International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol. 3, Issue. 6, Nov - Dec. 2013 pp-3641-3645 ISSN: 2249-6645

An Integrated Inventory Optimization for Deteriorating Products under Multi - Echelon Just In Time (JIT)

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ABSTRACT: *This paper deals with the deterioration inventory model which focuses on optimally coordinating Just In Time (JIT) policy among all the partners with various issues in the supply chain in order to minimize the joint total cost. The total cost for an integrated inventory model includes all costs from multiple suppliers, one producer and multiple buyers and the individual's total cost consist of ordering cost, holding cost, order receiving cost setup cost and deterioration cost. A multiple buyers –multiple suppliers coordination model is developed to facilitate the frequent deliveries in a small lot sizes in a manufacturing supply chain for the deteriorating item. The model based on the integrated total relevant costs for the multiple buyers, a single producer and the multiple suppliers, determines optimal order quantity and number of deliveries over a finite planning horizon in a relatively simple Just In Time scenario.*

Keywords: *Deteriorating Item,* Inventory, *Just in Time, Multi Echelon, Supply Chain, Traditional Production, Total Cost..*

I. INTRODUCTION

The ultimate goal of JIT from the production / inventory management standpoint is to produce small – lot sizes with high – quality products. Investing capital in shortening lead time and improving quality are regarded as the most effective means of achieving this goal. With such characteristics, researchers have modified traditional inventory models to incorporate the implementation of JIT concepts. Just – in – time (JIT) is a philosophy of manufacturing based on planned elimination of all wastes and on continuous improvement of productivity.

Deterioration is applicable to many inventory items in practice, like volatile liquids, agricultural products, radioactive substances, drugs, blood, fashion goods, electronic components, and high-tech products. The deteriorating items are subject to a continuous loss in their masses or utilities throughout their lifetime due to decay, damage, spoilage, and plenty of other reasons.

This paper develops a multiple buyer – multiple supplier coordination model to facilitate frequent deliveries in small lot sizes in a manufacturing supply chain. This based on the integrated total relevant costs of both multiple buyer and supplier, determines optimal order quantity, the number of deliveries over a finite planning horizon in a relatively simple JIT multiple buyer – multiple supplier scenario.

II. LITERATURE REVIEW

Liang-Yuh Ouyang et. al,discussed that an integrated inventory model with a price sensitive demand rate, determining jointly economic lot size of the buyer's ordering and the supplier's production batch, are developed to maximize the total profit per unit time. [1]

Monique Bakker et. al to give a comprehensive literature review of models for inventory control with deteriorating items and mentioned that Multi-echelon inventory control is gaining importance due to the need for supply chain integration in today's competitive environment. [2]

Kung-Jeng Wang et. al investigates how different deterioration rates in each echelon affect performances of individuals and integrated inventory policies. Sensitivity analysis is given to justify that the impact of changes in deterioration rates of each echelon is significant and the joint cost of the proposed integrated inventory policy is found to be much less than the individual policies. [3]

Ali Arkan, and Seyed Reza Hejazi extended inventory model for two-level supply chain which contains single buyer and single supplier, under the credit option. The uncertain demand faced by buyer is adapted with normal distribution. The lead time for receiving his order, can be reduced at an added crashing cost; in other words, it is controllable. On the other hand, ordering cost can also be controlled and reduced through various efforts. [4]

P.C Yang et. al discussed about a closed-loop supply chain inventory system with multi- manufacturing cycles and multi-remanufacturing cycles is analyzed using sequential and global optimization. In the case of sequential optimization, the decision is made initially by the down-stream player, then by the up-stream player. [5]

Hsin Rau et. al developed a multi-echelon inventory model for a deteriorating item and to derive an optimal joint total cost from an integrated perspective among the supplier, the producer, and the buyer. A computer code is developed to derive the optimal solution. the integrated approach strategy results in the lowest joint total cost as compared with the independent decision approaches. [6]

Changyuan Yan et. al developed an integrated production–distribution model for a deteriorating item in a two-echelon supply chain and determined the optimal supply chain decisions with the objective of minimizing the total system cost .[7]

Chao-Kuei Huang et.al dealt with the order-processing cost reduction and permissible delay in payments problem in the single-vendor single-buyer integrated inventory model and to minimize the annual integrated total cost by optimizing simultaneously the delivery interval, the number of deliveries per order and the investment cost in order-processing time. An integrated total cost function is derived, and an algorithm procedure is proposed for determining the optimal decision variables. [8]

