numbers. The charge number refers to the direct labor department in which the manufacturing expense occurred. For example, the charge number 78965 might

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[1]Matz, Adolph, Ph. D., Curry, Othel J., Ph. D., Frank, George W., M.B.A., C.P.A., Cost Accounting. New Rochelle, New York: South-Western Publishing Company, 1954 Pp. 31-2.

[2]Clark, E., Overhead Rates, 1960 & 1961 Distribution of Overhead Rates, Cost Accounting Department. Battle Creek, Michigan: Clark Equipment Company, 1961, P. 1.

be reported to the accounting department showing five hours of setup cost to an order in the machine shop, department 603.

Some expenses, such as heat, light, power, etc., are prorated as costs to direct labor departments by the departmental floor area in square feet compared to the total plant floor space. Other general service department expenses are allocated in still a different manner. Appendix I illustrates the method of allocating general service department expenses.

Once a year the cost accounting department sends to each department manager the illustration shown in Appendix I. This form lists all of the direct labor departments. The managers are requested to list, by percentage, the total amount of their general service department's budget which was expended for each of the direct labor departments listed. The grand total of all these percentages must equal one-hundred percent of each general service department's budget.

Calculation of the total overhead rate for a direct labor department consists of totaling the manufacturing expenses by charge number, the prorated expenses of heat, light, power, etc., and the allocated costs of the general service departments for that particular direct labor department. The total of these expenses divided by the total direct labor dollars expended by the direct labor department for that fiscal year equals the overhead percentage for that direct labor department. This percentage becomes the overhead rate for the new fiscal year until the rate is readjusted at the end of the year.

Many problems are encountered in using this present standard cost accounting data.

The Problems Encountered in Using Present Accounting Data

The problems in using present standard cost accounting data are related directly to the economical order quantity formula

$$q_o = \sqrt{2 \frac{R}{T} \frac{C_s}{C_1}}$$

The first problem arises in establishing the dollar cost of the factor C_s in the formula. C_s represents the setup cost per production run and the standard cost method only establishes the setup costs for the machining operations. Under the standard cost method the overhead costs are broken into three categories. The first category is variable costs, the second is fixed costs, and the third category is the costs which are partly fixed and partly variable. These terms are defined in Cost Accounting by Matz, Curry and Frank.[1] Variable expenses are directly proportional to volume and normally are those costs directly under the control of the production foreman. Fixed costs do not vary in direct proportion to volume and are generally assigned to the operating periods. Fixed cost responsibility largely rests with the top executives. Variable costs are fully absorbed in the production cost of the period;

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[1] Matz, Adolph, Ph.D., Curry, Othel J., Ph. D., Frank, George W., M.B.A., C.P.A. Cost Accounting. New Rochelle, New York: South-Western Publishing Company, 1954 Pp. 227-38.

whereas fixed costs may or may not be absorbed during the operating period.

Some expenses are semi-variable in nature. For example, one foreman may be sufficient to supervise the work of a department up to a certain level of production; whereas a second foreman may be added at some specific interval. However, the increase or decrease in this kind of expense is not in direct proportion to volume.

In examining the 48 cost factors[1] which make up the overhead expense category, it should be recognized that such groups as production planning, purchasing and receiving, standards, inspection, shop clerks, etc., are semi-variable. A portion of their costs must be considered setup costs. The basis for this is due to the purchasing policy where the frequency of reorder is closely tied to the frequency of production runs. Similar arguments can be made for the other factors listed. Whether these costs are placed in the C_s category or the C_1 category will make a difference in the solution generated by the economical order quantity formula. If these costs are placed in the C_s category, the size of the economical order quantity will increase. The standard cost method treats these costs as a percentage of direct labor in the C_1 portion of the economical order quantity of the formula. Increasing the C_1 factor decreases the economical order quantity size. The C_1 factor in the formula

[1]Factors established by Clark Equipment Company in their particular variation of a standard cost system.

represents the holding cost per unit of goods for a unit of time. In the standard cost system, the holding costs (inventory costs) are represented by a percentage of direct labor, material and overhead. It is suggested that the major problem outlined in this chapter is the exclusion of some relevant costs in the historical accounting definition of setup costs and inventory carrying costs.

The next chapter will further examine methods for measuring overhead cost factors and will analyze discrepancies between the method used in the standard cost system and these other methods to be recommended. The standard cost method will be referred to as historical and the proposed methods will yield the theoretical data required for improved economical order quantity formula application.

DISCREPANCIES BETWEEN HISTORICAL AND THEORETICAL ACCOUNTING DATA

The previous chapter examined the standard cost method as an historical accounting practice. It is also noted that standard cost is one of the few accounting methods acceptable to the federal government for inventory evaluation. Will the standard cost method provide the theoretical accounting data required for economical order quantity application?

As the theoretical accounting data requirements for economical order quantity are analyzed, it may be necessary to not only maintain the standard cost system, but to provide supplementary cost data.

Forty-eight major cost factors were isolated in the Industrial Truck Division of Clark Equipment Company. These forty-eight cost factors are:

A. Setup, inspection, tabulating (in part), shop clerks.

B. Labor, material.

C. Physical inventory.

D. Foremen, vacation and holiday, downtime, union activity, employee's welfare, workmen's compensation, social security.

E. Freight.

F. Rework and repair, defective and spoilage, scrap and recovery, warranty.

G. Supplies, power, depreciation, heat, others, miscellaneous, taxes, repairs and maintenance, plant protection.

H. Die, jig and fixture.

I. Development costs.

J. Engineering, tool design.

K. Interplant transportation.

L. Materials storing, inplant transportation garage, supplies storing.

M. Timekeeping.

N. Personnel

O. Production planning.

P. Purchasing, receiving.

Q. Tabulating (remainder).

R. Cost accounting.

S. Mettallurgy

T. Cost estimating.

U. Standards.

V. Plant administration

W. Shipping.

In the present accounting system, no distinction is made between fixed and variable overhead costs and setup costs. All these costs are treated as a percentage of direct labor dollars.

Calculation of the "K" inventory cost factor for use in the economical order quantity formula is very difficult. The initial method suggested, the one currently in use by Clark Equipment Company may be one of the least desirable. In the recommendations to follow, a more accurate method will be outlined. All in-process inventories are presently accumulated in one account. This means that there is no inventory segregation of purchased parts, in-plant manufactured parts, assemblies or sub-assemblies. Thus, based on available accounting information,[1] the accuracy of calculating the inventory cost factor for in-plant manufactured parts is subject to considerable error.

