*Proceedings of the 1994 Winter Simulation Conference*
*ed. J. D. Tew, S. Manivannan, D. A. Sadowski, and A. F. Seila*

# INVENTORY COST MODEL FOR 'JUST-IN-TIME' PRODUCTION

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## ABSTRACT

This paper presents the design and operation of a computer simulation model developed on a SLAM SYSTEM to compare the build up of set up costs and inventory carrying costs with varying lot sizes. While reduction of lot sizes is a necessary step towards implementation of 'Just-In-Time' (JIT) in a job shop environment, a careful cost study is required to determine the optimum lot size under the present set up conditions. A simulation model can be designed to graphically display the fluctuation of carrying costs and accumulation of set up costs on a time scale in a dynamic manner. The decision for an optimum lot size can then be based on realistic cost figures.

## 1 INTRODUCTION

Increasingly many industries in manufacturing are adopting a 'Just-In-Time' (JIT) philosophy and the 'Pull System' concept for reducing inventory carrying costs. While the 'Pull System' can be implemented with relative ease in assembly environment, it's concept can not be adapted easily in job shop setting where work centers can not be designated for unique processing. In such situations, the drive is to reduce lot sizes in order to minimize inventory build up. A reduction in lot size invariably results in frequent set ups with associated material and labor cost. While reduction of lot sizes and set up times is an admirable goal, too often hasty decisions are made to reduce lot sizes in a zeal to introduce 'Just-In-Time' without a careful cost study. The premise that 'inventory carrying costs far outweigh set up costs' may not be valid in all cases. The challenge lies in determining the optimum lot size that balances set up costs with carrying costs under the present set up conditions in a realistic manner. The traditional economic lot size formula is vague and uses inputs that are invalid.

At Gulfstream Aerospace Corporation, many detail parts are being fabricated in varied lot sizes in a job shop environment. In an effort to minimize work in process (WIP), the lot sizes are constantly being reduced. The tube shop had gradually decreased the lot size of tubes from (12) to (4) and the management was considering to reduce the batch size even further. Presently in tube forming, (apparently due to the inherent capability of the process), the first piece was being scrapped in each set up of (4) tubes. This was resulting in high scrap costs. Many process variables: such as metallurgy of tubes, set up procedures, equipment wear, data transmission to benders, etc., were under investigation. However, one thing was evident - scrap cost was directly related to lot size. A further reduction in lot size meant frequent set ups and higher scrap costs. Before a decision could be made to reduce the lot size further, it was imperative that the optimum lot size for tubes be established under the present operating conditions. To accomplish this, a computer simulation model was designed on a PC based 'SLAM SYSTEM' to graphically compare the build up of set up costs with carrying costs under varying lot sizes.

## 2 THE TUBE BENDING PROCESS

Presently, Gulfstream receives tubing's from several distributors. These distributors purchase the tubing from manufacturers, who make and treat it to Gulfstream specifications. The tubing is shipped from distributors to Gulfstream where it is stored in the warehouse until needed. The majority of the tube bending is done on Eaton Leonard numerical control machines that are linked to a Supraporte tube reader. This Supraporte tube reader stores the NC programs and transmits them to the tube benders on request by part number.

To bend a tube, the operator keys in the number of the part he wants to bend. The Supraporte calls up the appropriate program and transmits it to the desired NC tube bender. The operator lubricates the tube, loads it on the bender and initiates the operation. Most jobs take only one or two minutes of actual bending. After the initial part is produced, the operator takes it to the

Supraporte, where he scans the part and the Supraporte compares it to the original template. Tube parts experience a factor, called SPRING BACK, where the part rebounds a bit from bend. To compensate for spring back, the part may have to be bent a few extra degrees. This all depends on the strength of the material, how warm or cold it is, how long and where it has been stored and how it has been treated.

The Supraporte then makes adjustments in the programming for spring back, so that the next part should match the template. This updated program is transmitted to the NC bender. The operator loads another tube and initiates the program. This second part is theoretically supposed to be a "good" part.

