AN OPTIMIZING INTEGRATED INVENTORY MODEL WITH INVESTMENT FOR QUALITY IMPROVEMENT AND SETUP COST REDUCTION

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Abstract

This paper presents a vendor-buyer integrated inventory model. This paper considers the problem of a vendor and buyer integrated production inventory model for the vendor and the buyer optimization model under quality improvement investment and setup cost reduction in the production system such that the total profit is maximized. The relationship between demand and price is considered as a linear. Entirety profit is the supply chain presentation calculate and it is calculated as the dissimilarity among revenue from sales and total cost, where the last is the sum of the vendor's and buyer's setup/order and inventory holding costs, opportunity in setup cost and opportunity investment cost. This manuscript efforts to conclude the optimal production run time and capital investments in setup cost reduction and process quality improvement for production system such that the total profit is maximized. The main focus for this paper is the setup cost reduction and investment for quality improvement. The proposed model is based on the integrated total profit for both buyer and vendor which find out the optimal value of order quantity, opportunity investment cost for quality improvement and setup cost reduction. The solution procedure is developed in order to find the total profit of the vendor and the buyer which is to be maximized. To conclude, a numerical example is given to demonstrate the solution procedure.

Keywords

Integrated inventory model, Price-sensitive demand, Investment for quality improvement, Setup cost reduction.

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1. INTRODUCTION

Most of the inventory model, researchers considered only the independent viewpoint. However, in a supply chain environment, the coordination of all the partners is the key to efficient management of a supply chain to achieve global optimality. Study on coordinating supply chains is presently very popular. During the last few years, the concept of integrated vendor and the buyer inventory management has attracted considerable attention, accompanying the growth of Supply Chain Management (SCM). Recognizing the strategic the vendor and the buyer partnerships, as a fundamental driver for the success of the supply chain, increasing attention has been placed on the integrated vendor-buyer inventory models.

Inventory management is a science mainly about specifying the shape and assignment of stocked goods. It is required at dissimilar locations within a facility or within lots of locations of a supply network to precede the standard and intended course of manufacture and stock of materials. Inventory management plays a significant role in businesses because it can help companies reach the goal of ensuring prompt release, avoiding shortages, helping sales at spirited prices and so forth. To control an inventory system, one cannot ignore demand monitoring since inventory is partially driven by demand, and as suggested by Lau et al. [14] in many cases a small change in the demand pattern may result in a large change in optimal inventory decisions. A manager of a company has to investigate the factors that influence the demand pattern, because the customers' purchasing behavior may be affected by factors such as the selling price, inventory level, seasonality, and so on.

A supply Chain (SC) is a system among a corporation and its suppliers to create and hand out a specific product, and the supply chain stand for the steps it takes to get the manufactured merchandise or tune-up to the customer. Supply chain management (SCM) is a crucial process, because an optimized supply chain results in lower costs and a faster production cycle.

Supply chain management (SCM) is the active streamlining of a business' supply-side activities to capitalize on client value and gain a competitive advantage in the marketplace. SCM represents an attempt by suppliers to develop and employ supply chains that are as well-organized and economical as possible. Supply chains cover everything from production, to product development, to the in sequence systems needed to direct these undertakings. The three main flows of the supply chain are the produce run, the information run and the finances run. SCM involves coordinating and integrating these flows both within and among companies.

The effectiveness of coordination in supply chains could be measured in two ways: reduction in total supply chain costs and enhanced coordination services provided to the end customer and to all players in the supply chain. The integrated vendor-buyer problem is called the Joint Economic Lot Sizing (JELS) problem and can be considered as the building block for wider supply chain systems. The global supply chain can be very complex and link-by-link understanding of joint policies can be very useful.

The paper assumes a single product that flows along a two-level supply chain (vendor–buyer). We assumed that the buyer faces a linear demand, $D(\alpha) = a - b\delta$, $(a > b > 0)$ as a function of his/her unit retail price, which increases as the price decreases. furthermore , we utilize a mark-up policy where selling price is set based on the unit purchasing prices c, plus a stable percentage markup , i.e. linear demand, which is unspecified to be sensitive to price and mark-up policy.

This paper considers the problem of a vendor-buyer integrated production-inventory model. We have developed an optimizing integrated inventory model with investment for quality improvement and setup cost reduction. The model proposed, based on the integrated total relevant profits of both buyer and vendor, finds out the optimal values of order quantity, investment for quality improvement, setup cost reduction, using an analytical approach. Finally, a numerical example will be provided to illustrate the proposed model. By the logarithm investment function, the optimal investment quality improvement and setup cost reduction investment also are obtained.