Inventory factor "K"	$
Obsolescence	151,281.00
Inventory charges Allowances reported during the year Year in count Design changes Valuation reduction Deterioration	41,150.00
Other (taxes)	63,000.00
Cost of borrowing money (6% of average inventory)	351,000.00
Total Inventory Costs	$ 606,431.00

$$"K" = \frac{\text{Cost of Carrying Inventory Per Year}}{\text{Average Inventory Evaluation}}$$

Therefore, "K" = $606,431.00/ $5,852,000.00 = approximately 10%.

All of the items attributable to the cost of carrying inventory are listed above under <u>inventory factor "K"</u>. The Industrial Truck Division of Clark Equipment Company accumulates all of these accounts into four basic accounts which are: Obsolescence, year in count, others (such as taxes), and cost of borrowing money.

The Industrial Truck Division average inventory evaluation at

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[1] __________, General Ledger Accounts, Industrial Truck Division, Clark Equipment Company, Battle Creek, Michigan, 1962.

any time during the year was some $5,852,000.00 of which approximately $1,200,000.00 represents parts manufactured in the plant. Dividing the inventory costs by the average inventory evaluation for the entire year gives an average "K" to apply in the formula.

The inventory cost factor[1] is an average cost of carrying the inventory applied to all parts. This cost factor averages together raw materials inventory, in-process inventory costs, and finished goods inventory costs. Because of the company's account accumulation techniques, it is not now possible to break out these charges against individual part numbers for obsolescence, deterioration, and allowances reported during the year.

At some future date with a change in the accounting system to allocate these charges against specific part numbers, it will be possible to apply a variable "K" factor against individual part numbers when applying the economical order quantity theory. This in turn would give much better accuracy to the application of the E.O.Q. formula. Although accounting records show the inventory cost factor as being 10%, the corporation uses a factor of 24%. Twenty-four percent is the most typical carrying cost figure used by industry.[2] It is not known how individual companies derive their carrying costs, Clark's method may be suggestive of typical thinking.

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[1]Van DeMark, R.L., Now a 'Hidden Control for Hidden Costs'. Reprint from Purchasing News, February 1959, distributed by Van DeMark, P.O. Box 44, St. Clair, Michigan Pp. 1-4.

[2]ibid.

As the E.O.Q. theory is proven in manufacturing there will be a tendency on the part of accounting to make more and more direct allocations to specific part numbers which will alleviate these averaging techniques from the E.O.Q. formula application.

One reason for wanting to increase the inventory cost factor from 10% to 24% is a fallacy in thinking on the part of the representation of the inventory cost factor. It is felt that rather than utilizing 6% as the cost of borrowing money, a factor should be used which represents corporate profit on sales dollars as the factor for the corporation. It then can be seen that the difference between 10% and 24% is 14% additional increase in inventory cost factor established by the corporation. By adding that 6% already allowed for borrowing money to the 14%, a profit markup of 20% has been added to the inventory cost factor.

The fallacy in using a profit markup as part of the percentage in penalizing the cost of carrying inventory is that simply turning the inventory into cash and devoting it to business expansion is no assurance that the market will be there for the increased volume of manufacturing. In actuality, simply the employment of capital to expand business means very little unless the order rate can keep pace with production expansion. The corporation likewise can usually borrow money for expansion at 6%. There is no reason to penalize the average inventory cost factor for the additional 14%. However, for the present we are using this additional 14% in our economical order quantity formulation because of the stated corporate policy.

Areas of Conflict Between Historical and Theoretical Requirements

In the company's accounting system, no distinction is made between fixed and variable overhead costs and setup costs. All these costs are treated as a percentage of direct labor dollars. As the analysis proceeds, overhead costs will be distinquished from setup costs.

In order to develop measurements which will more accurately satisfy the theoretical requirements of economical order quantity application, certain techniques must be employed for measuring cost factors. The techniques employed for measuring the cost factors are:

A. Time Study.
   1. Direct labor hours.
   2. Machine setup hours.

B. Wage Rates.
   1. Direct labor employees.
   2. Overhead personnel.
   3. Administrative personnel.

C. Calculating Fringe Benefits.
   1. Insurance.
   2. Social Security.
   3. Retirement.

D. Ratio-Delay Studies.
   1. Materials handling costs.
   2. Route sheet order cost.
   3. Inspection.
   4. Number of operations per route sheet.

E. Individual Part Number Cost Measurement By. I.B.M. Routine.
   1. Setup.
   2. Materials handling.
   3. Labor, material and overhead.

F. Develop Formulas Based on Repetitive Constants and Variable Data.
   1. Routine sheet order cost.
   2. Setup cost.
   3. Materials handling cost.
   4. Inspection.
   5. Labor, material and overhead.

G. Systems Paperwork Flow Analysis to Prorate Costs of Overhead.
   1. Cost accounting.
   2. Purchase order cost.
   3. Receiving inspection routine.
   4. Order processing.

H. Cost Accounting Prorated Figures for Some Overhead Expenses.
   1. Annual report of overhead cost allocated against direct labor.
   2. Periodic adjustments.

I. Model Simulation to Simplify Complex Inter-Relationships.
   1. Inventory cost factor "K".
   2. Economical order quantity formula.
   3. Materials handling costs.

J. Pragmatic Solutions Recommending Continued Analysis.
   1. Overhead accounts.
   2. Recommendations for other uses of conclusions set forth in this paper.

Hypothesis

It is hypothesized that a comparison of results obtained for economical order quantity using historical accounting data, with the results from use of the new accounting data will show a significant difference.

The newly calculated factors will yield:

1. Difference in economical order quantities.
2. Difference in numbers of orders to be run per year.

3. Different total inventory cost per year.

In the next chapter, a calculation of economical order quantity will be made for a manufactured part using present accounting data. Calculations for proposed new accounting data will be presented and the new data will be used in the economical order formula: The comparison of the two results will provide the test of the hypothesis.

RESEARCH PROCEDURES

An economical order quantity will be calculated for a particular part using the present standard cost data. The total cost per year will be calculated using standard cost data. New cost data will then be generated and the economical order quantity and total annual cost will be recalculated. The results from the present and proposed data will be compared.

Calculation of Current Economical Order Quantity

The following calculations are used to determine the economical order quantity according to the formula (page 12), using standard cost accounting data[1] for part number 1303072:

A.	Material cost per piece 9¢ x 1.28 lbs.	$ 0.115
B.	Overhead rate[2]	594%
C.	Standard labor cost	0.035
D.	C1, inventory cost factor x unit cost	0.0072
E.	Inventory cost factor[3]/month	2%
F.	Unit cost[4], A + (CxB) + C	0.36

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[1]Clark Equipment Company (Industrial Truck Division), "Standard Cost Calculations." I.B.M. Print-out of 1964-65.