Jonas C. P. Yu et. al proposed a supply chain network system with two producers, a single distributor and two retailers. Each retailer has a deterministic demand rate. A mathematical model of deteriorating item is developed to consider a vertical integration of the producer, the distributor and the retailer and a horizontal integration of the producers. [9]

Jin-Shan Yang and Jason Chao-Hsien Pan presented an integrated inventory model to minimize the sum of the ordering/setup cost, holding cost, quality improvement investment and crashing cost by simultaneously optimizing the order quantity, lead time, process quality and number of deliveries while the probability distribution of the lead time demand is normal. This integrated inventory model is useful particularly for JIT inventory systems where the vendor and the purchaser form a strategic alliance for profit sharing. [10]

III. PROBLEM DEFINITION

Based on the research studies, it was observed that small lot sizing as a means of implementing successful JIT purchasing, with the buyer – supplier coordination focusing on material flows with an objective of minimizing supply chain costs. The total cost for an integrated inventory model includes all costs from both buyer and supplier. An integrated approach allows the buyer and the supplier to reduce their total costs as compared to non – integrated approach.

IV. INTEGRATED MODEL

Small lot sizing improves the system's productivity by obtaining lower levels of inventory and scrap, lower inspection costs for incoming parts, and earlier detection of defects, etc., even though possible higher delivery costs and loss of discount rates may be incurred. In general, implementation of frequent deliveries in small lots requires firms to reduce the number of suppliers (even to a single supplier). Otherwise, the potential strength of relationship between buyer and supplier would be weakened. Here, the supplier is viewed as part of a team, providing certified quality material at lower costs, rather than as an opponent who is consistently seeking short – term price breaks in an adversarial bargaining process. The supplier and buyer work in a cooperative manner to synchronize supply with actual customer demand. In this scenario, it could be more reasonable to determine the order quantity and the delivery schedule based on their integrated total cost function, rather than using the buyer's or the supplier's individual cost functions.

V. MODEL DEVELOPMENT

The model developed in based on the concepts of deterioration inventory system, the JIT production environment, and the supply chain system & multi stage multi echelon model. To consider a deteriorating item and to develop an optimal joint total cost from the perspectives of a multiple supplier, a manufacturer and a multiple buyer under a JIT production environment.

1. Assumptions

To derive optimal number of deliveries production and order cycle with multiple suppliers, manufacturer and multiple buyers when the integrated joint total cost is minimized globally.

- Demand rate and production rate is deterministic and constant.
- Production rate is greater than demand rate.
- Negligible lead time.
- Shortage is not allowed.
- Multiple supplier – One producer – Multiple buyer.
- Deterioration rate is deterministic and constant.
- Single item.
- Multiple lot size deliveries per order.
- Supplier delivers same lot size of same size of raw materials each time to the producer.
- Producer delivers same lot size of finished item each time to the buyer.

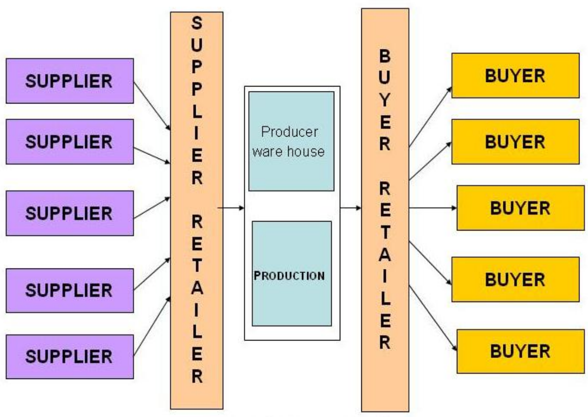

Fig. 1 Integrated Supply Chain Model

This integrated supply chain system model illustrates the supplier – retailer procures raw materials from outside suppliers and delivers them in fixed quantities to the producer's warehouse at a fixed time interval. The producer withdraws raw materials from the warehouse and processes them into finished goods. The producer then delivers the finished goods in fixed quantities to the buyer. Retailer at a fixed time interval and delivers to various buyers also at fixed time interval. The demand of the supplier retailer will be equal to the demand of the producer which will be procured from the outside suppliers and the buyer retailer will have the demand equal to the demand given by the outside suppliers