## 3 MODEL CONCEPT: DEFINITION OF SCOPE AND OBJECTIVES

The most apparent goal of a JIT system is to minimize WIP inventory. The purpose of reducing WIP inventory is two-fold: (1) reduce carrying costs and (2) improve quality and productivity. As lot sizes are reduced the control over quality is enhanced and inventories are minimized. For several years, the company has been striving towards a JIT environment and the benefits of this concept have proven themselves over and over again in areas where JIT has been applied. Since late 1990, the tube shop has been attempting to take steps towards JIT. However, some problems were discovered and needed to be addressed in order for the JIT to be successful. The most disturbing problem was the first piece of scrap that resulted every time a set up was performed. The tube bending process is complicated and tedious. Many internal and external factors are involved. The scrap is usually caused by problems with the tubing material (heat treatment, age), how tight or loose the mandrel is within the tube during bending, the amount of lubrication required and other set up procedures.

Aluminum tubing is produced by a series of drawing operations and the associated heat treatments. The drawing techniques vary from one manufacturer to another. These variations combined with the composition differences produce a product with varying degrees of spring back. Steel tubing is produced by rolling the strip and then welding it. The tube is then drawn to its final size. Again, the drawing techniques differ from one manufacturer to another resulting in product with varying degrees of spring back.

A team consisting of Industrial Engineers, Manufacturing Engineers and Buyers was actively pursuing the elimination of the first piece scrap in the tube shop. Many options were being considered. One option was to tighten the chemical composition tolerance. This option would lessen the variance but would not eliminate it. Additionally, it would require the prior agreement of a major steel producer with the possibility of mill run procurement. Another option was to implement strict controls on the drawing process. This would require prior approval by the tube maker and would likely lead to a sole source situation with direct procurement in large quantities from the tube manufacture. The tubing would be produced to premium quality requirements with an associated price increase. Currently, tubings were purchased from distributors in small lot quantities. This would not be possible with the above changes. Additionally, there would be significant cost impact.

The team was also addressing other issues such as: data transmission to the Supraporte, preventative maintenance and set up procedures. As quick results were not anticipated, it was proposed that in the interim we evaluate the magnitude of scrap costs and carrying costs at different lot sizes using simulation technique. The overall objective was to determine the optimum lot size that will minimize the overall cost. A SLAM model was conceptualized and is illustrated in figure (1). The model was envisioned to use a 'Just-In-Time' production schedule for a given lot size with information by part number on raw tubing cost, set up hours and man hours added for scrapped and finished tube to keep track of inventory carrying cost and set up cost at each manufacturing day. One tube was to be scrapped at each set up because of the present process capabilities. It was intended that the model graphically display the build up of inventory of tubes in stock, set up costs, accumulated carrying costs and average carrying costs with the advance of each manufacturing day.

## 4 DATA GATHERING AND INPUT TO MODEL

Once the model was conceptualized, the next task was to identify the sources of input. The data resided in many formats and had to be extracted from different sources. A 'SAS' program on mainframe and some clipper programs on the PC were developed to prepare the data for input to SLAM. The input data included the following information:

(1) Projected production schedule for tubes for a given lot size along with information on part number, aircraft number, quantity per ship, lot size, start date, completion date and due in stock date.

(2) Raw material code, cut size and cost of raw tubing by part number.

(3) A fixed percentage factor for computing carrying costs from inventory dollars.

(4) Man hours per set up.

(5) Added man hours for scrapped tube.

