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## Survey of Techniques Used by Small Manufacturing Businesses to Implement Production Control

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SURVEY OF TECHNIQUES USED BY SMALL  
MANUFACTURING BUSINESSES TO IMPLEMENT PRODUCTION CONTROL

BY

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B.S.E.E., University of Michigan, 1960

RESEARCH REPORT

Submitted in partial fulfillment of the requirements  
for the degree of Master of Science in Engineering  
Industrial Engineering in the Graduate Studies  
Program of the College of Engineering  
of Florida Technological University

Orlando, Florida

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## CHAPTER 1

### Introduction

An overwhelming number of all business enterprises in America are classified in the small business category. In fact, of all business concerns in the United States, only 0.1 percent of all manufacturing industries are in the large category, employing more than 2,500 people (6). Eighty nine percent employ less than 100 people. The Small Business Administration classifies a business as small when it has 250 employees or less. Hence, if one considers businesses of up to 500 employees, this would include approximately 98 percent of all business concerns now operating. This encompasses about 25 to 30 percent of the total labor force and therefore has a considerable impact on the nation's economy.

Many problems face the small business entrepreneur. Of particular concern are the lack of adequate finances and poor business management, statistically the major causes of business failures (6). However, inadequate business or operations methods also take their toll in the business world. Of course, this falls under the general heading of business management, but specifically, this can be categorized under production management for a manufacturing concern. Production management deals with the task of combining labor, machinery and raw materials in an organized fashion such as to produce

a finished product within a regular scheduled time frame. This report touches on all these aspects as they are related to production scheduling, inventory control and forecasting. Future trends are projected by forecasting which supplies the feed back information to adjust the manufacturer's production scheduling and material inventory levels. How a small manufacturing business approaches these tasks may well determine its survival. Generally, this segment of the business community does not have the formal academic tools required for the more sophisticated controls.

### 1.1 Purpose

The purpose of this report is to survey and analyze some of the present methods used in handling production scheduling, inventory control and forecasting future needs by small manufacturing companies. In general, the guide lines used to established that a company is in the small business category are those specified by the Small Business Administration. In the case of the manufacturing and service companies, a business is considered small if it has 250 employees or less. In considering this survey, this range has been extended to include those companies having up to 500 employees.

### 1.2 Scope

The scope of this report includes a summary of the traditional methods of (job shop) scheduling, inventory controls, and forecasting. An informal interview was arranged with three companies (after contacting several) to determine what types of systems are actually in use.

Since it did not seem practical or feasible to obtain a large enough sample by this means, a mailed questionnaire was also sent to approximately 40 companies. The results were tabulated and analyzed. Additional information pertinent to small business operation were compiled and summarized briefly.

## CHAPTER 2

### Question Survey

Considering the operating practices referred to in chapter 1.0, a questionnaire on scheduling, inventory control and forecasting was developed which was presented to approximately 40 small businesses in order to analyze the small business approach to these areas of business concern. The questionnaire was sectioned into four categories as follows:

- I. Questions 1 - 5: Specific data on the company and its operations
- II. Questions 6- 11: Questions relating to forecasting
- III. Questions 12-21: Questions relating to inventory control
- IV. Questions 22-23: Questions relating to scheduling

#### 2.1 Questionnaire Analysis of Category I

Based on the responses in Category I of the questionnaire, a profile of the average business surveyed would be:

- o A business with an median labor force of 26

to 100 employees. (see Table 2-1)

- o A business having an median yearly gross sales of a little over \$1,000,000/yr. (see Table 2-2)
  
- o A business having been in operation between 10 and 15 years.

In general, the responses indicated that the product line was almost an even mix between custom and proprietary products (for each business). However, a few respondents (30 percent) indicated custom type products only. There was very little indication of any seasonal or cyclical variations of business. Approximately half of the questionnaires were sent to electronics - oriented companies and the remainder covering a range of other product lines. The returns were 90 percent from electronic - related companies, and 10 percent from the remainder (a box manufacturing company). Two questionnaires were returned unopened - the companies were no longer in business. One of these was in the clothing manufacturing business (listed employees of 50). The other was in some metal forming type of business. The high response from electronics related companies was either a coincidence, or electronics-oriented people have a higher appreciation for educational efforts. Table 2-3 lists the principle products of the businesses surveyed.



Tables 2-1 through 2-3 were derived from the answers given to questions in Category I of the survey.

TABLE 2-1 LABOR FORCE

NUMBER OF EMPLOYEES	PERCENTAGE OF COMPANIES WITH EACH EMPLOYMENT LEVEL
8-25	30
26-100	40
101-250	30
250 +	0

TABLE 2-2 GROSS SALES/YR

SALES - \$	PERCENTAGE OF COMPANIES WITH EACH SALES LEVEL
Less than \$100,000 -	0
\$100,000 - \$250,000	20
\$250,001 - \$1,000,000	30
\$1,000,001 - \$ \$5,000,000	40
Greater than \$5,000,000	10

TABLE 2-3 PRINCIPLE PRODUCTS

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PRODUCTS	NUMBER OF COMPANIES INVOLVED
Computers	1
Government Electronics	2
Electronic Sub-systems	2
Airport Radio Equipment	1
Shipping Containers	1
Printed Circuit Boards	2
Laser Equipment	1
Total	<u>10</u>

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## CHAPTER 3

### FORECASTING

This chapter relates to forecasting as practiced by the small manufacturing business. Six questions were directed to this area of business endeavor. Prior to tabulating the results of this section of the questionnaire, a summary of the standard forecasting methods is given.

Tabulation of the resultant answers show that no true formal methods of forecasting were practiced. Most forecasting was of limited nature. The last section of this chapter summarizes these results.

#### 3.1 Forecasting - Standard Methods

The basic application for forecasting on projections is that of gross sales (2). This can be made in terms of yearly, monthly or weekly periods. If any type of advanced planning is considered, a market or sales projection is essential. Based on a sales forecast (or product demand anticipation), one can then plan an inventory policy and inventory levels to be maintained, labor force to acquire, finances to arrange for, product distribution methods, machines and plant capacity to invest in, plus many more factors to consider in order to plot a profitable future course for the business operation.

Various types of forecasting are used, depending on the size and service area of the company. Basically there are three main methods used. They are:

- 1) Committee or single person forecasts (based on the judgment of experienced individuals)
- 2) Market survey
- 3) Mathematical methods (of which two are predominant).
  - A) Time Series Analysis (analyzing historical data to determine underlying sales trends)
  - B) Correlation Analysis (projections based on correlation to other data which has an effect on the forecast being analyzed)

Establishing sales goals and forecasting sales are not necessarily related, though the former may be realistically derived from the latter. In the book Small Plant Management (5), a rule of thumb is:

- 1) First year sales forecast goal: net sales = net asset investment (or capitol).
- 2) Second and third year sales forecast goal: net sales should at least = net asset investment.
- 3) Succeeding years sales forecast goals: based on ratio of small plant sales to total sales of similar product in its marketing area.