[2]Calculated as a % of direct labor.

[3]See page (27) of this thesis for derivation.

[4]Matz, Adolph, Curry, Othel J., Frank, George W. Cost Accounting. New Rochelle, New York: South-Western Publishing Company 1954 Pp. 223-38.

G.	Setup cost, C_s @ \$3.00/hr.	\$ 6.00
H.	R, Monthly usage	50 units
I.	T, time period	1 month

The setup hours, number of operations, direct labor cost, etc., are given on the route sheet and tool sheet.[1]

$$q_o = \sqrt{2\,\frac{R}{T}\,\frac{C_s}{C_1}} = \sqrt{\frac{2 \times 50 \times 6}{1 \times .0072}} = 285 \text{ pieces}$$

$$\text{Number of Runs per Year} = \frac{R \times 12}{q_o} = \frac{50 \times 12}{285} = 2.11$$

$$\text{Number of Months Supply} = \frac{12 \text{ months}}{\text{No. of runs}} = 5.6$$

Total Yearly Cost = NO. RUNS (Set up + unit cost + inventory cost)

$$\text{Where Inventory Cost}^{2} = \text{Inventory Cost Factor} \times \left(\text{No. of Months Supply} \middle/ 2 \right) \times \text{unit cost}$$

Inventory Cost = 2% x (5.6/2) x 285 pcs. x \$0.36 = \$ 5.75

Total Yearly Cost = 2.11 (\$6 setup + 285 pcs. x \$0.36 + \$5.75) = \$240

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[1]See Appendix II.

[2]Churchman, West C., Ackoff, Russell L., and Arnoff, Leonard E., Introduction to Operations Research. New York: John Wiley and Sons, Inc., 1961 P. 203.

Calculation of New Accounting Data

Of the forty-eight cost factors listed on pages 24 and 25 of this paper, more than one fits the definition given on page 12 for "C_s" setup charges. An analysis of those costs which are segregated into "C_s" setup charges, unit costs, and inventory costs follows.

Analysis of Term "C_s", Setup Costs

Setup costs are not just the costs of preparing the machinery used to produce the part, or even the cost of producing the paperwork for processing the parts through the shop. Setup cost (as used here) is a broad term referring to all costs occurring during the design, paper processing, administration, machine operation, materials handling, assembly, storage, and even the shipping stage of production, which can be considered semi-variable costs regardless of quantity. These costs are partially dependent on the frequency of runs.

Some of the setup costs for the machining departments of the Industrial Truck Division of Clark Equipment Company will be given. Not all of the setup costs which are incurred wil be individually considered. Many of the setup costs are still lumped into overhead costs simply because attention has not been directed, nor time has not allowed for analyzing these costs on an individual part number basis. Present allocations erroneously places these costs in the unit cost factor of the economical order quantity formula, as a percentage of direct labor. The result is to incorrectly enlarge the unit cost factor which is part of the denominator in the formula. By enlarging the denominator, the result of each economical order quantity determination is understated. As logical means of measuring these other setup costs are devised they will be included in the setup cost portion of the formula and omitted from the unit cost factor.

It must be recognized that in referring to "setup cost" the setup costs will be accurate within reasonable limits based upon the mode of transportation, the level of engineering excellence, methods, ingenuity of tooling, etc. To be certain that the new economical order qunatity is conservative, and because as explained, a system for collecting some types of charges by model or part number is lacking, setup costs will include only machine setup, materials handling, order processing costs, and certain selected general expense costs.

Later in this paper will appear a summary of all unanalyzed direct and general expenses and in that portion of the thesis will be explained the other costs which have been left in the unit cost category. Following is an analysis of the measurable setup costs:

A. Setup hours costs:

Total setup hours on a machine shop order route sheet for an individual part number multiplied by \$3.30 + 28% benefits...................... = Hrs. x \$4.22.

The \$3.30 represents the average hourly setup wage of the shop employees. The 28% benefits represents the cost of hidden benefits such as retirement fund, cost of living allowance, etc. This portion of the setup cost is easily established. The setup hours on the route sheet and tool sheet[1] were taken by time study, and are simply multiplied by hourly costs of making the setup. The setup cost here is based on standard hours, rather than actual hours. If greater accuracy closer to the actual hours is necessary, this forula can be modified by the efficiency factors of the operators performing the setup task, because their time is punched into I. B. M. cards from the operators' individual time cards.

B. Materials handling costs:

Industrial engineering studies[2] show approximately .3 hours for moves between operations in the same department, and .5 hours for moves between departments. The tabulating department has punched cards containing the number of operations per part number on the route sheets and tool sheets. A formula can be developed to compute these costs. Computer equipment can be used to count the number of departments from punched card information. The material moves between departments and can also be calculated from punched card information.

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[1]See Appendix II.

[2]Hampton, D. J., Clark Equipment Company Earned Hour Control Report Program and Affiliated Ratio Delay Studies of 1959-1960. Industrial Engineering Department, Battle Creek, Michigan.

Because every part manufactured per the instructions on the route sheet must be brought out of stock and put back into stock after processing the order through the shop, there is a fixed charge allowed for stockroom moves. However, a portion of this fixed charge is absorbed because the computer is programmed to count the departments and changes in department numbers rather than moves between departments. This makes a difference of one in counting the number of moves. Since the number of moves counted is one more than actually occurs, the number of operations counted absorbs .3 of an hour for the last move of the half-hour it takes going into stock.

Let N = Number of operations excluding to and from stockroom.

C = Number of departmental changes excluding to and from stockroom.

.7 = Allowance for stockroom moves. (.3 hours already absorbed by the method of counting N.)

Materials Handling = (.3N + .2C) x labor rate + .7 x labor rate.
" " = (.3N + .2C) \$3.34 + \$2.33.

The formula just shown states the cost of transporting material between departments and between operations in the processing of material throughout the shop. In the case of materials handling costs, actual rather than standards are used, since the operator's efficiency is not calculated against any material handling move standards. It is recognized that the time allowance for the moves between operations is excessive, but it is the actual amount of time being taken by the truckers, either in idle time or in actual move time.

Direct labor employees are on incentive and normally operate at or above one hundred percent of standard. In a ratio delay study performed by the industrial engineering department, it was found that materials handling efficiency was somewhat below fifty percent. Until such time as this is corrected, the materials handling costs should be calculated as stated above.

The greatest portion of time taken up in the materials handling moves (recognizing that all of the material is moved on Clark lift trucks, regardless of size) is used in positioning, picking up and releasing the material. Because of travel time cost, one other significant variable is the distance between operator work stations in the move sequence.