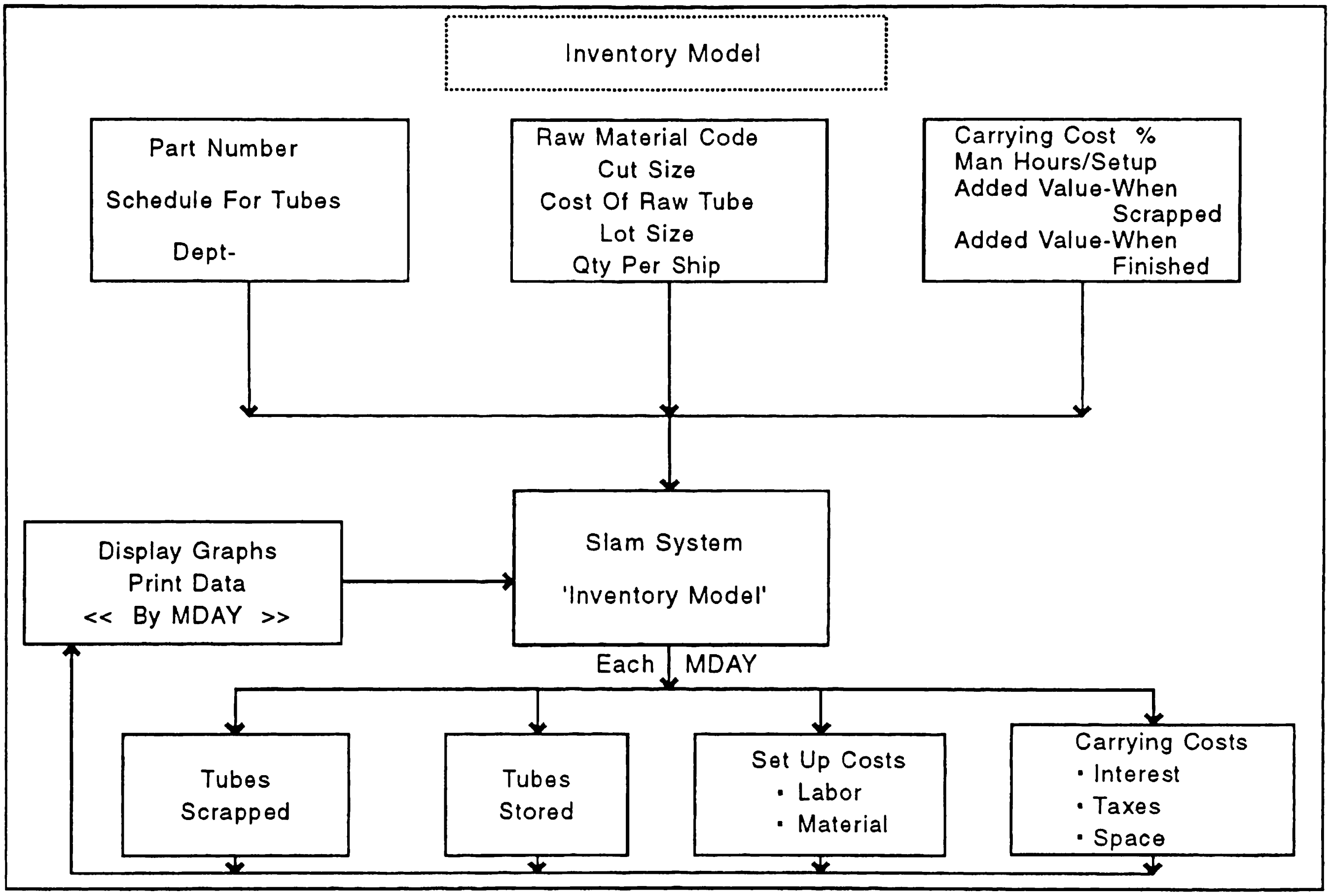


Figure 1: Model Concept

(6) Added man hours for finished tube.
(7) Labor rate.
(8) Production rate (24 aircraft per year; Flow rate = 10 manufacturing days).

## 5 MODEL CONSTRUCTION

The model was constructed using screen management and the graphical capabilities of SLAM, FORTRAN user inserts, Clipper compiled PC programs, mainframe 'SAS' programs developed outside of SLAM and various downloads from an existing MRP system.