Forecasting is often based on information derived

from demand and supply condition studies which can be obtained from published studies prepared by the United States Department of Commerce. The expected demand of a specific product then can be correlated to the percentage of the market a certain company expects to acquire, hence giving an indication of a rising, steady or falling trend for the future period (usually a year). This would be a Market Survey method of obtaining the necessary information.

Forecasting is usually categorized into three time-spans. They are:

- 1) Immediate future forecast:
  - for current operational information.
- 2) Medium range forecasts covering a period anywhere from 6 months to a maximum of 5 years:
  - provides information for production capacity adjustment.
- 3) Long range forecasts covering periods of five years and more:
  - provides information for major company decisions such as plant and warehouse locations, etc.

The latter categories depend on:

- 1) The regional or national economy
- 2) Technological developments, etc.
- 3) Consumer preferences, trends, etc.

In the job shop type of production situation, the immediate future forecasts have a bearing on the economic order quantity required for inventories, the 'lot' sizes of production runs, and production scheduling in general.

Since usually the job shop operation does not carry a finished goods inventory, these forecasts will affect the labor skills and equipment which must be available over the period.

Mathematical methods of forecasting can become very complex and are often computerized. Basically they consist of analyzing past sales data to determine if certain trends exist. By projecting or extrapolating this trend line, one can accurately estimate what the future sales will be for a given period. The initial step in this procedure is to tabulate a past history of sales per period. Next, one makes a graphic plot of sales versus time. Trends may become apparent. Cyclical and random variations can be smoothed out by using a moving average technique. Basically, this is accomplished as shown in Table 3-1, where:

The three month total is given on the mid line of the months, as: 3 month total = 1520, the total sales of Mar. (380), Apr. (675) and May (465). The three month moving average is the total divided by three, and  $\Delta$  is the difference in these averages. To obtain the forecasted sales for the next month (Jan.) the procedure is as follows:

Forecast sales (Jan.) = sales (Dec.) + (the algebraic average of the summed delta (  $\Delta$  ) values). Thus, Jan. sales = 680 + 8 = 688

TABLE 3-1 Computation of a moving average data trend for smoothing out cyclical and random variations.

MONTH	SALES	3 MONTH TOTAL	3 MONTH MOVING AVERAGE	$\Delta$
Jan.	461	---	---	---
Feb.	524	1365	455	---
Mar.	380	1579	526	71
Apr.	675	1520	506	-20
May	465	1658	553	47
June	518	1367	456	-97
July	384	1570	523	67
Aug.	668	1524	508	-15
Sept.	472	1670	557	49
Oct.	530	1374	458	-99
Nov.	372	1582	527	69
Dec.	680	---	---	---
Jan.	---	---	---	---

To derive a trend curve which gives more emphasis to recent data, the Exponentially Weighted Moving Average can be used (1). The equation for forecasting succeeding months is:

$$\bar{F}_t = \alpha D_t + (1 - \alpha) (\bar{F}_t - 1) \quad (3-1)$$

Where:

$\alpha$  = a fraction between 0 and 1 (usually 0.01 to 0.3).

$D_t$  = the actual current demand, and  
 $\frac{D_t}{F_t} - 1$  = the last average forecast demand  
 for the current period.

More exacting equations can be derived which will 'fit' the curve (trend line) by use of the more advanced mathematical methods. The general polynomial equation to describe this curve is:

$$\hat{Y}(t) = a + b t + c t^2 + g t^{n-1} + h t^n \quad (3-2)$$

for an nth - order polynomial, where  $\hat{Y}(t)$  is the estimated value of Y (t) at time period t and a, b, . . . ., h are fitted coefficients of the polynomial.

The mathematical methods of obtaining this equation are:

- 1) Method of difference fit.
- 2) Least Squares Regression Analysis.
- 3) Exponential Smoothing (an extension of Exponential Weighting.)

Correlation analysis utilizes these tools, but correlates one trend to another which influences the first, for example, in relationship of glass sales to building starts in the construction industry.

Though forecasting can be an essential part of business procedure, it can never be an exact one. Projected values are all hypothetical; however, they are better than none at all, since they represent a goal to



work towards for planning purposes. Many small businesses do little, if any, forecasting. In times of a continual upward trend in the economic climate, the effect was not too adverse. When a troubled economy emerges (as it had), those few which did rely on forecasting to adjust their production and expenses ahead of the times were more likely to survive.

### 3.2 Tabulation of Questionnaire Results Relating to Forecasting.

Six questions were asked in the general area of forecasting. The response to the first question, whether the company engaged in any type of forecasting, was:

- 60% (6) Answered that they did not.
- 40% (4) Answered that they had.

As shown, the majority of the small firms made no attempt at forecasting, either as to sales, inventory or production scheduling. This, perhaps, is a contributing factor to the problem of not being prepared for a sudden change in business conditions.

The second question asked was: are your forecasts primarily of a short or medium term nature? That is, do they project six months ahead or are they longer ranged to, perhaps, two years in the future? The responses showed that:

- 40% (4) Indicated forecast were short term only.
- 60% (6) Indicated medium term.

Various methods of forecasting are utilized. Most of these are not rigidly formulized. Table 3-2 lists the results of the question: What method of forecasting do you primarily use?

TABLE 3-2 Primary methods of forecasting used.

FORECASTING TYPES	PERCENTAGE OF BUSINESSES USING
Committee Agreement	20
Market Survey	40
Time Series Analysis	20
Correlation Analysis	10
other	10

To determine what faith these entrepreneurs had in their own forecasts and what general accuracy figures they would ascribe to them, the question was asked: How accurate do you rate your forecast? Table 3-3 tabulates these results.

TABLE 3-3 Short and medium term accuracy of forecasts  
versus percentage of those judging these accuracy ranges.

ACCURACY RANGES IN PERCENT	PERCENTAGE WHO ESTIMATED THEIR FORECASTS FELL WITHIN THIS BRACKET	
	<u>SHORT TERM</u>	<u>MEDIUM TERM</u>
0-10	40	30
11-25	10	20
26-50	20	30
51-75	10	20
76-100	10	0

The last question in this category related to the factors which influenced forecasts the most significantly. Table 3-4 compiles the responses to this question.

TABLE 3-4 Factors which influenced forecasted projections vs. percentage of those who considered each the most influential.

INFLUENCING FACTOR	PERCENT WHO TERMED EACH PRIMARY
Supplies salesman	10
Trade Magazine Predictions	20
Customers Projections	40
Other	30

### 3.3 SUMMARY OF RESULTS

As indicated in section 3.2, 60 percent of the companies were engaged in some type of forecasting which was primarily of a medium term nature (six months to two years). The largest of those responding used committee agreement and market surveys as their principle methods of forecasting. Only a little over 30 percent utilized any standard mathematical methods. This appears to correlate with a survey made by the University of North Carolina in medium and large companies (7). This published report indicated the use of mathematical tools of only 40 percent.