2. Buyer –Retailer's finished Good Inventory Model

The total cost of finished goods for the buyer retailer per period 'T' can be expressed as the sum of the order cost, receiving cost, holding cost and the deteriorating cost

$$TC_{BR} = A + n.F_{BR} + n.\Sigma.\left(\frac{H_{BR}}{\theta_{BR}{}^{2}}(e^{\theta_{BR}t} - 1 - \theta_{BR}t) + P_{BR}(e^{\theta_{BR}} - 1 - \theta_{BR}t)\right) \quad (1)$$

Where, TC_{BR} is Buyer – Retailer's total Cost, H_{BR} is the holding cost per unit per unit time by Buyer-retailers, θ is Deterioration rate for Buyer - Retailer, P_{BR} is deterioration cost per unit per unit time by retailers, A is ordering cost per time, n is Number of deliveries of finished goods from the producer to buyer per order cycle T, F_{BR} is Receiving cost of finished goods per receiving for the buyer, t is replenishment cycle time for buyer - retailer.

3. The Producer's Warehouse Raw Materials Inventory Model

Total cost for the producer's ware house raw material can be expressed as the sum of the receiving cost, holding cost and the deteriorating cost.

$$TC_{PW} = n.\left(F_{PW} + A_{PW} + H_{PW} + P_{PW}(q_{PW} - pt_{P})\right) \quad (2)$$

Where , TC_{PW} is Producer warehouse total cost , n is number of deliveries , F_{pw} is Receiving cost of raw materials per receive for the producer , A_{pw} is ordering cost per time from producer's warehouse, H_{pw} is holding cost per unit per unit time by producer's warehouse , P_{pw} is deterioration cost per unit per unit time by producer's warehouse , q_{pw} is Lot size raw materials per delivery from the supplier of the producer's warehouse , t_P is replenishment cycle time for producer.

4. The Producer's Finished Good Inventory Model

The total finished goods cost for the producer can be expressed as the sum of the setup cost, delivery cost, holding cost and deteriorating cost

$$TC_{P} = n.\left(S_{P} + F_{P} + (Pt_{P} - q_{BR})\left[\frac{H_{P}}{\theta_{P}} + P_{P}\right]\right) \quad (3)$$

Where TC_P is Producer's Total Cost , q_{BR} is Lot size raw materials per delivery from the supplier of the buyer-retailer , H_p is holding cost per unit per unit time by producer , θ_p is Deterioration rate at producer , P_P is deterioration cost per unit per unit time for producer , S_p is Setup cost of per setup for the producer , F_P is Delivery cost of finished goods per deliver for the producer.

5. The Supplier –Retailer's Inventory Model

Total raw material cost for the supplier retailer can be expressed as the sum of the order cost, delivery cost, holding cost and the deteriorating cost

$$TC_{SR} = S + n.\left\{F_{SR} + H_{SR}\left[\frac{Q_{PW}\left[(1-\theta_{SR})^{t} - Q_{PW}\right]}{\ln(1-\theta_{SR})}\right]\right\} \quad (4)$$

Where , TC_{SR} is Supplier –Retailer's total cost , H_{SR} is holding cost per unit per unit time by supplier – retailer , θ_{SR} is Deterioration rate at Supplier – Retailer , Q_{PW} is Lot- size of raw materials from the outside supplier to the supplier , t is replenishment cycle time at supplier retailer , S is Setup cost of per setup .

6. Integrated Joint Total Cost

The integrated total cost for the buyer – retailer, the manufacturer and the supplier – retailer TC_I is

$$\mathbf{TC_I = TC_{BR} + TC_{PW} + TC_P + TC_{SR}} \quad (5)$$

VI. NUMERICAL EXAMPLE

1. Buyer - Retailer's Parameter Data

Demand rate of finished goods is 9500 units per week. The ordering cost of finished goods is Rs.280 per order; the receiving cost of finished goods is Rs.23 per receiving; the holding cost of finished goods per unit is Rs.14; the deteriorating cost of finished goods per unit is Rs.105; the deterioration rate is 0.07.

2. Producer's Parameter Data

Production rate of finished goods is 19500 units per week. The setup cost of finished goods is Rs.475 per setup; the delivery cost of finished goods is Rs.140 per delivery the holding cost of finished goods per unit is Rs.11.50; the deteriorating cost of finished goods per unit is Rs.85; the deterioration rate is 0.09. The receiving cost of materials is Rs.17 per receiving; the holding cost of raw materials per unit is Rs.10; the deteriorating cost of raw materials per unit is Rs.80, the deterioration rate is 0.095.