The 'SAS' program designed in mainframe extracted the projected production schedule for tubes for a range of aircraft. The schedule was then downloaded in a Dbase file. The raw material code, cut size and cost of raw tubing were downloaded in anther Dbase file from present MRP system using OLQM (on line query menu). A sample of raw tubing data is shown in table (1). A Clipper program consolidated the two files to provide information on projected schedule and also the raw tubing cost by part number based on its' dimensions. The entire schedule with pertinent data was then loaded to the SLAM SYSTEM in ASCII format. A SLAM network was then constructed for tracking flow of parts through the system as illustrated in figure (2). Many user written FORTRAN subroutines were incorporated in the model for reading input data, adjusting schedule for a desired lot size, computing the various costs and displaying the resulting information graphically on screen. The model also included a script for animation purposes.

## 6 OPERATING THE SIMULATION MODEL

A flow chart depicting the SLAM network is illustrated in figure (3). The simulation began with the user's input on the following variables: the lot size, starting manufacturing day, man hours for each set up, labor rate, man-hours added for scrapped and finished tube and the fixed percentage factor for converting inventory dollars to carrying costs. The factor applied to current inventory dollars for computing carrying costs accounted for interest, taxes, insurance and space usage. The projected schedule that was loaded to SLAM SYSTEM was first adjusted for the desired lot size. The event routine then read the information on part number, start date, completion date, due in stock date, cost of raw tubing, quantity per ship, lot size e.t.c. from the schedule file. All the pertinent information was stored as attributes of the part number that was regarded as a unique entity in the system. The due in stock day of all part numbers was then compared to the current MDAY (manufacturing day) and the parts that had the same due in stock day as the current MDAY were filed for storage in stock. The tubes that were put in stock were added to the inventory and the inventory dollars were computed based on the raw tubing cost and the added labor cost. Inventory carrying costs were then calculated by applying the fixed percentage factor. The set up costs, that include labor cost of each set up and actual material and labor cost of scrapping (1) tube were also computed for the part number that was stored. The simulation progressed with lapse of each MDAY and the process was repeated by comparing the due in stock date of all parts in schedule with current MDAY.

The model kept track of schedule and cost of each tube stored as attributes of the part number. Each tube in the lot remained in storage for (10) MDAYS (flow rate) from the day it was initially filed in storage. After the lapse of (10) MDAYS, the tube was depleted from the stock and the lot in the stock for this part was depleted by (1) tube. The inventory and carrying costs were also depleted according to the cost attributes of the tube. When all the tubes had been depleted from the lot, the entity was terminated from the system. The simulation continued with the advance of each manufacturing day. The various costs were recomputed and accumulated by each MDAY for a total simulation length of (250) days. The average carrying cost was also continuously updated by dividing the accumulated carrying cost with the total number of days that had elapsed.

For each manufacturing day, the animation graphically depicted the build up of set up costs and the fluctuation of accumulated carrying costs and average carrying costs. Samples of displayed graphs are shown in figures (4) and (5). With this data, a dynamic picture of set up and carrying costs could be observed for a given lot size on a time scale. All costs were recorded in a file by MDAY for future print out. A sample print out is shown in table (2). The simulation was then repeated for different lot sizes (4, 6, 8, 12) for the same length of time (250 MDAYS). This allowed management to review set up and carrying costs at different time periods during the year for a given lot size. In order to analyze weekly manpower requirements, work load graphs were created for lot sizes of 4, 6, 8 and 12. A typical work load bar graph for a lot size of (4) is shown in figure (6).