About 70 percent stated that the accuracy of their short term forecasts were deemed 50 percent or less accurate. Medium term forecasts were judged in the same percentage range. Generally, forecasts were influenced by their customers' projections and other conditions

(As proposals outstanding). This amounted to about 80 percent of the total.

## CHAPTER 4

### INVENTORY CONTROL

Inventory control is of prime importance to a small business. Often a large portion of their capital assets are invested in inventory goods, investments which could sometimes be better used in other areas of the organization.

The standard methods of inventory control are summarized in section 4.1. Section 4.2 lists the tabulation of the inventory related questions and attempts to put them in perspective. A summary of these results follows in the last section.

#### 4.1 Inventory Control - Standard Methods

The purpose of an inventory control system is to provide the most economical supply of materials on hand consistent with efficient manufacturing operations. Control of the amount invested in inventories is very important since a manufacturer often has up to 25 percent of his total capital invested in this area. Costs associated with procuring and holding this inventory stock can be as high as 25 percent of the base price of the inventories (6). These cost include the following:

A) Holding Costs

1. Cost of spaced used
2. Cost of possible obsolescence
3. Cost of spoilage or deterioration
4. Cost of price changes
5. Cost of interest lost on money invested
6. Cost of insurance
7. Cost of taxes
8. Opportunity costs - Money tied up in inventory which could have been used more effectively or profitably elsewhere

B) Procurement Costs

1. Costs for preparing orders and other associated costs

Various factors must be taken into account in establishing inventory policies. Factors such as discounts for larger purchases, transportation costs per unit (lower on large quantities) and shortage costs (due to running out of stock) need to be considered. The costs of shortages are:

- a) Cost of idle labor
- b) Cost of idle facilities
- c) Cost of possible customer alienation

Various methods of inventory control are available. These range from simple types to the complex mathematical models. The following are some of the most prevalent.

1. Random Visual Checking

Manager 'notes' that a stock has reached a low level and thus orders a certain quantity.

2. Periodic Salesman Calls

Supplier makes regular routine calls on customers, thus replenishing inventories.

3. Two-bin Policy

One bin is stocked with sufficient material to last for the lead time required between order placed and order received. The other bin is stocked with material sufficient to last a specific time period. As soon as this latter bin is empty, an order is placed.

4. Mathematical Models

These attempt to determine the most economical inventory policies with regard to order quantities and order periods. In general, three models are utilized.

- a) Procurement or instantaneous receipt model
- b) Shortage model
- c) Quantity discount model

5. A - B - C Control Method

Often it is found that a small percentage of



the inventory accounts for a large amount of the dollar value of the total inventory. These would be classified 'A' items and be under strict control. 'C' items would constitute a large volume of inventory but be only a fraction of the cost total. 'B' items are those in between. As an example, the following situation could exist:

	<u>PERCENT OF STOCK</u>	<u>PERCENT OF INVENTORY COST</u>
'A' Items	10	75
'B' Items	20	20
'C' Items	70	5

In this case, items A and B would be under tight inventory control, (in particular item A) and C would be under a loose 'bin control' arrangement.

The general mathematical model (procurement) gives rise to the "Economic Order Quantity" (EOQ) formula (1), which is:

$$Q_0 = \sqrt{\frac{2 (C_p) R}{C_h}} \quad (4-1)$$

Where:  $Q_0$  = the most economical order quantity size

$C_p$  = procurement cost per order

$C_h$  = holding costs (per unit/yr)

$R$  = annual requirements in units

An example application of this formula would be: assume the XYZ company had established that it required

1,000 widgets annually ( $R$ ) and the average holding costs ( $C_h$ ) were \$2.00 per unit per year. The procurement costs are \$10.00 per order ( $C_p$ ). Therefore:

$$Q_o = \sqrt{\frac{2(10)(1000)}{2}} = \sqrt{10,000} = 100 \text{ units}$$

The number of orders placed per year is then:

$$N_o = \frac{R}{Q_o} = \frac{1000}{100} = 10$$

which means an order on the average is placed every 5.2 weeks,  $\frac{(52)}{(10)}$ .

If the 'lead time' is one week for widgets, a graphical presentation of such an inventory condition would be as shown in Figure 4-1.

Actually, the average order placement time is the stock depletion time cycle (5.2 weeks). Usually a 'buffer' or 'safety' stock is maintained such that the stock level does not reach zero at the end of the depletion cycle but rather to a certain pre-determined minimum amount. Often, an additional quantity of stock is also maintained which is used to offset seasonal variations in product demand (if such exists). These are called cycle stocks. Both of these in general vary as the square root of sales. A graphical solution showing the minimum ( $C_p + C_h$ ) costs (where the optimum order quantity exists) is shown in Figure 4-2.

Note that points 1 and 2 on the summation curve differ by only a small increase in cost per unit while there is a wide variation in  $Q$ . Therefore it is evident

that the EOQ need not be an absolute figure, but can be varied considerably and still maintain a low overall summation cost level. It is rather interesting to note that two textbooks, Buffa (p.233) and Bedworth (p.339) appear to be direct contradictions of each other in stating  $Q_o$  occurs at the curve crossing of holding costs ( $C_h$ ) and order costs ( $C_p$ ). For the basic inventory model (with no safety stocks or other unusual cases), this is true, though Bedworth seems to indicate that this holds true for all models.

To monitor inventory levels (especially of critical high cost stocks), certain control records are required. A 'balance of stores' ledger sheet is a typical system. Such a system is illustrated in "How to Organize and Operate a Small Business" (6, pages 422-3).