More accuracy may be desired in this portion of the setup cost formula. With some effort, a variable can be developed by assigning distances between operations into the computer program. Next, a variable for truck speeds could be established based on optimum conditions of accelerations achieved over varying lengths of distance. There is so much more that needs to be done in measuring other cost factors not yet analyzed, that this would seem to be a refinement which could be done very much later in the analysis of the economical order quantity formula.

In Appendix III can be found the actual summary of costs related to the route sheet and tool sheet order processing costs. These costs were measured by Mr. John R. Dean of the Clark Manufacturing Engineering Department.

C. Order processing costs:

Route sheet costs = \$4.31 (See enclosed analysis by J. R. Dean)

The order processing cost is the cost of actually processing the form which carries the operation sequence through the scheduling department, material stores, and the shop operations themselves.

D. General expenses directly relating to the number of orders processed, other than route sheet costs, which can be ascertained at this time are inspection costs, key punch operators cost, and shop clerks cost.

The average number of orders processed per month in the machining division is 3,293. Historical data was used to arrive at the number of orders processed because this is the initial installation of the economical order quantity formula on the computer. In the future applications the cost of the number of orders processed can vary from month to month and be divisible into these general expenses, based on the approximate orders which would be generated through the economical order quantity formula on a trial and error basis.

Expenses/Month	(Ave. Cost/Month Supplied by Accounting)[1]
Inspection	\$ 10,889.00
Tab Operators	650.00
Shop Clerks	1,559.00
Total.................	\$ 13,098.00/ 3,293 orders
	\$4.10/ order

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[1]Clark, E., Overhead Rates, 1960 & 1961 Distribution of Overhead Rates, General Service Division Distribution, Battle Creek, Michigan: Clark Equipment Company, Cost Accounting Department, 1961, P. 1.

The cost of the inspectors operating in the machining division is $10,889.00 a month. The inspectors devote 90% of their time to inspecting the initial setup of each order being run in the shop. Only a small percentage of their time is spent actually inspecting parts outside of the first piece run on the setup standard. Therefore, the inspection cost is a fixed charge per order regardless of the quantity involved and fluctuates basically with the number of orders processed in the shop per month.

The $650.00 a month cost for the tabulating operators is based on the amount of time two tabulating operators devote to key punching the time clock information turned in by the direct labor employees. The amount of time spent by the tabulating operators in this instance is based on the number of orders processed per day recorded by each direct labor operator. Therefore, regardless of the quantity of pieces involved, it is the number of orders which generates the cost of these particular tabulating operators.

The $1,559.00 expense for the shop clerks represents a charge paid by the company in order to keep track of the orders in the machine shop. The shop clerks' prime responsibility is in moving the orders from department to department, and keeping track of these orders, regardless of quantity. Therefore, it has been possible to arrive at a cost of these three general expense items and relate these costs back to each part number and into the setup costs in the economical order quantity formula.

Should inspection standards be established for inspecting the setup of each part number, based on the work involved in setting up these machines and checking dimensions of the part, it would be possible to directly relate each inspection cost to its particular part number. For the present, the total inspection costs are averaged over all part numbers without regard to individual variations in the amounts of inspection.

The machine setup costs, materials handling costs, the order processing costs, and the general expenses directly related to the number of orders processed has been discussed. These comprise the costs which have been analyzed in arriving at the new setup charges used per part number in the economical order quantity formula.

Here is a summary of the setup cost formula for machine setup, materials handling, order processing costs, and certain general expense costs:

Setup Costs	=	Machine Setup Costs + Materials Handling Costs + Order Costs + Expenses
Setup Costs	=	Setup Hrs. x \$4.22 + (3N + .2C) \$3.34 + \$2.33 + \$4.31 + \$4.10
Total Setup	=	Setup Hrs. x \$4.22 + (.3N + .2C) \$3.34 + \$10.74

RECALCULATING ECONOMICAL ORDER QUANTITY USING NEW DATA

$$q_o = \sqrt{2 \frac{R}{T} \frac{C_s}{C_I}}$$

Where:

R, monthly usage	=	50 units
C_s [setup hours x \$4.22+(.3N+.2C) \$3.34+\$10.74]	=	\$19.18 + (.3N+.2C) x \$3.34
N (number of operations excluding to and from stockroom)[1]	=	3
C (number of departmental changes excluding to and from stockroom)[2]	=	2
T, time period	=	1 month
C_I, inventory cost factor x unit cost	=	\$0.0072

Therefore:

$$q_o = \sqrt{\frac{2 \times 50 \times \ 2\times4.22 + (.3\times3 + .2\times2)\ \$3.34 + \$10.74}{1 \times .0072}} = 572 \text{ pieces}$$

$$\text{Number of runs per year} = \frac{R\times12}{q_o} = \frac{50\times12}{572} = \text{approx. } 1$$

$$\text{Number of months supply} = \frac{12 \text{ months}}{\text{Number of runs}} = 12$$

Total yearly cost = number of runs (setup + unit cost + inventory cost)

$$\text{Total yearly cost} = 1 \left[\$23.50 + 600\text{pcs.}\times\$0.36 \text{ (see page 33)} + \frac{600\times\$0.36\times24\%}{2}\right]$$

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[1] See route sheet and tool sheet Appendix II.

[2] ibid.

Current Economical Order Quantity Results Compared
to Proposed Economical Order Quantity

Current Quantity	=	285 Units, a 5.6 months supply
Calculated Annual Cost	=	$240
Number of Runs per Year	=	2.11
Proposed Quantity	=	572
Calculated Annual Cost	=	$263
Number of Runs per Year	=	1

In the next chapter, these findings will be evaluated and the validity of the hypothesis determined. Testing the hypothesis requires a comparison be drawn between the results of the present and proposed cost techniques. Conclusions will be drawn from the comparison.

CONCLUSIONS AND RECOMMENDATIONS

In Chapter V "Research Procedures", the newly developed data indicated a significantly different result in economical order quantity calculation. It is the magnitude of these differences that is important. The magnitude of differences indicates that measuring and separating setup costs by part number gives significantly different results, as compared to standard cost information. The calculated difference in annual costs, however, requires an explanation. A dilemma appears to be present.

The calculated annual cost of the present method was lower than the annual cost of the proposed method. The result would seem to indicate that the present method is the best. Certainly the present method would be best if the calculation and basic data were correct. The data experimentally assembled to calculate the proposed economical order quantity, however, highlights the lack of validity of the presently used basic data.

