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Procurement Strategy for Manufacturing and JIT

D. K. Singh[1] and Dr. Satyendra Singh[2]
[1]Associate Professor, [2]Associate Professor
[1]Division of MPA Engineering, Netaji Subhas Institute of Technology, New Delhi – 110078.
[2]Deptt. of Mechanical Engg, B. T. Kumaon Institute of Technology, Dwarahat-263653 (Almora).

Abstract: - Procurement involves the purchase of goods and services from the suppliers for the manufacturing units. Procuring the items in the most optimized way is very much desired to implement JIT effectively. Manufacturer-supplier relationship is very crucial for effective procurement policy. The present paper deals with various procurement strategies of manufacturing that include the optimization of manufacturing quantity along with the procurement of multiple input items. The procurement cycles for input items are considered in small lot sizes, which are essential for the effective implementation of JIT. The method of integer programming has been used to find the optimum integer values of number of orders for procuring the input items, which is usually found to be in fraction for a real manufacturing environment.

Keywords: - JIT, Lot size, Procurement, Supply chain management.

Notations used
A_i = Fixed ordering cost for input item *i*
C = Fixed set-up cost for end item
d_i = Replenishment rate of input item *i*, units/period
E = Total relevant cost considering end product and input item together
F = Annual holding cost fraction
G_i = Unit purchase cost for input item *i*
k_i = No. of orders for procurement of input item *i* in a production cycle
m = No. of input items required
n_i = Units of input item *i* required for unit end item
p = Production rate (including defective units), units/period
P = Unit production cost (including value addition)
Q = Production lot size (including defective items)
r = Demand rate for end item, units/period
R = Annual demand for end item
V = Maximum inventory level (excluding defective end items)
y = Proportion of non-defective end items in a lot

I. INTRODUCTION

Inventory management is a key management issue for the plants. It is of strategic importance rather than a mere buying function performed at lower levels of the organization, as has been the case in the past. Just in time (JIT) has been used as one of the most effective methods to control the level of inventory in the recent past, and is used even today most competitively and aggressively. It smoothens the flow of materials to arrive just at the time of their requirements. Deliveries are made directly to the factory floor, thus eliminating the scope of storage, inspection and transportation. JIT is dependent upon both the excellence of the internal manufacturing capabilities, and the development and management of strategic relationships with suppliers. The success of JIT is attributed to the close manufacturer-supplier relationship as a part of procurement strategy [1]. The strong manufacturer-supplier relationship makes a production system more dependable and eliminates any uncertainty regarding manufacturing schedule [2], and hence makes procurement easy for JIT to work more effectively. In case of late deliveries from the supplier, a company will be forced to keep large, costly inventories to keep their own products from being late to their customers [3]. Easy procurement and smooth flow of materials is directly linked to effective supply chain management. Whom to buy materials from, how to transport goods and services, and how to distribute them in the cost-effective, timely manner contributes to much of an organization's strategic planning. Choosing a wrong supplier and a trust deficit in the supplier-manufacturer relationship can result in poor quality and late deliveries, which are detrimental in the interest of an organization. To make an efficient supply chain network, members of the supply chain are required to collaborate and work together, that is, a synergy is required between them, which in turn, greatly depends on the integration of the components of the information system [4]. A supply chain network can fail in the absence of effective information system.

The complete elimination of inventories is very appealing, but it is not always feasible due to economic considerations. It is shown, although in case of complex assemblies, that lot-for-lot production in small batches may not be the best JIT strategy [5]. Significance of lot sizing will always be there whether JIT or traditional approach is applied for managing production-inventory system. Small lot sizes are useful in the implementation of JIT, as they tend to fulfill quick customer requirements. Easy and fast consumption of items in small lot size accelerate the pace of JIT and further procurement becomes more frequent.

The basic EOQ model is a mathematical formulation to find the optimal order size that minimizes the sum of carrying costs and ordering costs. It is modified by incorporating different complexities [6]. A lot size model is developed for procurement of any input item in one or more lots during the production cycle [7]. But replenishment rate of the input item is considered to be infinite. The model is extended in the present paper to incorporate finite replenishment rate for input items and quality defects in a production system. Further a methodology is proposed in order to overcome computational difficulties for evaluation of procurement cycles.