## 7 CONCLUSIONS

A summary of costs for (250) days of operation is prepared in table (3). The results showed an annual cost saving of \$ 38,142 when the lot size increased from (4) to (6). The scrap cost decreased by \$ 40,724 while the average carrying cost increased by \$ 2,582. The net cost

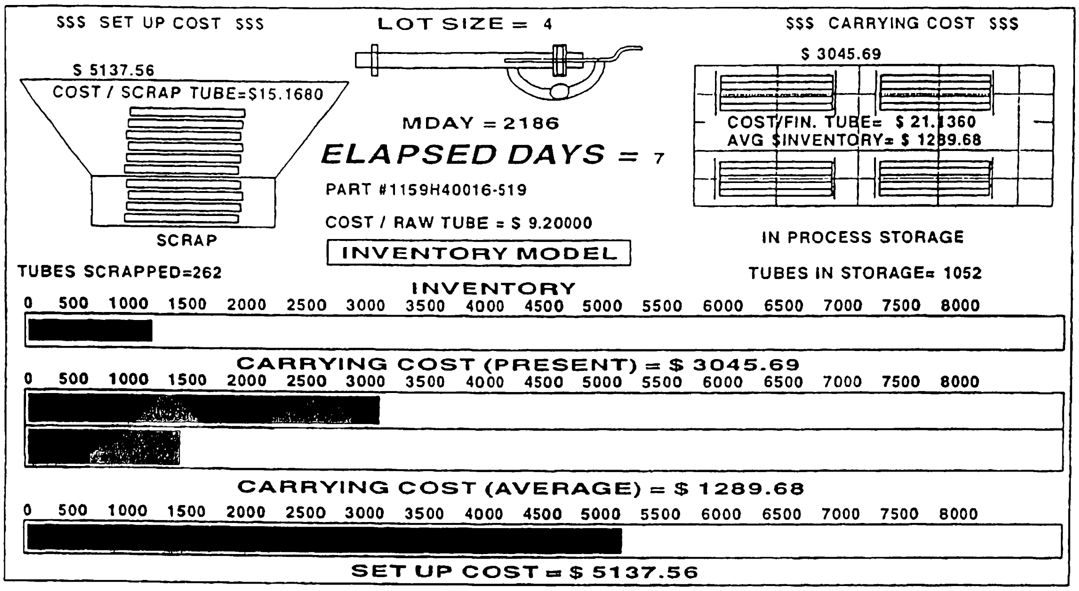


Figure 4: Sample of Displayed Graph

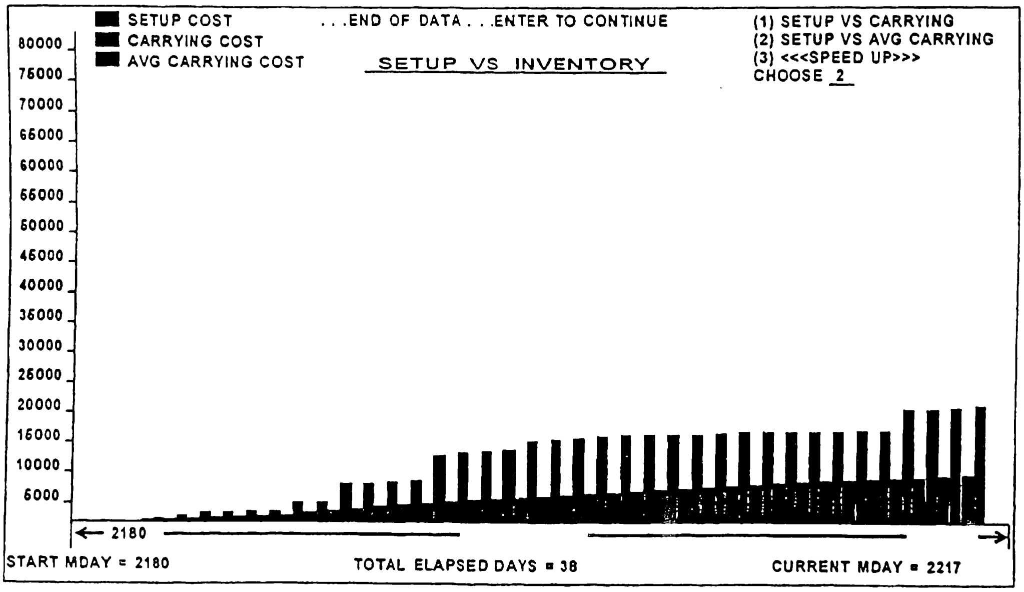


Figure 5: Sample of Displayed Graph

Table 2: Detailed Report by MDAY

| MDAY | SCRAP TUBES | STORED TUBES | $INVENTORY PRESENT | $INVENTORY ACCUM | $INVENTORY AVG | $SETUP COST |
|---|---|---|---|---|---|---|
| 2180 | 6 | 24 | 57.69 | 57.69 | 57.69 | 99.09 |
| 2181 | 8 | 32 | 109.24 | 166.93 | 83.46 | 182.62 |
| 2182 | 128 | 516 | 1387.19 | 1554.12 | 518.04 | 2346.23 |
| 2183 | 130 | 524 | 1402.47 | 2956.58 | 739.15 | 2373.09 |
| 2184 | 139 | 560 | 1512.76 | 4469.35 | 893.87 | 2558.85 |
| 2185 | 139 | 560 | 1512.76 | 5982.11 | 997.02 | 2558.85 |