A. The standard cost overhead percentage of 594% is calculated in the following manner:

The total expenses and fixed costs allocated to a particular department are divided by the total direct labor of the department. Yet over 2,500 parts a month are produced in varying quantities from one to tens of thousands per part. The average overhead may be 594%, but the actual overhead for a particular part, because of quantity, shape, machining characteristics, etc., could be almost any percentage of direct labor, since no direct relationship can be demonstrated between direct labor and most overhead expenses.

1. Machine setup is not a function of the direct labor utilized in the production of a particular manufactured part.

2. Engineering costs are not a function of the direct labor utilized in the production of a particular manufactured part.

3. Trucking costs are not a function of direct labor utilized in the production of a particular manufactured part.

In fact, it would be very difficult to represent any of the 48 cost factors as a percentage of direct labor in the production of a particular manufactured part.

B. The more pieces of a part produced at one time, the more total overhead costs the part number absorbs according to the standard cost method. Of course, some costs do increase proportionately but not many. Setup, engineering, order entry, purchasing, industrial engineering, are some of the costs which do not increase proportionately.

C. The standard cost system projects overhead rates on past performance and reflects an overall cost based on past history. These cost percentages are then applied to individual parts based on direct labor. The overhead costs are allocated to individual parts by this gross averaging method. Decisions must be made affecting individual part numbers, assemblies, and products on the basis of this averaging technique when no other method is available.

<u>Conclusions</u>:

It was hypothesized in Chapter IV that differences in results would occur in the economical order quantity when the new data was applied, specifically:

1. A difference in economical order quantities.
2. A difference in number of orders to be run per year.
3. A different total inventory cost per year.

The calculations in Chapter V indicate a significant change in the economical order quantity, the number of runs per year, and the total inventory cost per year. The results of the calculations confirm the correctness of the hypothesis. The following conclusions are drawn from the findings in this study, for the example chosen:

1. Historical accounting data does not permit accurate use of economical order quantity theory.
    a. Optimal economical order quantity may be invalid.
    b. Calculated annual cost may be incorrect.
    c. Optimal number of production runs per year may be invalid.
2. Continuous review of cost factors is required.
3. Plant loading, manpower requirements, and financial expectations are significantly different using historical as compared to more theoretically accurate data.

It was demonstrated that the average methods used in the standard cost system gave significantly different results than more accurate cost analysis techniques. It is felt by the writer and asserted on the basis of his qualitative observations that the new cost data does in fact yield more valid conclusions.

Methods for continuously analyzing the cost factors will be suggested. It should be remembered that only the more obvious set-up costs were analyzed and that further analysis of other cost factors were recommended on a cost benefit basis.

The third conclusion is that plant loading and manpower requirements using the two sets of data differ significantly. The example used in Chapter V was only one of thousands of parts produced each month in the manufacturing departments of the company studied. Furthermore, the newly developed economical order quantity data indicated that a greater quantity of units would be produced in a given month, but a smaller variety of parts would be manufactured during the month. A proper analysis of the change in manpower requirements could best be accomplished through the use of specifically calculated data through a simulation study. If the direction of change is consistent between parts, then fewer total orders would be produced of a large quantity per order. Plant loading would require fewer setup personnel, materials handlers, and inspectors.

Recommended Methods of Measuring Other Cost Factors

A recommended outline of methods to more accurately measure other costs follows. Some of these costs will be analyzed individually, others will be grouped into categories. The first category is listed below. Some dollar amount of the costs, in the group below should be placed into the setup portion of the equation. The remainder of costs stays in the unit cost portion of the equation.

- Foremen
- Vacations and Holiday
- Downtime
- Union Activity
- Employee Welfare
- Workmen's Compensation
- Social Security

Standard cost methods totally apportion these costs to direct labor because these costs are incurred by the direct labor operators located in the plant.

The effort put out by the direct labor operator, however, is not only absorbed in producing parts but a certain amount of the direct labor operator's time involves setup. Increasing the number of units produced at any one time would decrease the number of setups, provided the total volume of parts produced in one year remain constant. The beginning inventories would increase but the total number of setups would decrease, therefore, in a large manufacturing operation a total reduction in setup man hours would reduce the fringe benefit costs required.

Freight

Freight costs can be related to specific parts received in a given period. These costs can be applied to purchased parts. presently, freight is reported as a percentage of direct labor. Another group of costs can be directly related to specific parts and shown as an increased unit cost. This group is:

- Rework and Repair
- Defective and Spoilage
- Scrap and Recovery
- Warranty (Customer)

For increased accuracy, these costs should be charged directly to the specific parts on which the rework and repair occurred. A per-unit cost could be compiled by dividing the costs allocated to the various parts by the quantity of each part built over a given period of time and summing for each part number.

This cost information would have additional value. Certain parts have very high rework and repair, and / or scrap and recovery costs because of the technical nature of the parts. Those parts incurring an unusually high amount of these costs could be analyzed for possible engineering changes and redesign. The same type of cost distribution should be made for the warranty account.

As a result of analyzing costs in this manner, we begin to get more and more accurate data on expenditures and ways to reduce them. Applying these costs as they actually occur, reduces the unfair burden of overhead placed on some parts. Much more analysis is required to measure and understand the reasons for fluctuations in overhead cost categories. All overhead cost cannot validly be represented as a percentage of direct labor expense, since all overhead accounts do not vary in direct proportion to direct labor. This problem of correct analysis has been noted by other investigators. A typical comment is the following by Stanley B. Henrici:[1,2]

> "....to summarize, the correct method for setting indirect-labor standards is to determine by means of time studies, inspector records, production records, and materials-consumption records just how much indirect labor is required for a P.S.H. on each operation. This determination really boils down to answering the questions: What does this indirect labor do? How long should be required to do it?"

Another group of costs are those costs that can be readily measured as a function of machine running time. This group consists of the following:

- Supplies
- Power
- Depreciation
- Taxes
- Repairs and Maintenance

These costs should be charged to the machinery on which the parts are made. The charges to the machines can then be pro-rated back to the parts which were produced on the machines. These costs would definitely be the most difficult to analyze. The method recommended would probably only slightly improve the accuracy over a basic average overhead allocation across all parts. The final group of costs do not lend themselves to a single method of handling, and

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[1]Henrici, Stanley B., Standard Costs for Manufacturing. New York, N. Y.: McGraw-Hill Book Company, Inc., 1953, P. 80.

[2]P.S.H. As used by Henrici means Production Standard Hour of Labor.

will be considered individually. This group consists of the following costs:

. Dies, Jigs, and Fixture Costs
. Development Costs
. Engineering and Tool Design Costs
. Interplant Transportation
. Material Storing and Material Transportation
. Timekeeping
. Personnel
. Production Planning
. Purchasing and Receiving
. Tabulating
. Accounting
. Metallurgy
. Standards
. Plant Administration

The costs of dies, jigs, and fixtures should be accumulated against the specific parts for which tooling costs occur. These costs would be divisible by the number of units produced per part over an agreed upon depreciation period. It is illogical to apply overhead burden rates for tooling to all parts even though they do not have any die, jig, and fixture costs.