II. MODEL FORMULATION

The model formulation for the procurement policy is based on the following assumptions:

- During the production of a batch of end item, 100% inspection is carried out and rejected items are not added to end item inventory.
- Smaller lot sizes of input items are replenished at the finite rate.
- No price discount is considered on procured input items.
- Replenishment rates of input items are greater than the rate of consumption of these items.

Consider Fig.1, which shows the production-inventory cycles for end items and input items shown together.
Annual inventory holding cost for end items = $(V/2)\, PF$

$$= (yp\text{-}r)\, PFQ/2p \quad [\text{Since, } V = (yp\text{-}r)\, Q/p] \qquad (1)$$

The total annual cost for end product consists of set-up cost and holding cost, that is,

$$(TC)_e = RC / yQ + (yp\text{-}r)\, PFQ/2p \qquad (2)$$

If Q is the production lot size, n_iQ/k_i is the procurement lot size for input item i. Since input items inventory exists for a fraction of cycle time, which is $(Q/p) / (yQ/r)$, that is, r/yp.
Annual inventory carrying costs for input items

$$= \sum_{i=1}^{m} (d_i - pn_i)\, n_i\, r\, G_i\, F\, Q / (2k_i\, d_i\, y\, p) \qquad (3)$$

The total annual cost for all the input items comprising of costs of carrying and ordering is expressed as

$$(TC)_i = \sum_{i=1}^{m} (R\, k_i / y\, Q)\, A_i \; + \; \sum_{i=1}^{m} [(d_i\text{-}pn_i)\, n_i\, r\, G_i\, FQ / (2k_i\, d_i\, y\, p)] \qquad (4)$$

$$E = (R/yQ)\left(C + \sum_{i=1}^{m} A_i\, k_i\right) + (FQ/2p)\left(P\,(yp\text{-}r) + \sum_{i=1}^{m}\left\{(d_i\text{-}pn_i)\, n_i\, G_i\, r \,/\, (y\, k_i\, d_i)\right\}\right) \qquad (5)$$

As the above equation is a convex function, Q can be obtained in terms of k_i by equating partial derivative of E with respect to zero, given as

$$Q\,(k_i) = \left((2pR\,/\,yF)\; \left\{C + \sum_{i=1}^{m} A_i\, k_i\right\} \Big/ \left\{P\,(yp\text{-}r) + \sum_{i=1}^{m} (d_i\text{-}pn_i)\, n_i\, G_i\, r \,/\, (y\, k_i\, d_i)\right\}\right)^{0.5} \qquad (6)$$

Substituting equation (6) into equation (5), we get

$$E = \left((2RF/py) \left\{ C + \sum_{i=1}^{m} Ai\, k_i \right\} \text{ x } \left\{ P\,(yp\text{-}r) + \sum_{i=1}^{m} (d_i\text{-}pn_i)\, n_i\, G_i\, r /(y\, k_i\, d_i) \right\} \right)^{0.5} \qquad (7)$$