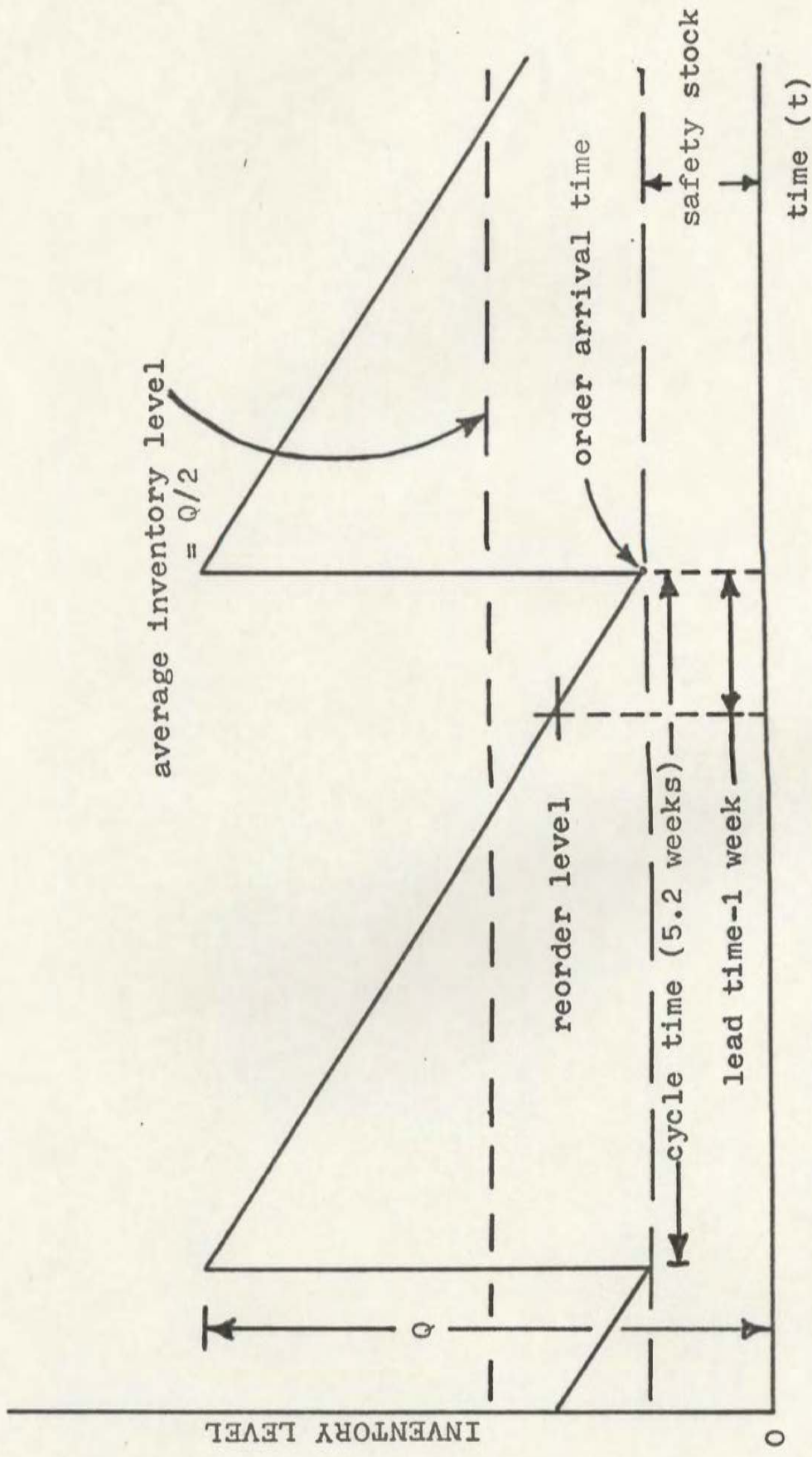


FIGURE 4-1 EOQ Model Graphical Example Including Safety Stock (source: Bedworth...Industrial Systems Planning, Analysis and Control)

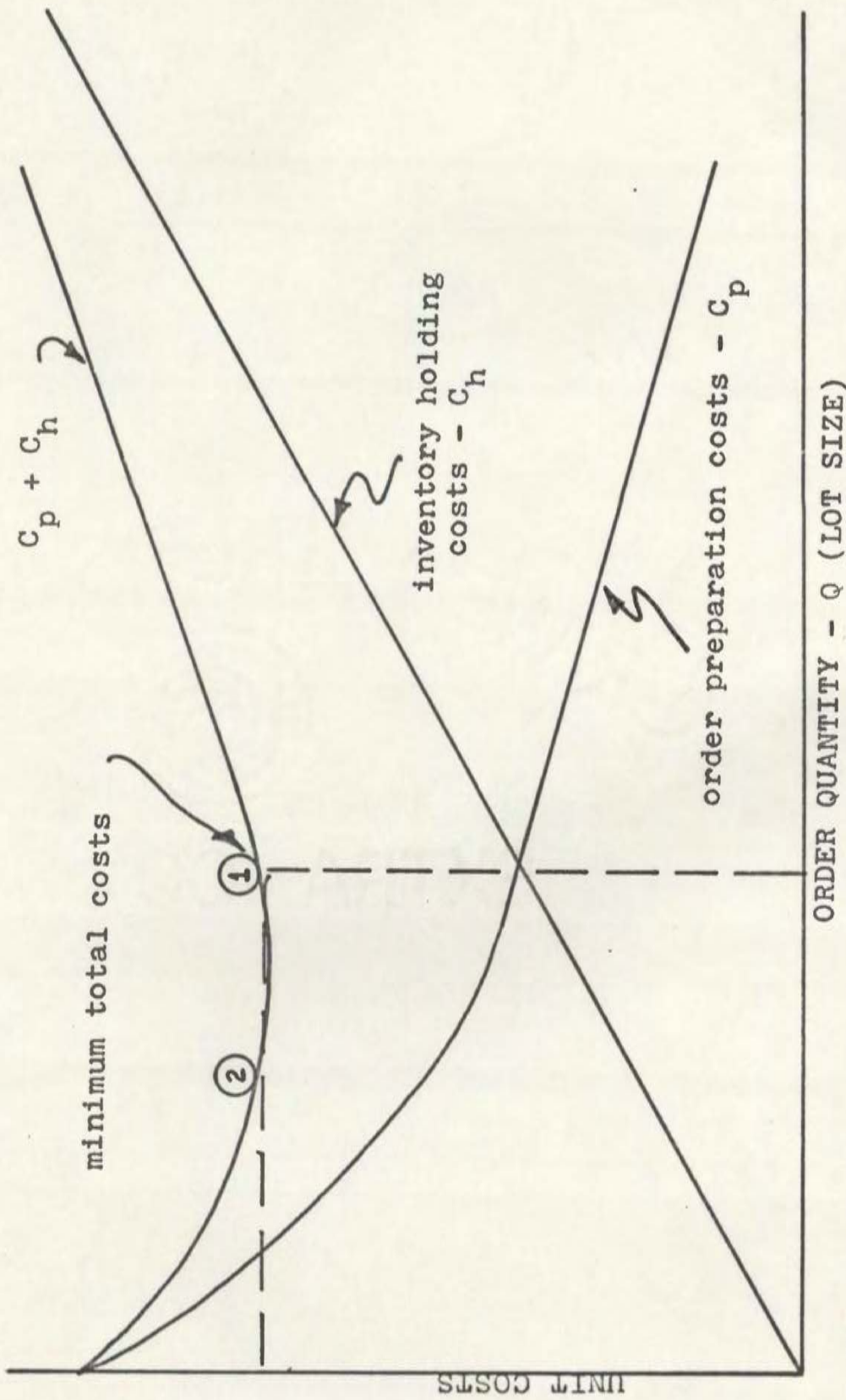


FIGURE 4-2 Graphical Solution of the Basic EOQ Inventory Model (Source: Bedworth...Industrial Systems Planning, Analysis and Control)

In conclusion, a typical procedure for establishing an inventory policy for a small business depends on:

- 1) Whether the inventory requirements are large enough to warrant it. .
- 2) Whether the present method has caused any problems.
- 3) How much time and expense is warranted in operating the inventory control system in relation to other activities and company/inventory size.