Development costs are fixed cost recoverable over a period of time. Development costs should be charged to specific parts, subassemblies, and models. Based on the amount of development costs occuring, a depreciation period should be established and the volume of parts or models built over this period should carry the depreciation charge.

Interplant transportation cost should be applied similarly to the freight costs discussed previously.

The costs of engineering and tool design can be analyzed by part number or model; similar to the development category discussed above. In the allotment of costs directly to the part such as engineering, tooling, development, warranty, defective and spoilage, the costs should be allocated to purchased parts as well as parts manufactured by in-plant direct labor. In this manner, an analysis of overhead costs caused by purchasing parts can be made.

Costs should be properly attributed to purchased as well as manufactured parts. The costs of material storing and material transportation should be allocated to parts which are purchased as well as manufactured, since both are stored and transported. It would be relatively simple to let the industrial engineering department make ratio delay studies of these costs and apply them directly to the relevant parts. The cost of counting would be a function of quantity. The cost of handling would be a function of distance and number of moves. This method would eliminate much inaccuracy occurring when these costs are applied as a percentage of direct labor. It is the physical size, number of moves, and quantity of a particular part number which determines its material transportation and storage costs.

Timekeeping is an expense having several cost components. Three major parameters will be considered. These parameters are:

- The number of indirect personnel reporting time to the timekeepers
- The number of direct labor personnel reporting time to the timekeepers.
- The number of orders processed in the plant over a period of time

A brief, once-a-year sampling analysis of the time cards would measure the costs allocated to other indirect departments. These costs could be determined by a series of charge numbers filled out by the employee on the back of the time card referring to the department for which a service was performed. A percentage of timekeeper costs can be found that represents the share that is related to the number of direct employees in the plant. A fixed charge per order and part can also be established by sampling analysis.

The personnel cost category should be analyzed according to the number of people in the indirect categories utilizing the personnel services. The indirect categories can then be applied based on the number of personnel in each, and applied to the particular department which employs these personnel. Other personnel costs which are based on the number of direct labor personnel should be applied as a percentage of direct labor and setup.

Production planning costs should be analyzed by sampling the work of every individual in the department. Costs could then be charged to the accounts to which the effort applies. Much of this cost would go against the number of orders processed in the shop, and therefore, become a setup cost per part. The number of units ordered does not significantly affect the effort put out by the people in the production planning group.

The purchasing and receiving cost categories can be analyzed in much the same manner as the route sheet cost. These costs have been calculated as recorded in the enclosed analysis by J.R. Dean.[1] Purchasing and receiving costs should be treated as part of the material setup cost for a production order and divisible by quantity.

The tabulating and the accounting costs can be determined based on the amount of time personnel expends in such activities as indirect labor, direct labor, number of orders, number of invoices, and upkeep of the cost system. Some costs would be distributed as overhead percentages of direct labor, while other costs would be prorated to departments based on the amount of indirect labor. Some of the costs would be setup charges which apply to invoice processing, order processing, and industrial engineering standards.

Metallurgy costs could be handled through a direct charge system by reporting all metallurgical investigations against specific part numbers or models. These charges would increase the unit cost factor in the economical order quantity equation.

Standard costs could be analyzed as basically a fixed charge per part number for establishing standards. A more accurate method would be to provide time study personnel with daily labor distribution cards,

[1]Appendix III

recording time spent per part number. These costs would be treated as a setup cost over a fixed number of parts.

Plant administration costs could be allocated to those departments (areas) where most of administration effort is concentrated. A ratio-delay study could determine the percentage of allocation.

Even though four or five accounts have been analyzed and measured in Chapter V, there remain the many costs just discussed which are still applied as an overhead percentage of direct labor. By studying the techniques recommended for measuring these costs, it can be seen how some costs are fixed costs divisible by quantity of the part number produced. In recognizing these peculiarities of our overhead expenses, it should become a matter of good management to establish more accurate overhead allocations.

The end result of this investigation can be:

- Improved systems to easily collect the cost data accurately.
- Cost reduction through a more specific understanding of which parts are creating the additional costs.
- More accurate economical order quantities manufactured within the plant and purchased from outside vendors.

Once an organization begins to analyze its costs in the prescribed manner, overhead ceases to be a vague term. Many hidden costs once allocated on the basis of direct labor become prime areas for cost reduction and management control. Every day all production facilities not taking advantage of the important aspects of economical order quantity principles are making serious mistakes in the future planning of their organizations. Improper cost reporting results in poor management decisions.

IMPLICATIONS & INFERENCES

The value from application of economical order quantity theory is the resulting increase of net profits. Once cost data has been collected as suggested in the previous chapters to meet the requirement of economical order quantity theory, several additional benefits can be expected. This chapter presents some of the expected results of having better cost data available.

Accuracy of Economical Order Quantity Solution Improves as the Measurement of the Cost Factors Improves

A variety of cost analysis techniques have been demonstrated and recommended. The purpose of these measuring techniques was to establish a more accurate allocation of overhead costs to a product or part. Different methods were required to accurately distribute costs to a particular product or part. The application of these methods is a management decision.

It must in every instance, be determined when the optimum benefit from this analysis is reached. Optimum value has been reached when further analysis becomes as costly as the benefits reaped. In the majority of the accounts yet to be examined, the amount of work necessary to measure these costs as recommended is not an exceptionally tedious task. Special techniques such as work sampling can be utilized over a short period of time, and the results can be reevaluated as relevant changes are known to occur.

Disadvantage of Economical Order Quantity System

It would be inaccurate and misleading if the disadvantages of an economical order quantity system were not pointed out. From the analysis of the critical factors analyzed in the preceding chapters, four major disadvantages stand out.

A. Although there is a factor for engineering obsolescence in the inventory carrying costs, when carrying larger inventories resulting from economical order quantity calculations, the cost of obsolescence can rise.

B. Accounting costs may increase due to more detailed accounting information being necessary. These additional accounting costs will, of course, be offset by peripheral benefits in other (control) areas. These increased accounting costs will also be offset by the availability of information for better decision making in other areas.