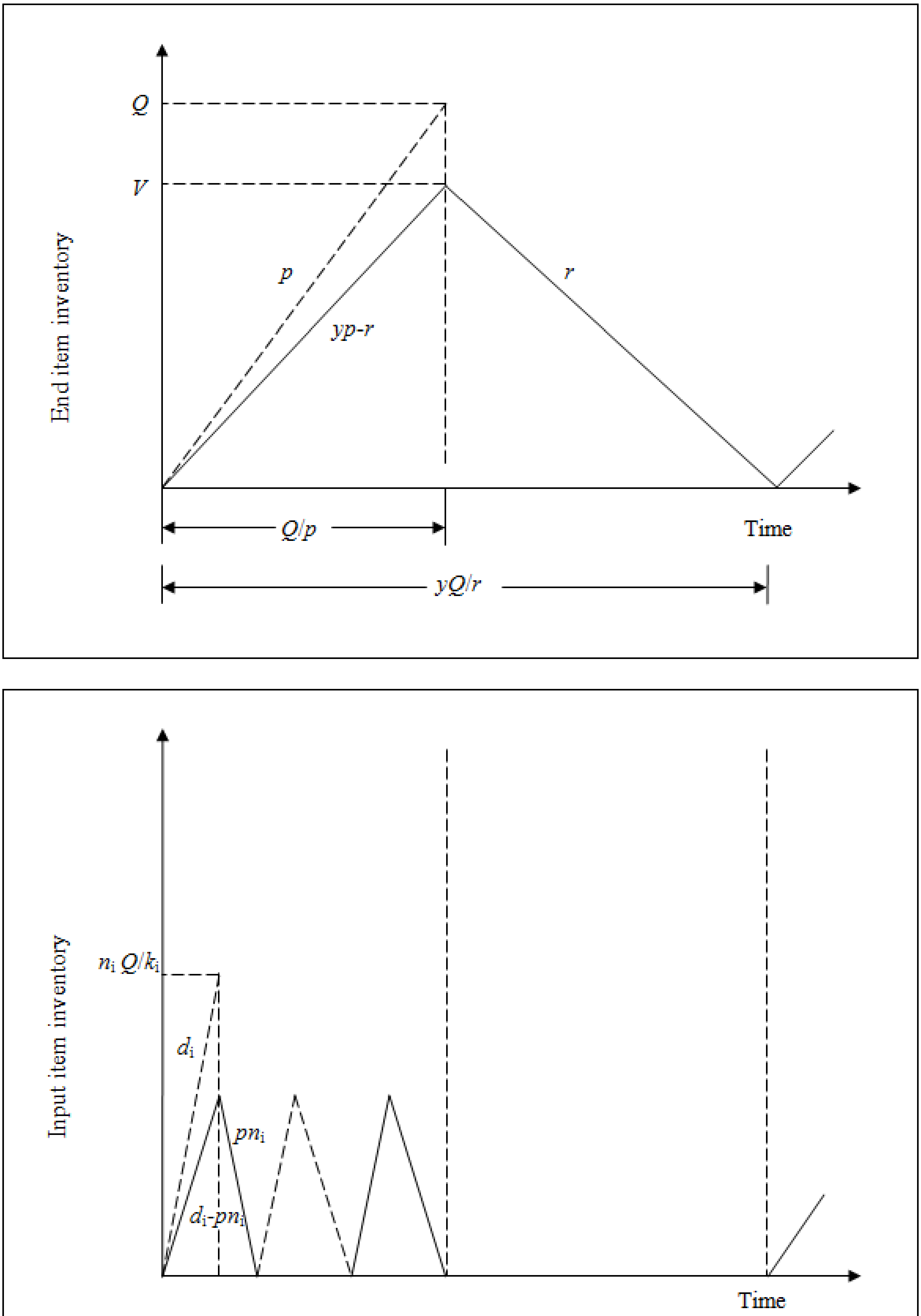

Fig. 1: Production-inventory cycles for end item and input item

Equating partial derivative of equation (7) with respect to each k_i to zero gives

$$k_i = \sqrt{\frac{[C + \sum_{i=1}^{m} A_i k_i]\ [(d_i - p n_i)\, n_i\, G_i\, r]}{y\, d_i\, A_i\, [P\,(yp-r) + \sum_{i=1}^{m} \{(d_i - p n_i)\, n_i\, G_i\, r\,/\,y\, k_i\, d_i\}]}} \qquad (8)$$

Equation (8) can be used to find the optimal solutions of k_i, where i =1, 2, 3… m, as number of equations are equal to number of variables. But due to structure of equations, computational difficulties arise, which further increase as more number of input materials/components is used in real environment. Following methodology is proposed to overcome the problem. Let

$$X = \sqrt{\frac{r\,[C + \sum_{i=1}^{m} A_i k_i]}{y\,[P\,(yp-r) + \sum_{i=1}^{m} \{(d_i - p n_i)\, n_i\, G_i\, r/\,y\, k_i\, d_i\}]}} \qquad (9)$$

and

$$k_i = X \sqrt{\frac{(d_i - p n_i)\, n_i\, G_i}{d_i\, A_i}}\ , i = 1, 2, 3, \ldots\ldots m \qquad (10)$$

From equation (10), values of k_1, k_2… k_m can be found in terms of X. Solving these equations, we can obtain k_2, k_3, … k_m in terms of k_1, and from equation (9), X is evaluated in terms of k_1 only. Value of X, thus, obtained is substituted in equation (10) in order to get a simple quadratic equation in terms of k_1. Optimal value of k_1 is computed, and eventually optimal values of k_i for i = 1, 2, 3… m can be obtained easily. However, these values of k_i are most probably in the decimal form. To find out the integer optimum values of k_i, method of integer programming may be adopted.