A standard procedure for establishing an inventory policy would be:

- 1) Determine the classes (A,B or C) of inventories and their respective percentages of quantity and total costs.
- 2) Determine whether class A and B types warrant strict inventory control.
- 3) Determine whether class C items will be under 'period check' or 'bin control'.
- 4) If classes A and B are to be monitored carefully, determine which mathematical model will govern the EOQ (and other associated factors).
- 5) Regulate, monitor and tabulate these items (A and B only) with standard form records as the 'Balance of Stores' ledger sheets previously mentioned.

#### 4.2 Tabulation of Category III Results on Inventory Control

Ten questions were asked concerning inventory control. They ranged in nature from methods to opinions and results of these controls. Table 4-1 illustrates the primary methods used and their extent of use.

TABLE 4-1 Percent of Respondents using each Inventory Control System.

METHOD OF INVENTORY CONTROL	PERCENT USING EACH
Visual check	20
Scheduled restocking	40
Continuous formal records	40
Mathematical models (EOQ)	0

The second question asked whether the company considered their inventory control methods adequate. Of those responding, 85 percent stated yes, 15 percent no. In answer to the third question, whether a large or small inventory was kept, 85 percent indicated small, while 15 percent stated large. The fifth question which was concerned with the dollar volume average generally invested in inventory, gave a range of \$5000 (a five employee shop) to \$200,000 (a one hundred forty employee shop). Whether vital stock was often depleted was the subject of question seven. Answers were nearly evenly divided here between often and rarely. Table 4-2 gives a comparison

between the relative company sizes and their respective answers.



TABLE 4-2 Comparison of Several Companies and Their  
Answers to Various Inventory Questions

Questions Related to:	Responding Companies		
	#1	#2	#3
Gross Sales	\$900,000	\$10,000,000	\$700,000
No. of Employees	45	140	25
Sales per Employee	\$20,000	\$71,430	\$28,000
<u>Inventory Questions</u>			
#2 Adequate Controls	yes	yes	yes
#3 Inventory Size	small	small	small
#5 Dollar Volume	\$50,000	\$200,000	\$15,000
Percent of Gross Sales	5.6	2.0	2.1
#6 Percent of Shop Area Used for Inventory	2.0	12.0	10.0
#7 Vital Stocks Depleted	Often	Rarely	Rarely
#9 Employee Time for Inventory Control	1 man per week	no answer	1¼ man per week

NOTE: Not all recipients were listed here since some did not respond to several of these questions.

TABLE 4-2 - Continued

Responding Companies			
# 4	# 5	# 6	# 7
\$2,500,000	\$150,000	\$1,500,000	\$4,800,000
90	5	20	185
\$27,775	\$30,000	\$75,000	\$25,145
yes	yes	yes	no
small	small	large	small
\$80,000	\$5,000	\$75,000	\$100,000
3.2	3.3	5.0	2.1
20.0	5.0	60.0	10.0
often	rarely	rarely	often
4 men per week	1/5 man per week	4 men per week	9 men per week

Table 4-3 Gives a breakdown of the 'lead' time required for raw material as answered in question four. As can be seen in the Table, no lead times greater than sixty days were reported.

TABLE 4-3 Normal Lead Times Reported Vs. those in Percent Indicating that Time

'LEAD' TIME IN DAYS	PERCENT REPORTING THESE TIMES
30	70
60	30
90	0
90	0

The estimated carry costs of the inventory value (question 10) are listed in Table 4-4. All those responding indicated their estimates at being 20 percent or less.

TABLE 4-4 Ranges of Percentages of Inventory Value Carrying Costs and Percentage of Respondents Estimating These.

INVENTORY CARRYING COSTS IN PERCENT OF VALUE	PERCENT OF COMPANIES ESTIMATING THEIR COSTS WITHIN THESE RANGES
0-10	30
11-15	40
16-20	30
21-30	0
Greater than 30	0

The response to question eight (factors in establishing a inventory policy) was limited. From this limited source of information, the underlying theme seemed to be: Policy is established by reviewing the history of past demands and reliability of subcontractors delivery schedules.

#### 4-3 SUMMARY OF RESULTS

In Category III, inventory control, no company indicated the use of mathematical models as an inventory control aid (see Table 4-1). Eighty percent used a schedule restocking system or continuous record system. The remainder relied only on an occasional visual check of inventory levels. It appears that shorter lead times in procuring raw materials was a deciding factor in how extensive an inventory control system was implemented.

Seventy percent of those surveyed showed lead times of 30 days or less (Table 4-3). Sixty days or less was the response of the remainder. No company responded with greater lead times. One possible reason could be that since all of these companies were small, their orders were generally smaller, and therefore could be more rapidly serviced.

The majority (70 percent) estimated the carrying costs of inventory value as being 15 percent or less (Table 4-4). Thirty percent estimated a higher carrying cost. This also was probably due to the overall shorter lead times required in obtaining material. The economic climate at present also has some effect. In 1974 and 1975, inventories were drastically reduced in most companies due to recession conditions, the continuing low economic outlook, and uncertainty. Most concerns have not increased their inventories to the pre-1974 levels even though business conditions have improved considerably. It appears to have become a standard policy now with many firms to maintain lower inventory levels.

Table 4-2 was formulated to show a comparison between responses of firms as to like questions and their relative size. The first rather surprising fact which emerged was that the majority of firms had gross sales per employee in the close range of \$20,000 to \$30,000. The remaining two had sales/employee of \$71,430 and \$75,000 each. Were they more efficient? The one firm which stated they felt their inventory controls were not adequate often had vital stocks depleted. They also maintained the largest work force to man inventory levels. On the average, dollar volume of inventory represented

from 2 percent to 5.6 percent of a firm's gross sales. Most of the inventory occupied 10 to 20 percent of the total shop area. Some were as low as 2 to 5 percent and one reached 60 percent. The latter must have been low cost inventory since it only represent 5.0 percent of his gross sales. This company also had the highest sales ratio per employee.

## CHAPTER 5

### SCHEDULING - JOB SHOP OR SEQUENTIAL

One of the toughest problems for any small manufacturing business is that of scheduling. As any small entrepreneur will tell you, this is a source of continual aggravation. Getting a 'handle' on a smooth production process is similar to scooping up quick-silver. Something always alludes you. There are always too many variables. Sometimes these are new and unknown.

The following sections examine this area. A summary of standard schedule practices precedes the actual tabulated data from the questionnaire sent out. A short analysis follows this.

#### 5.1 Scheduling - Job Shop or Sequential - Standard Methods

In general, with larger companies, scheduling encompasses the overall operations of the company. Production is planned such that consideration is given to:

- a) the available work force,
- b) delivery dates,
- c) machine breakdown,
- d) machine or process capacities,
- e) inventories,

- f) absentees,
- g) hiring and attrition rates,
- h) overtime,
- i) reject rates,
- j) additional shifts,
- k) subcontracting,

and probably many more, such as seasonal affects, and random affects such as vacations. The main goals are to minimize the processing time, to reduce non-productive time, and to meet delivery schedules.