C. Although it is not a hard and fast rule, very little individual judgement should be used in altering calculated economical order quantity requests. Production control clerks who would normally be provided with simple techniques for recalculating economical order quantities are not in a position to judge whether the quantity calculated is irrational. When a production control clerk questions the results of the economical order quantity calculation, the clerk should not arbitrarily make his own judgement as to what the quantity should be. However, the question should be brought to the attention of the production control manager. If the production control clerks are permitted to arbitrarily let individual judgement of the quantity required, be substituted for the calculated economical order quantities, the system will no longer be valid. When there is a choice to be made, in the long run it would be better to accept the calculations rather than to rely on subjective intuitive judgement of a production control clerk.

D. If the economical order quantity theory is not properly applied, greater amounts of corporate cash are needed to maintain stock levels. It is easy to permit a technique such as economical order quantity theory to become part of a bureaucratic procedure. Bureaucracy is difficult to change once it has been established. When excessively large amounts of capital are employed in change over to economical order quantity methods, confidence in the system lessens. The cost benefits from the application of economical order quantity are not easily seen, but any shortcomings, real or imagined, are readily identified with the technique.

E. One problem which must be recognized in applying economical order quantity theory is discontinuous cost relationships. If some of the relevant cost functions show a stepwise progression it becomes important to consider the relevant range over which the cost data is valid. A typical example is the cost of foremen supervising direct labor. The number of foremen need not be increased (nor necessarily decreased) except as direct labor changes over a wide range.

When properly applied, in conjunction with modern methods of machine loading and material handling, economical order quantities can reduce the cost of inventories. The volume of parts in stock may increase, but at the same time indirect expenses attributed to processing these parts per unit may decrease. The reduced expenses can offset, or even be greater than, the added material and labor costs of the increased volume of parts. Because of the uncertainties of engineering obsolescence, storage, and sales fluctuations, a practical policy is to limit the economical order quantity of a single part to twelve months.

Advantages of Economical Order Quantity Usage

The many gains from economical order quantity formulation are contingent upon successfully determining the relevant costs. Management must be prepared to eliminate and / or increase certain costs (personnel, equipment, inventories) to increase profitability through application of the economical order quantity theory.

A good approach towards reducing costs is a computer simulation of the effects of economical order quantities for all relevant manufactured and purchased parts. A sales forecast could be used as the basis of monthly requirements. Once the economical order quantities have been established for each part, the number of orders to be processed per month in the production departments or placed with vendors can be compared to expectations from the present system.

When the economical order quantity is calculated for each part (recalculation is necessary when demand changes) and the total number of orders per month is known, the expected total inventory cost can be calculated. Comparing cost reductions in the setup costs, and the possible decrease in the number of orders processed through the production departments to the inventory carrying costs, minimization of total net costs can be approached.

When, because of a change in usage, it is necessary to recalculate a part's economical order quantity, this re-evaluation can be performed either manually or with the computer. It is not difficult to perform the calculations manually, using nomographs as calculating tools. Management can effect the cost reduction recommended through the change in number of orders processed. The change in number of orders, reduces the total of setup, materials handling, and order processing costs.

Example:

> If the simulation study shows a reduction from 4000 orders a month to 2000 orders a month, then this represents a 50% reduction in orders.
>
> If the number of machine shop inspectors was 15 originally, the number should be cut

approximately 50%[1], say from 15 to 9, thus providing for a margin of error.

A similar reduction should then occur in many categories of setup costs. Overall cost reduction cannot be accomplished one part at a time. A complete system, including thousands of parts, must be analyzed as a whole to take advantage of group cost reductions and reassignment of work effort.

Other Areas Where The Recommended Cost Measurements Can Be Applied

Another reason for analyzing the costs of manufactured parts is to establish the following questions in the minds of management personnel:

A. If the economics of doing business as presented in this research analysis of manufactured parts is profitable, how is this profitability accomplished?

B. Can these same analysis principles be applied in other areas of the business?

C. Are costs accurately measured for properly determining our short and long range profitability goals?

D. Are budgets realistic and how can they be improved?

E. Do managers presently understand the inter-relationships of all cost factors? If managers do not understand these inter-relationships what courses of action can be taken?

F. How are the conflicts between short and long range profitability goals resolved?

A brief comment is in order about those areas were improved

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[1]Review page 40.

cost measurement can assist management in arriving at workable solutions for the questions asked. These suggestions are based on insight gained during the pursuit of this study.

The additional profitability in question A can be achieved by the application of an economical order quantity system using the cost measurements outlined in this paper. Before installation of such an economical order quantity system, a computer simulation study (depending on the volume of parts and sophistication of the cost data developed) or some alternative sampling procedure to test the theory should be performed.

The same cost measurement techniques tested in Chapter V and recommended in Chapter VI can be applied to other business decisions as inferred by question B. Examples of these business areas are given in answers to questions C and D.

Question C referring to short and long range profitability goals, and question F pertaining to conflicts between short and long range goals, can be resolved by having accurate cost information. The manager can better evaluate the short and long range profitability goals, and can also select the more profitable solution when the goals conflict. Short range goals and long range goals often conflict, and accurate cost information is necessary to properly evaluate the effects of both these planning goals.

Without accurate cost information it is difficult for budgets to be realistic as indicated by question D. Budgets can be better evaluated after analyzing overhead costs to understand when and why personnel are required. Present budgets are usually based on the profit budgeted from forecasted sales dollars and sales volume. Yet many costs are based on the number of orders, number of models, number of vendor orders placed, as well as the number of parts produced. As stated in the analysis, orders, models, quantity of parts, etc., are not directly proportional to sales dollars and sales volume.

It is doubtful as asked in question E that most managers presently understand the complexity of measuring most cost factors. All cost factors should be explained to managers after accounting personnel have reached agreement on the various measuring techniques established in Chapters V and VI. The managers should then work as individuals and as team members to reduce costs through simplified systems and elimination of unnecessary overhead.

Question F infers that conflicts in short and long range goals should be resolved. Conflicts between short and long range profit goals are not only difficult to resolve, but many times managers do not realize that these goals can be conflicting.

Example:

> On accepting one special order from a customer there is no additional cost to manufacturing except labor and material, unless a company is operating at absolute peak capacity. Normally, there are adequate personnel in engineering, accounting, production control, personnel, etc., etc., to process this one extra order.
>
> It could be argued for various business reasons that the order should be accepted and priced out with normal standard cost overhead rates. It could even be shown that the overhead charges were actually profits, since no additional personnel are required and idle time would occur if the order were not accepted.

> The decision to accept the order would then be a decision based on a short term goal of utilizing excess capacity. However, if many orders were accepted over the same period of time, eventually more personnel would be added to overhead in excess of the cost charged to the customers.

Thus, the short range goal of increased profits would not be compatible with the long range results of increased costs. If managers understand the cost relationships they will be better prepared to choose between and implement short and long range objectives.