Analytical Data

We consider the values of various parameters, which are near to practical values. Taking R = 1200, y = 0.9, C = Rs. 200, F = 0.3, p =120, r =105, P = Rs. 300, and m = 4, the values of A_i, d_i, G_i and n_i are obtained, and are given in Table 1.

Table 1: Data for input items

i	A_i, Rs.	d_i	G_i, Rs.	n_i
1	20	150	15	1
2	50	400	20	3
3	40	300	10	2
4	70	200	50	1

Now from equation (10), we have

$$k_1 = X \sqrt{(d_1 - 120 n_1)\, n_1 G_1 / (d_1 A_1)}$$

Substituting values of parameters from Table 1, we get

$k_1 = 0.3873\ X$ (11)

Similarly,

$k_2 = 0.3464\ X$ (12)

$k_3 = 0.3162\ X$ (13)

and $k_4 = 0.5345\,X$ (14)

Dividing equations (12), (13) and (14) each by equation (11), we get

$k_2 = 0.8944\,k_1$ (15)

$k_3 = 0.8164\,k_1$ (16)

and $k_4 = 1.38\,k_1$ (17)

Using equation (9), we have

$$X = 10.80\sqrt{\frac{200 + 20k_1 + 50k_2 + 40k_3 + 70k_4}{900 + 116.67\,[(3/k_1) + (6/k_2) + (4/k_3) + (20/k_4)]}} \qquad (18)$$

Substituting the values of k_2, k_3 and k_4 from equations (15), (16) and (17), we get

$$X = 10.80\sqrt{\frac{200 + 193.976k_1}{[900 + (3395.1811/k_1)]}} \qquad (19)$$

Using equation (11), we have

$$k_1 = 4.18284\sqrt{\frac{200 + 193.976k_1}{[900 + (3395.1811/k_1)]}} \qquad (20)$$

Or $900\,k_1^2 + 1.3478\,k_1 - 3499.2301 = 0$

Which gives $k_1 = 1.971$

From equations (15), (16) and (17), we have

$k_2 = 1.763$

$k_3 = 1.609$

and $k_4 = 2.72$

Using equation (7), we get E = Rs. 3190.78.

To find out the optimum integer number of orders for procurement of input items, proposed heuristic algorithm [7], which is stated to be more efficient than branch and bound method, is used.

Fig. 2 represents the procedure starting from node I, which is the non-integer solution obtained before. Since, the value of k_1 is 1.971, nearest integers surrounding it are 1 and 2. Node II and Node III represent the solutions corresponding to k_1=2 and 1, respectively. As the value of E with Node II is lesser in comparison to Node III, Node II is considered for further branching with surrounding integer values of k_2. Nodes IV and VII are chosen in a similar way for emanating the branches. Node VIII represents the integer optimum with cost, E = Rs. 3198.70. Optimum production lot size, Q can also be obtained using equation (6) by putting values of k_i, and it is found to be 525.21.