Accordingly, there are five general operational systems for scheduling (1). They are:

1. The distribution system -  
Provides the required inventories to the service demand.
2. The production-distribution system -  
For high volume standardized products.
3. The closed job shop system -  
For varied products and several processes but still having a forecastable line of products.
4. The open job shop system -  
For custom products and several processes but no forecastable amount.
5. The one time (usually long term) project -  
Produces a final product and will have no finished goods inventory.

This study was concerned only with the third and fourth types of system, i.e., the job shop systems, or, as sometimes referred to, the sequential systems. Of the



five, these represent the most difficult type of schedule problem, since there are often many orders (jobs) of various complexities involved during the same time period and each will involve several operations, not necessarily in the same sequence. Also, the amount and complexity of the incoming jobs are not predictable, especially in the case of the open job shop system.

Several mathematical methods of production scheduling are explained in various textbooks (1, 2). Most are rather complex. *Queueing theory*, using waiting line models, is being researched from a machine or labor limited system point of view. These involve the assumption of Poisson arrival rates and exponential process times. Computer programs have been developed to find solutions to those scheduling problems which involve large quantities of incoming jobs at random rates and that involve several processes each.

Another method is through the use of the Gantt bar chart (2). This chart graphically depicts the schedule along a horizontal time flow. With only a few jobs and a few processes per job, an optimal minimum time solution can be determined. However, as the jobs ( $N$ ) and operations ( $M$ ) increase, the number of sequences becomes insurmountable, i.e., they will be  $(N!)^M$ . Here again, computers could be and often are utilized to solve such problems. A graphical solution has been devised by Akers (3) and Beckman (4) which makes it easier to derive and recognize an optimum solution involving a few jobs and processes.

The preceding methods concentrate on minimizing the

total production time of a number of orders. They also consider other criteria which are:

1. To minimize the average flowtime per order through the shop.
2. Have a maximum average number of jobs in the shop system.
3. Minimize the average due-date slippage of orders.
4. Maximize the average ahead of schedule deliveries.
5. Minimize the waiting time of a job prior to a certain processing operation.
6. Maximize machine process and personnel utilization, i.e., have very little non-productive time.

Two goals to achieve in scheduling, in the final analysis, are to enable one to realistically promise a specific delivery date of a customer's order (when other orders are being worked on) and to enable production to meet that date.

In a small shop situation (in the range of 10 to 50 employees), most managers do not have the time or expertise to engage in these more complex schedule operations. Therefore it is important that a simple and quick method be utilized which meets the most important aspects of scheduling (i.e., correctly project delivery dates). It should also be flexible enough such that it is applicable to other scheduling criteria.

A simple adaptation of the Gantt bar chart (2)

seems most feasible, along with some basic rules of thumb to follow to obtain the best results.

An example to illustrate a Gantt type scheduling process is described as follows. This procedure was developed specifically with a small printed circuit board manufacturing company in mind.

One of the first considerations in approaching the scheduling problem is to do a time study of an average job lot going through each machining (or other) process. Some processes can be bulked together and considered as a departmental processing for ease of scheduling. Table 5-1 lists the results of such a study.

TABLE 5-1 Time-Study of a 50 Board lot of Single-Sided Printed Circuit Boards.

DEPARTMENT NUMBER	ACTIVITIES/ DEPT.	HOURS TO COMPLETE
#1	A) Select Base Material B) Shear to size C) Scrub/Clean D) Oven Dry	1.5
#2	A) Resist Coat B) Oven Dry C) Expose and Develop D) Oven Dry	6.0
#3	A) Inspection B) Touch Up C) Solder Plate D) Clean	2.0
#4	A) Etch off Unwanted Copper	1.5
#5	A) Drill (assume 1 hole/sec. and each Board has 300 holes).	5.0
#6	A) Route to Size B) Clean up	2.0
#7	A) Quality Inspection B) Bag C) Package, Label, and Prepare for Shipment	3.0

With the preceding used as baseline figures, other job lots can be extrapolated so that a schedule can be worked out. Table 5-2 illustrates a hypothetical schedule for a five job situation.

TABLE 5-2 Job Lot and Time Spent in Each Department

<u>DEPT.</u>	<u>JOB A</u>	<u>JOB B</u>	<u>JOB C</u>	<u>JOB D</u>	<u>JOB E</u>
Dept # 1	1.5 hrs	0.5 hrs	2.0 hrs	1.0 hrs	6.0 hrs
Dept # 2	6.0 hrs	2.5 hrs	12.0 hrs	3.0 hrs	24.0 hrs
Dept # 3	2.0 hrs	1.0 hrs	4.0 hrs	1.0 hrs	8.0 hrs
Dept # 4	1.5 hrs	.6 hrs	3.0 hrs	.8 hrs	6.0 hrs
Dept # 5*	5.0 hrs	1.0 hrs	1.0 hrs	7.5 hrs	10.0 hrs
Dept # 6	2.0 hrs	1.0 hrs	4.0 hrs	1.0 hrs	8.0 hrs
Dept # 7	<u>3.0 hrs</u>	<u>1.5 hrs</u>	<u>6.0 hrs</u>	<u>1.5 hrs</u>	<u>12.0 hrs</u>
Total Time	21.0 hrs	8.1 hrs	32.0 hrs	15.8 hrs	74.0 hrs
Boards/Job	<u>50 ea</u>	<u>20 ea</u>	<u>100 ea</u>	<u>25 ea</u>	<u>200 ea</u>
Holes/Board	300*	100*	50*	1000*	50*

Utilizing the figures from Table 5-2, a Gantt Bar Chart is constructed as shown in Figure 5-1. The uppermost bar for each department line indicates the first schedule try. As can be seen, department utilization becomes very small in the latter departments. After four days, only three jobs have been completed. In the first try it became evident that Dept. 2 was a bottleneck. Therefore, its capacity was doubled. Also, Job E was split into two lots, E-1 and E-2. The utilization factor of the various departments improved considerably so that after four days, 3½ jobs have been completed. A further split of Job C into C-1 and C-2 improves department utilization so that now four jobs can be completed in four days.

From such a bar graph, various factors are revealed. It shows that the capacity of certain departments must be increased if increased output is to be realized. Breaking jobs into smaller segments increases productivity, but this must be within the constraints of extra bookkeeping involved. Also, a percent utilization can be worked out for each department so that labor can be used efficiently.