| 2186 | 262 | 1052 | 3045.70 | 9027.80 | 1289.69 | 5137.57 |
| 2187 | 263 | 1060 | 3063.48 | 12091.29 | 1511.41 | 5152.96 |
| 2188 | 263 | 1060 | 3063.48 | 15154.77 | 1683.86 | 5152.96 |
| 2189 | 269 | 1084 | 3219.90 | 18374.67 | 1837.47 | 5406.31 |
| 2190 | 419 | 1682 | 4846.93 | 23221.61 | 2111.05 | 8182.61 |
| 2191 | 419 | 1680 | 4834.04 | 28055.65 | 2337.97 | 8182.61 |
| 2192 | 436 | 1627 | 4686.53 | 32742.18 | 2518.63 | 8476.66 |
| 2193 | 438 | 1633 | 4698.62 | 37440.79 | 2674.34 | 8504.51 |
| 2194 | 681 | 2604 | 7183.64 | 44624.43 | 2974.96 | 12763.48 |
| 2195 | 710 | 2720 | 7432.94 | 52057.38 | 3253.59 | 13196.28 |
| 2196 | 715 | 2617 | 7090.25 | 59147.63 | 3479.27 | 13267.09 |
| 2197 | 737 | 2703 | 7406.42 | 66554.05 | 3697.45 | 13800.87 |

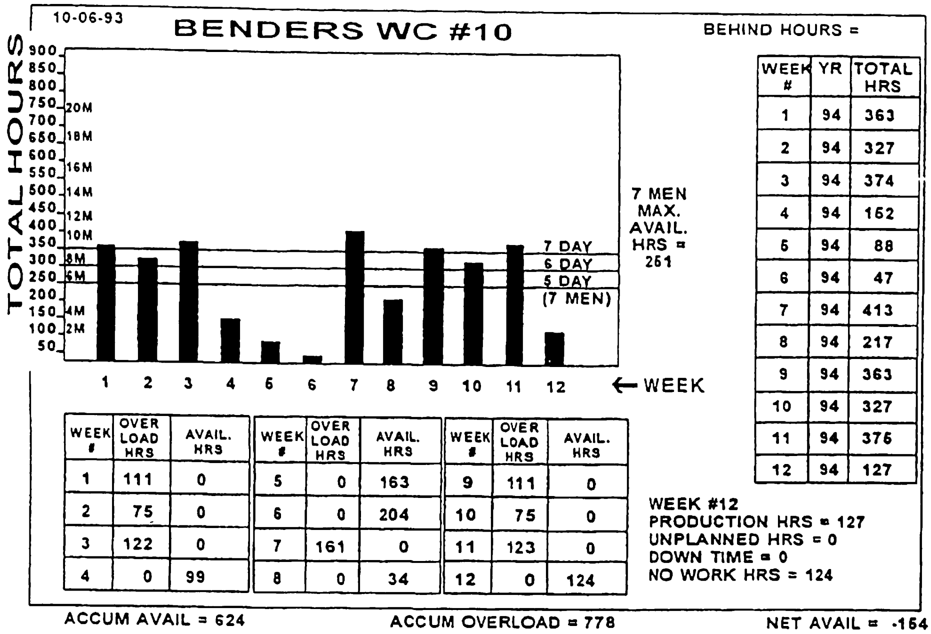


Figure 6: Work Load Analysis Bar Graph

Table 3: Summary of Results

SET UP COSTS VS CARRYING COSTS
( 250 DAYS OF OPERATION )