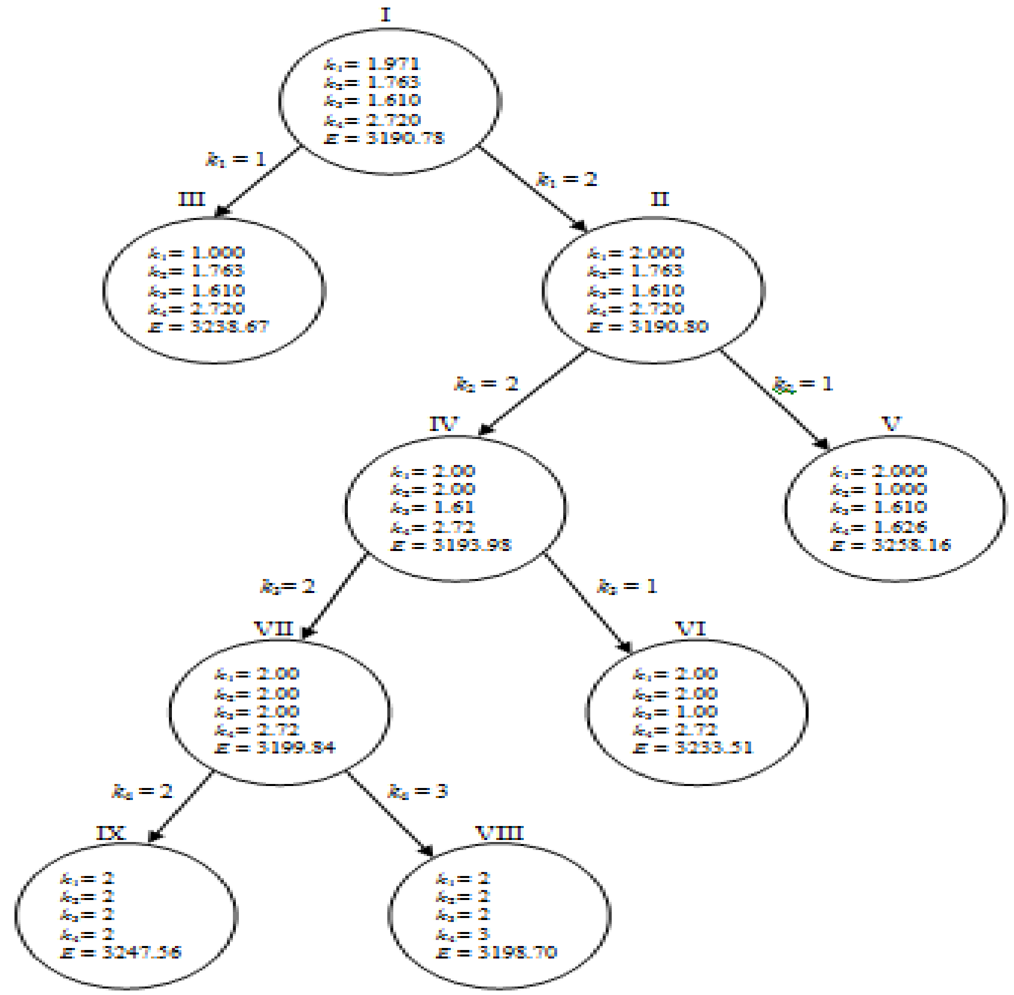

Fig. 2: Finding of optimum integer values for procurement orders

III. DISCUSSION OF RESULTS

(a) Effect of decrease in ordering cost on total annual cost

Fig. 3 shows the effect of decrease in ordering cost for input items on total annual cost. For the data taken, average ordering cost is decreased by a certain percentage uniformly for each input item, that is, for i = 1 to 4. We find that with up to 30% decrease in average ordering cost, the percentage decrease in total annual cost is of the order of 11%. In the uncertain economic environment, cost of capital and thus the inventory carrying cost fraction F varies. The computation is made for various values of F, that is, 0.2, 0.25 and 0.35. Fig. 3 is the representative of these calculations because the relative decrease in E is similar. This is also evident from equation (7) as the absolute values of E only differ and percentage decrease in E at various values of F due to similar percentage decrease in ordering cost may be similar. Values of k_i are independent of F and these are found to be increasing with decreasing A_i, which is obvious.

Fig. 3: Effect of decrease in average ordering cost on total annual cost

(b) Effect of decrease in set-up cost on total annual cost

Fig. 4 shows the effect of decrease in set-up cost for end item on total annual cost. For the data taken, fixed set-up cost (*C*) for end item is decreased. We find about 6% decrease in total annual cost for 30% decrease in set-up cost.