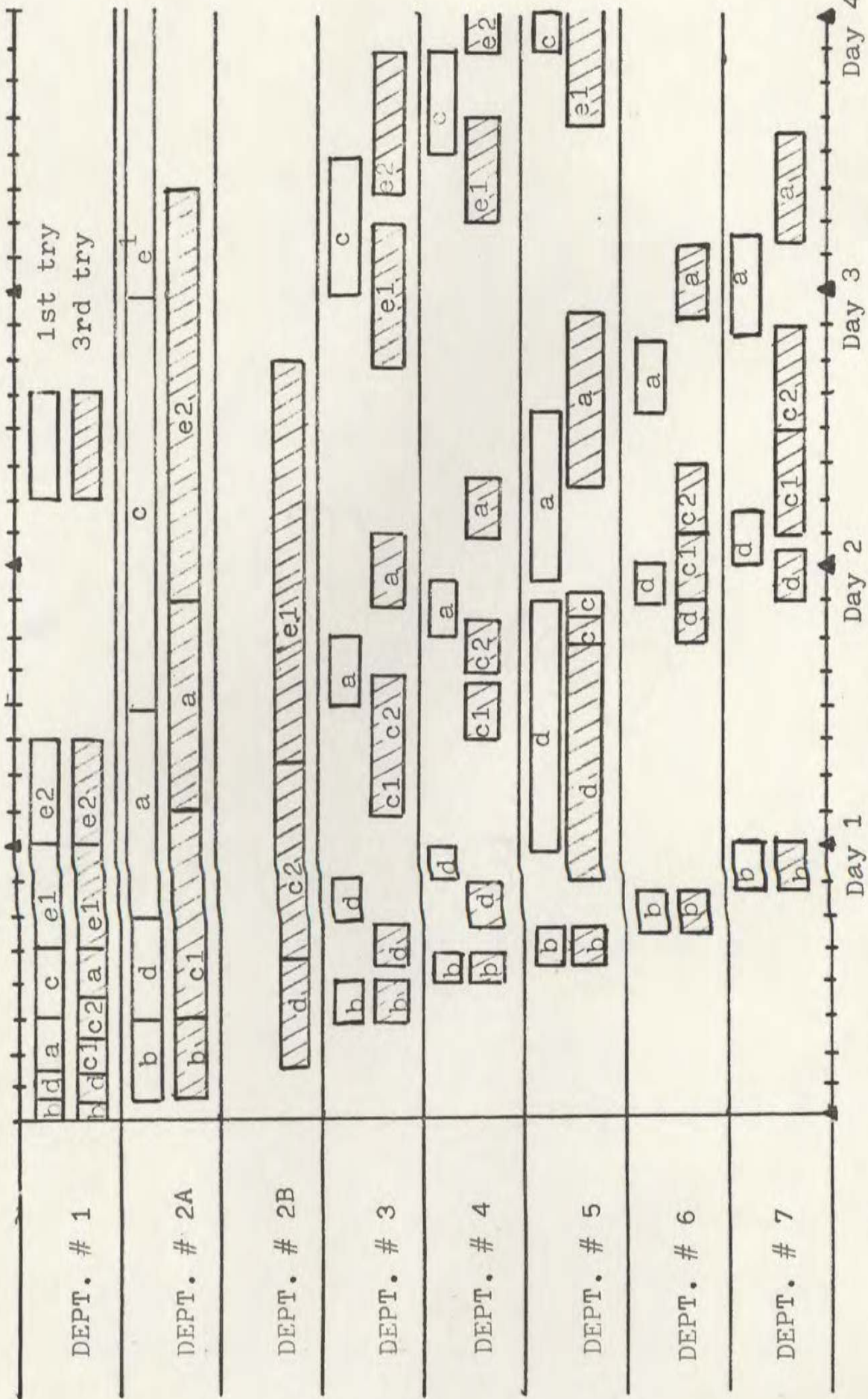


FIGURE 5-1 Gantt Schedule for Two Possible Sequences for Data Table 5-2

Some basic rules of thumb to follow(2):

1. Schedule the Shortest Operation Time (SOT) jobs first.
2. It is usually better to break up large order jobs into smaller job lots.
3. Depending on the reject rate expected, it is generally needed to add that percentage to the order going through the shop.
4. A good practice is to have several workers able to perform several processes so they can be shifted around.

As indicated by the previous Gantt chart (Figure 5-1), department utilization can be increased by reducing lot size of each order. This has to be weighed against the increased paper work required and the increased likelihood of order foul-ups due to more lots to keep track of in the shop. One can effectively decrease lot size by running 'panel' lots in printed circuit work where the 'panel' consists of a number of boards on one base material sheet.

In the aggregate scheduling of a job shop operation, due to the many variables which upset the detailed type of scheduling, a simpler method should be used, especially in relation to delivery date promises. After a certain experience history, it is usually found that the shop can on the average produce a certain gross dollar volume per week. As efficiency becomes greater, or new machines are added or processes are shortened, this volume can be expected to increase a certain percent in following weeks. Therefore, if the average gross output



of orders per week has been \$3,000, one could promise delivery of orders totaling only \$3,000/wk for the succeeding weeks. However, if a trend in efficiency indicated a 5 percent increase per week, one could conservatively increase promised orders totaling, say, 2.5 percent greater each week.

## 5.2 Tabulation of Questionnaire Response in Category IV

Two multiple answer questions were asked in this category. The first concerns scheduling jobs to meet specific delivery dates. This question was asked to determine how many small companies actually attempted a formal structured scheduling process. Table 5-3 records the results.

TABLE 5-3 Methods of Scheduling Finished Goods for Delivery Vs. the Percent using these

METHOD USED	PERCENT USED
Review of jobs in process and finish date of new order	50
Review of dollar value of products in process and estimate finish date	20
In-house scheduling chart	20
Other methods	10

The second question was more difficult to tabulate. Ten different factors which caused the greatest difficulty in meeting scheduled delivery dates were

listed. Apparently this question also was somewhat too time consuming since some recipients did not complete this. In ranking the trouble spots, the firm was asked to rank the most troublesome factor, # 1 through to the least troublesome one as # 10. Each answer was ranked differently by the various companies, however, a discernable pattern emerged in that certain answers generally received higher ratings than others. To arrive at a meaningful table, the sum of the ratings given were divided by the number of firms responding to this answer to give a scale factor, where a singularly high or low ranking number for a particular answer was left out. Table 5-4 lists the results of this question after 'normalizing' these ratings. The smallest numbers indicated the greater problem areas in the opinion of the respondents, with the highest giving the least concern.

TABLE 5-4 Factors Causing Problems in Meeting Delivery Dates Vs. the Relative 'Normalized' Ranking of These.

FACTORS CAUSING MISSED DELIVERY DATES	RELATIVE RANKING ON A SCALE OF 1 TO 10
1. Over-optimism in scheduling	1.4
2. Raw material not delivered in time	2.0
3. Worker apathy	4.5
4. Worker negligence	4.7
5. Raw material rejects	5.5
6. Wrong or insufficient information from customer	5.7
7. Machine breakdown	6.8
8. Process out of control	7.9
9. Worker absenteeism	7.9

### 5.3 SUMMARY OF RESULTS

In Category V, dealing with scheduling, it appears that 50 percent of the smaller firms determined schedule delivery dates by reviewing the present work load and estimating a date based on the size of the order placed. The remainder of the responses were evenly divided between the remaining choices. It would seem that most order processing was scheduled through intuitive guesswork, rather than any more scientific methods.

Question two under scheduling methods was asked to determine which factor was the greatest cause for failure to meet agreed delivery dates. Ten possible

causes were given for the recipient to check. After recording these, they were arranged, as shown, in Table 5-4. The topmost consisted of the most significant causes for schedule slippage, with the succeeding rows of successively less significance.