| LOT SIZE | SET UP COSTS | CARRYING COSTS | TOTAL COST | NET COST SAVINGS |
|---|---|---|---|---|
| 4 | $121,973 | $ 7,067 | $129,040 | |
| 6 | $ 81,249 | $ 9,649 | $ 90,898 | $38,142 |
| 8 | $ 61,042 | $ 12,095 | $ 73,137 | $55,903 |
| 10 | $ 47,486 | $ 13,985 | $ 61,471 | $67,569 |
| 12 | $ 40,637 | $ 14,563 | $ 55,200 | $73,840 |
| 16 | $ 40,579 | $ 23,442 | $ 64,021 | |

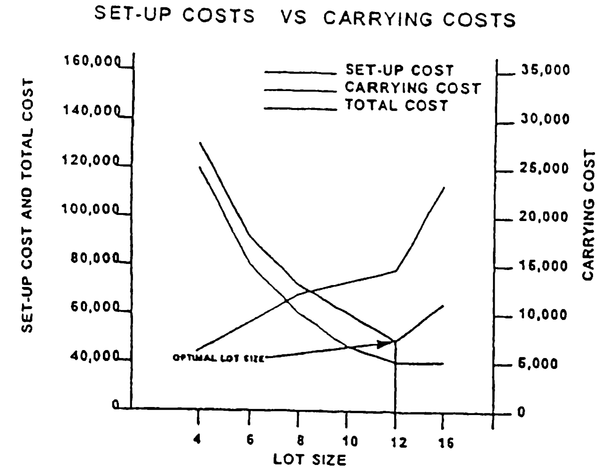


Figure 7: Break Even Chart

savings increased to $ 55,903 when the lot size was changed from (4) to (8). In general, the set up costs decreased drastically as the lot size increased. The carrying costs, however, did not increase in the same proportion. The material & labor cost due to first piece scrap amounted to approximately 60% of total set up costs, the remaining 40% incurred in the labor cost for set ups. The break-even point was reached at lot size of (12). The chart is illustrated in figure (7).

The workload analysis showed more pronounced fluctuations in man power as the lot size was increased from (4) to (12). The higher the lot size, the more pronounced were the fluctuations. This suggested that additional leveling of manpower would be necessary with a higher lot size.

Although a lot size of (8) or (12) proved to be more economical from inventory carry cost and set up cost analysis, it also created additional manpower fluctuations from week to week that already existed with present lot size of (4). With above considerations a lot size of (6) appeared to be optimum.

The results were presented to the team and management. The magnitude of scrap and set up costs that accumulated over the year were quite revealing and prompted management to give this project a high priority. The team was directed to actively pursue all options to minimize the first piece scrap and set up costs. It was decided not to reduce the lot size any further at this time. Increasing the lot size to (6) was also deferred until the team had the opportunity to fully explore all options aimed at reducing the set up and scrap costs.

It should be noted that a lower lot size has many other intangible benefits such as quicker response to customer requirements and improved quality control that can not be quantified in a cost model alone. These factors must be evaluated in considering lot sizes in the implementation of 'Just-In-Time' in a job shop environment. Perhaps the greatest benefit of minimizing WIP is the vastly improved visibility of problems in the manufacturing process. The problems which contribute to consistently low quality, high rework, large inventories and low throughput. Progress towards quality and productivity can only be accomplished when process flaws are exposed and effectively acted upon. Reduction in carrying costs can be viewed as an important fringe benefit.

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## AUTHOR BIOGRAPHY

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