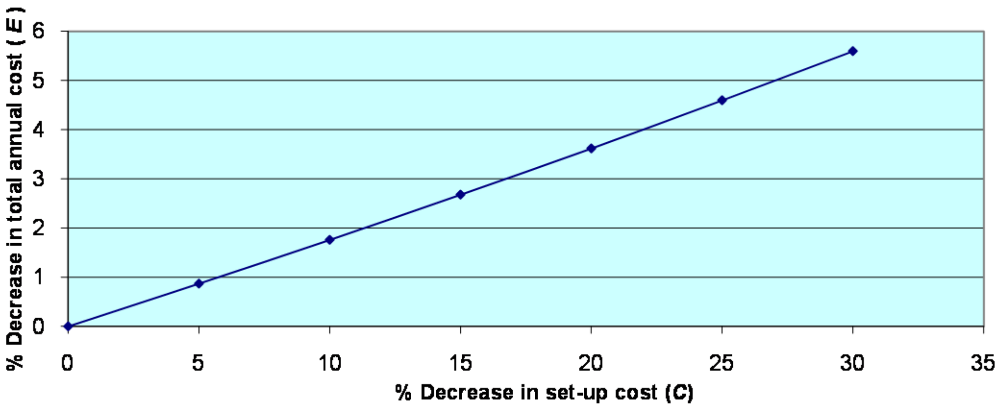

Fig. 4: Effect of decrease in set-up cost on total annual cost

(c) Effect of decrease in non-defective end item on total annual cost

Fig. 5 shows the effect of decrease in proportion of non-defective end items (*y*) in a lot on total annual cost. For the data taken, the total annual cost increases with decrease in *y*. We find the increase of about 5% and 11% in total annual cost corresponding to a respective decrease of about 5% and 10% in the value of *y*. The theoretical value of *y* should be 1. But in many real manufacturing environments, it is not feasible. The development of a new product is a challenging task as far as its quality control is concerned. It contains many untried elements that cause unexpected problems [8].

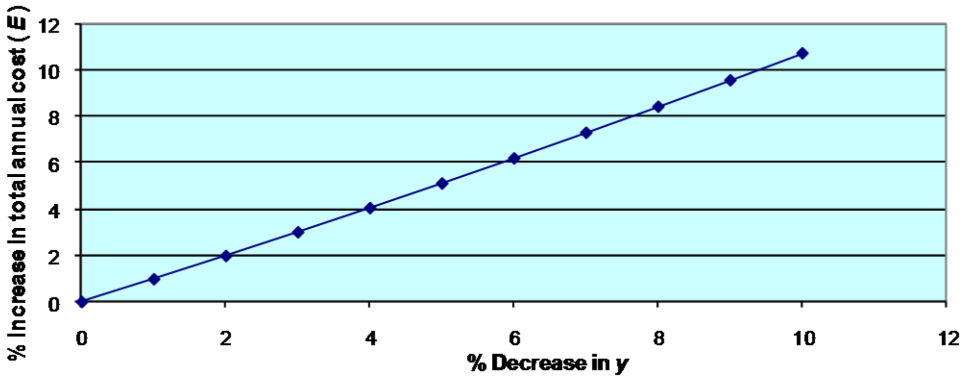

Fig. 5: Effect of decrease in proportion of non-defective end items in a lot on total annual cost

Failure cost increases with the development of product. However, as long as the increase in sales revenue exceeds the increase in cost, it is allowed from managerial, profit-oriented point of view. In yet another case, a company may decide to use an old facility also to take benefit of increase in demand. In spite of old facility generating more number of defective items, profits may be earned. It is of interest to determine ordering policy with respect to quality defects. To conduct the sensitivity analysis with respect to quality level, production cost as well as purchase cost of input items should also be included, since they increase with the increase in quality defects. Since P is unit production cost including value addition, $[(R/y)P]$ represents annual production and purchase cost and it is added in corresponding total cost E obtained earlier from equation (7). The sensitivity analysis is useful in deciding whether to allow more proportion of quality defects in specific situations.

IV. CONCLUSIONS

The procurement model manifests the procurement policy of lot sizing, and includes some realistic manufacturing conditions like finite replenishment rate of input items and quality defects in a production system. Quality and JIT has to work together for better procurement policy, which drastically cuts the level of work-in-process inventory. The TQM is an integral feature for JIT to be successful in manufacturing plants. Simultaneously, optimum number of cycles for the procurement of input items has been derived to obtain the initial solution, and its integer optimum values have also been obtained using method of integer programming.

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