As Table 5-4 indicates, the major causes for schedule slippage were: over-optimism in scheduling; with raw material not being delivered on time running a close second. Examination of the data showed that the various factors could be grouped, since they were closely ranked. Worker apathy and worker negligence ranked 4.5 and 4.7 respectively. Factors # 5 and # 6 were also similarly ranked as was # 8 and # 9.

It would appear that the human factors outweigh the material ones in causing the predominant delays in schedule dated.

SUMMARY AND CONCLUSIONS

In conclusion, the mathematical tools available for scheduling, inventory control and forecasting were found to be seldom used in the small business area by the respondents to the survey instrument used in this study. This condition possibly exists either because there is little knowledge of their availability (which is highly likely), there is a certain reluctance to use them or, perhaps, due to the cost of implementation. There is some evidence that the latter may be the case. A study of big business methods (7) indicated low usage of these analytical tools as well. Large concerns would certainly have a greater awareness of their existence, since a greater number of these employees would be college-educated.

Apparently, the most troublesome areas are those dealing with efficient planning. This is in relation to inventory levels and production scheduling. The end problem emerges as delayed delivery of the end product to the customer. As the questionnaire suggests, the inventory level control is not adequate for production levels in most cases. Mostly small businesses were reluctant to keep larger inventory stocks since it tied up needed capital. In general, only 10 percent or less of total shop area was allocated to hold inventory.

Scheduling production was reported to be more intuitive than scientific and over-optimism was cited

most often as the reason for delivery delays. Worker apathy and negligence was blamed as a significant cause in schedule slippage. This could be more of a 'scape-goat' reasoning than the actual causes. Since problems relating to the product manufacturing were lowest in rank, it would indicate that most enterprises were technically competent but lacked the knowledge and skills relating to industrial engineering practice.

A P P E N D I X

QUESTIONNAIRE USED

The following questions are intended to provide an insight into small business' approach to the particular problems of operational projections (forecasts), inventory control and scheduling. In particular, this survey is concerned with the job shop or custom product type of manufacturing company. As stated, this questionnaire is divided into three sections: Forecasting, inventory control and scheduling. The recipient is requested to check the appropriate spaces for answers to each question. The first group of questions are for general information.

GENERAL INFORMATION

1. Number of Employees ----- \_\_\_\_\_
2. Approximate Gross Sales/yr ----- \$ \_\_\_\_\_
3. Principal Product ----- \_\_\_\_\_  
     Type of operation  
         Custom Products ----- \_\_\_\_\_  
         Proprietary Products ----- \_\_\_\_\_
4. Number of years in business \_\_\_\_\_
5. Cyclical Variations of Business - % per quarter  
     year  
         Winter ----- \_\_\_\_\_  
         Spring ----- \_\_\_\_\_  
         Summer ----- \_\_\_\_\_  
         Fall ----- \_\_\_\_\_

FORECASTING

6. Does your company engage in any type of formal recorded 'Forecasting' (future projections) as related to sales projections, inventory projections or production scheduling?  
     Yes \_\_\_\_\_ No \_\_\_\_\_



7. Are forecasts primarily of:

- A. A short term nature (for immediate operations) \_\_\_\_\_
- B. A medium term nature (6 mo to 2 yrs) (from projected capacity increases as to plant size and new equipment) \_\_\_\_\_

8. What method of forecasting is used?

- A. Committee agreement ----- \_\_\_\_\_
- B. Market surveys ----- \_\_\_\_\_
- C. Time series analysis (mathematically analyzing historical data to find underlying trends) ----- \_\_\_\_\_
- D. Correlation analysis (projections based on correlation to other pertinent data) \_\_\_\_\_
- E. Other ----- \_\_\_\_\_

9. How accurate do you rate your short term forecasts in general?

- 0-10% ----- \_\_\_\_\_
- 11-25% ----- \_\_\_\_\_
- 26-50% ----- \_\_\_\_\_
- 51-75% ----- \_\_\_\_\_
- 76-100% ----- \_\_\_\_\_

10. How accurate do you rate your medium term forecasts in general?

- 0-10% ----- \_\_\_\_\_
- 11-25% ----- \_\_\_\_\_
- 26-50% ----- \_\_\_\_\_
- 51-75% ----- \_\_\_\_\_
- 76-100% ----- \_\_\_\_\_

11. Are your forecasts influenced by:

- A. Suppliers' salesmen ----- \_\_\_\_\_
- B. Trade magazines' predications ----- \_\_\_\_\_

- C. Your customers' projections  
(for custom operations)----- \_\_\_\_\_
- D. Other----- \_\_\_\_\_

INVENTORY CONTROL

12. What methods of inventory control are utilized?
- A. Periodic visual check (unscheduled)--- \_\_\_\_\_
- B. Scheduled restocking (determined by  
level or a time period)----- \_\_\_\_\_
- C. Continuous formal records----- \_\_\_\_\_
- D. Mathematical models (EOQ) and formal  
records----- \_\_\_\_\_
13. Do you consider your inventory control methods  
adequate?
- Yes \_\_\_\_\_ No \_\_\_\_\_
14. Do you generally keep a large or small inventory of  
raw materials?
- Large \_\_\_\_\_ Small \_\_\_\_\_
15. What is the normal 'lead time' (days from placing an  
order and its delivery) of your most used raw  
material? \_\_\_\_\_ days
16. What approximate dollar amount of inventory do you  
carry on the average? \$ \_\_\_\_\_
17. What approximate percent of total shop space is used  
for inventory storage? \_\_\_\_\_ %
18. Do you often 'run out' of any 'vital' base material?
- Yes \_\_\_\_\_ No \_\_\_\_\_
19. What various factors do you consider in establishing  
your inventory policy? (as cost of obsolescence,  
spoilage, price changes, capital invested, product-  
ion delays to shortages, etc.)? \_\_\_\_\_
-

20. What percentage of time (or hours/wk) is devoted to inventory control functions? \_\_\_\_\_ %
21. What do you estimate the carrying costs of inventory value to be?

- 0-10%-----
- 11-15%-----
- 16-20%-----
- 21-30%-----
- Higher than 30%-----

22. In scheduling to meet delivery dates, how is a delivery date determined when a customer order is placed?

- A. By reviewing quantity of products now in process and estimating a date-----
- B. By reviewing gross value (in \$) of products now in process and estimating a date-----
- C. By referring to an in-house scheduling chart and determining a date-----
- D. Other methods (please explain)\_\_\_\_\_

23. Scaling the following causes from 1 to 10, which factors cause the greatest (#1) to the least (#10) problem in meeting scheduled delivery dates?

- A. Process out of control-----
- B. Worker negligence-----
- C. Raw material rejects-----
- D. Raw material not delivered on time\_\_\_\_\_
- E. Worker apathy-----
- F. Machine breakdown-----
- G. Over optimism in scheduling-----
- H. Worker absenteeism-----
- I. Wrong or insufficient process information from customer-----

J. Other (specify) \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

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