3. Supplier – Retailer 'S Parameter Data

The ordering cost of raw materials is Rs.240 per order; the delivery cost of raw materials is Rs.120 per delivery; the holding cost of raw materials per unit is Rs.7; the deteriorated cost of raw materials per unit is Rs.70, the deterioration rate is 0.1.

The above parameters data is substituted into the derived supply chain inventory model for deteriorating items in the JIT environment. The problem is to determine the optimal value of N that minimizes TC. A computer code using the software Mat lab is develop to derive the optimal solution; namely the optimal delivery times N and total cost.

VII. RESULTS AND DISCUSSION

The comparison between integrated view of JIT and traditional view is made. In JIT, the optimal number of delivery is 23 and for the traditional is 48. Optimal joint total cost in traditional view is Rs.88288 and Rs.37611 for JIT respectively showing that JIT implementation is more cost effective than the traditional view.

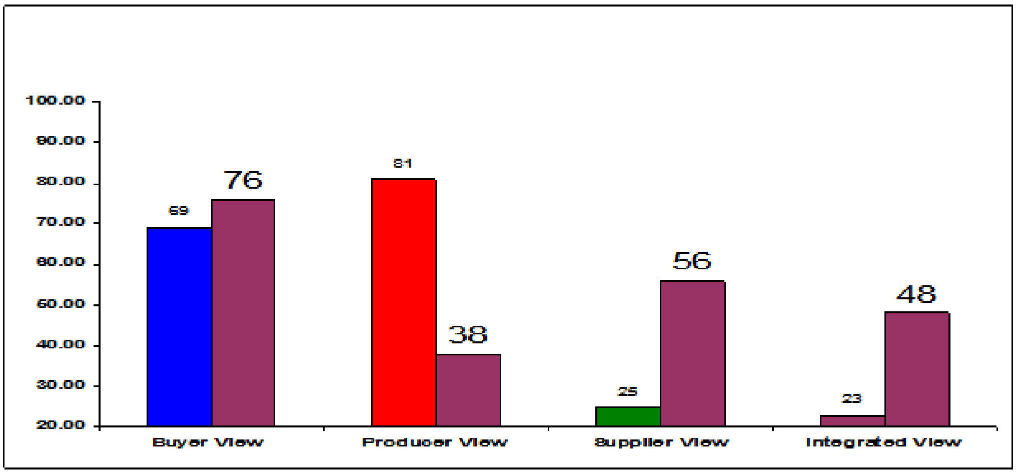

Fig.2 JIT Vs Traditional Number of deliveries for the different views

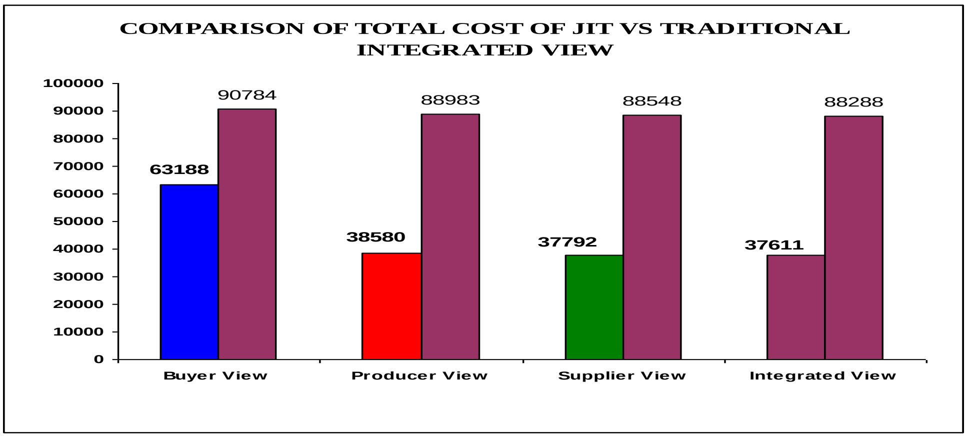

Fig.3 Comparison of Total Cost of JIT Vs Traditional Integrated View

VIII. CONCLUSION

The JIT production was adopted to achieve lower inventory costs. From model development, we determined how to minimize the total cost in each view. It was also shown that the integrated approach has the lowest joint total cost among all views. The JIT integrated view is compared with traditional inventory system show the JIT production environment is more cost effective than the traditional production environment for deteriorating item.

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