There are many types of conflicts in business decision making where long and short range profit goals are in direct conflict. These will not be discussed individually. However, a list of major categories is offered for use as a guide.

1. "Make or buy" decisions.
2. New model costs.
3. Government contract bidding.
4. Special order pricing.
5. Stanard cost burden application.
6. Direct cost burden application.

In proposing the type of cost analysis suggested in this thesis, an accountant's first reaction would be to point out the excessive cost of obtaining, analyzing, and reporting the data. In reality, once this type of cost analysis is demanded by management, there are many short cuts which can be taken toward collecting, evaluating, and reporting the findings. Many years have been spent reducing the cost of direct labor through the addition of more sophisticated machinery and automation, but the cost of all of the overhead factors creeps upward continuously. Management should attempt to analyze as many expenses as possible as direct labor or setup costs, since all necessary expenditures in a corporation contribute to the design, manufacture, distribution, and sale of the product.

APPENDIX I
ALLOCATION OF EXPENSE FOR
1963 - 64 STANDARDS

%	%		NO. OF DIRECT LABOR PEOPLE AS OF 4/30/63
		600 Industrial Truck Division	
		602 Welding Department	41
		603 Machine Dept.	88
		604 Upright Machining & Welding Dept.	26
		605 Cutting Department	27
		606 Tilt & Lift Cylinder & Valve Dept.	9
		607 Sub Assembly Dept.	18
		608 Heavy Assembly Dept.	20
		609 Modification Dept.	53
		611 Paint Dept.	24
		612 Carrier Assmy. Dept.	2
		613 Light Assmy. Dept.	18
		614 Motor Assmy. Dept.	13
		615 Upright Assmy. Dept.	8
		616 Burr Dept.	25
		617 Shear & Form Dept.	9
		618 Heavy Aux. Assmy. Dept.	12
		621 POW Assmy. Dept.	4
		622 Attachment Mach. Dept.	89
		623 Attachment Assmy. Dept.	49
		625 Reach Truck Assmy. Dept.	7
		626 Carrier Fab. Dept.	10
		Total 600 Division	552
		630 Tool Manufacturing Div.	
		640 Maint. & Repair Div.	
		666 Central Development Div.	
		667 Service Engr. Div.	
		669 Tech. Service Div.	
		155 Export	
		153 Sales	
		Branch Accounting	
		Grand Total	

0270R Rev. 10-58 Route Sheet & Tool Sheet
Date 4-19-63

CLARK EQUIPMENT COMPANY
INDUSTRIAL TRUCK DIVISION
BATTLE CREEK, MICHIGAN

Page 1 of 1 Part No. 1303072
Rev. No. 2

Part Name Block Side Plate Retainer

Material Location____	Used on Assy.NC-50-60-70	Reord.____	Planner	Coverage	Last Change No.	Qty. Ordered	Date Required

Description of Material
1 x 1 3/4 HRS. 1.24#

Attachment Parts List

	Oper. No.	Description of operation	Tools & Fixtures	Dept. No.	Mach. Code No.	Rated S.U. Set Up	Rated S.U. Tear Down	Date of Rate	Exp. Prod. Per Hr.	Pay Std.	Cost Std.
Same Station Count 1 oper	010	Saw to length. Pt 643324 (4 Bar Load)		605	068	.5		3-9-64	264.	.0038	.0038
	1010	Saw to length. Pt 643324 (2 Bar Load)		605	068	.5		3-9-64	213	.0047	.0038
Same Station Count 1 oper.	020	Drill, chamfer & Tap (1) 1/2-13 hole. Chamfer			132	.5		3-20-64	89.3	.0112	.0112
	1020	Drill, chamfer & tap (1) 1/2-13 hole		603				(Full Count, 1/2 Time)			
	2020	Drill, chamfer & Tap (1) 1/2-13 hole		603	132	.5		3-20-64	47.9	..0209	.0112
	030	Burr.		612	077	-0-		Est.			.0050
	Del.	to Area-K.									

Change No. 1-Note added & Rate entered on oper. 010. Alt. oper. 1010 added & Rate entered (3/10/64)
Change No. 2-Oper. 1020 added to oper. 010. Rate Entered. Alt. oper. 2020 added & Rate entered (3/23/64)

OPERATIONS, METHODS, TOOLS & EQUIPMENT NOT TO BE CHANGED UNLESS PROPERLY CLEARED THROUGH INDUSTRIAL ENGINEERING.

Appr. by Ind.Eng.Dept. W.Y. Tool Eng. R.R. Dept. Supt. ________

APPENDIX II

APPENDIX III
ROUTE SHEET COST

SUPPLIES

PAPER,white,850,000 sheets,1700 reams @ 1.29	$ 2193.00
DITTO MASTERS,10,000 @ 60.514M	605.14
FLUID,100 gal. @ 1.70 gal.	170.00
FORM C-358, 25,000 @ 301.82 per 20M	452.73
PAPER, yellow, 100 reams @ 1.29	129.00
MOVE TICKETS, 70,000 @ 11.68 per M	817.60
CARBON PAPER, 1,000 @ 4.75 per C	475.00
CORRECTION TAPE, 10 @ .45 roll	4.50
NINE MONTH TOTAL	$ 4846.97

$\frac{4846.97}{9} = \frac{538.55}{3293}$ per month Per Order / Ave. per month $.163541

LABOR

MACHINE SHOP SCHEDULERS, nine	$ 4800.00
CLERKS, in shop Dept. five @ 400.00 Mo.	2000.00
STOCK HANDLERS, 603 Stock,nine @ 450.00 Mo.	4050.00
STOCK HANDLERS,Main Stock,three @ 450.00 Mo.	1350.00
	$12200.00

$\frac{12,200.00}{3293} = 3.70482$ per order $3.70482

OFFICE LABOR

INDUSTRIAL ENG., one and 3/4 Typists	@250.00	$ 437.50
COST DEPT. one and 1/4 Clerks	@275.00	375.00
TABULATING DEPT., Two Clerks	@336.00	672.00
		$ 1484.50

$\frac{1484.50}{3293} = .44776$ $ .44776

MATERIAL HANDLING

One Route Sheet average five operation, three dept. 2.6 x 2.50
$ 6.50

<u>OR</u>

Actual at 100% efficiency 1.7248 x 2.50 $ 4.312

AVERAGE ORDERS PER MONTH - 3293

TOTAL COST PER ORDER W/O MATERIAL HANDLING	$ 4.31612
TOTAL COST PER ORDER W/MATERIAL HANDLING	$10.81612
TOTAL COST PER ORDER W/M.H. Efficiency-100%	$ 8.62812

J. R. Dean
Mfg. Eng.
10-1-60

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