2.LITERATURE REVIEW

The extraordinary interest in supply chain management related investigate in the last decade has been due to its important possible to improve the efficiency of operations and decrease of cost. Each human being party in the supply chain can benefit from side to side closer collaboration with other parties and through the integration of various decision processes. The single-vendor and the single-buyer problem are considered as the building block of any supply chain. Many load policies have been proposed in literature for this problem. Goyal [4] suggested a lot-for-lot policy with the assumption of unlimited production rate. Banerjee [1] planned a lot-for-lot policy with the assumption of finite production rate. Goyal [5] relaxed lot-for-lot assumption and assumed that the vendor ships the lot in a number of equal size shipments. Goyal [6] developed a policy where the shipment sizes increase by a factor increasing geometrically. Hill [8] generalized the model developed by Goyal [6] by considering the geometric growth factor as a decision variable. Hill [9] found the optimal solution of the problem without any assumptions about the shipment policy. Goyal et al. [7] Considered a policy where the first shipment is small and the following shipments are larger and of equal size. For comprehensive reviews to Goyal et al. [3] and Ben-Daya et al. [2] for comprehensive reviews.

The systematic draw near to reduction or removal of waste, revise, and losses in production process. Quality management is the act of overseeing all activities and tasks needed to maintain a desired level of excellence. This includes the determination of a quality policy, creating and implementing quality planning and assurance, and quality control and quality improvement. It is also referred to as total quality management (TQM). Quality has been extremely emphasized in modern production/inventory management systems. Also, it has been supported that the success of Just-In-Tim (JIT) production is partly based on the belief that quality is a controllable factor, which can be improved through various efforts such as worker preparation and dedicated tackle acquisition. In the classical economic order quantity (EOQ) model, the quality-related issue is often neglected; it implicitly assumes that quality is fixed at an optimal level (i.e., all items are assumed with perfect quality) and not controllable. However, this may not be true. In real production surroundings, we can often observe that there are defective items being produced. These defective items must be discarded, fixed, revised, or, if they have reached the customer, refunded; and in all cases, substantial costs are incurred.

Porteus [21] and Rosenblatt et al. [22] are the first to openly complicated on the important association among quality imperfection and lot size. specially, Porteus [21] extended the EOQ model to include a situation where the production process is imperfect, and based on this model he further considered the effects of investment in quality improvement by introducing the additional investing options. Since Porteus, several authors proposed the quality improvement models under various settings, see e.g. Keller et al. [13], Hwang et al. [12], Moon [16], Hong et al. [10] and Ouyang et al. [18]. We note that in the body of literature [10, 12, 13, 14, 15, 16], a common approach utilized to develop the total cost of quality improvement model is adding the investment cost necessary for quality improvement to the system operating costs, where the investment amount is further charged a fixed opportunity cost instead of modeling the system with discounted costs. However, in practice, the opportunity cost rate (e.g., interest rate) may not be fixed; it may slightly change from time to time, particularly, in an unstable environment.

We think that the association connecting setup cost reduction (or process quality improvement) and capital investment can be described by the logarithmic investment function. This logarithmic investment function which has been used in earlier researchers by Paknejad et al. [20], Nasri et al. [15], Sarker et al. [21], and Hofmann [11], In addition, a procedure is provided to find the optimal production runs. Ouyang et al. [17] discussed a lot size, reorder point inventory model with controllable lead time and setup cost. Porteus [21] proposed an inventory model with optimal lot sizing, process quality improvement and setup cost reduction. Ouyang et al. [19] talk about quality improvement setup cost and lead time reduction in lot size reorder point models with an imperfect production process.

Setup costs are bringing upon you when production or assembly lines are changed for example, when the manufacturing department has to change equipment for a different product or part to be manufactured. It is easier for businesses to understand and be pleased about the costs involved in manufacture setups than the costs of ordering objects from a vendor. Manufacturing companies are often too aware of the costs of changing the manufacturing line from creating one item for creating another. There have often been much conversation and analysis of the best way to minimize the occasion and price of changing production on the shop floor. But with setup costs, there are still two component costs; fixed and variable.

In a manufacture setup the fixed costs will include the costs of the capital equipment used in tearing down the production line used for the old items and setting up machine for the new items. The variable costs in production setup include the personnel costs in changing overproduction, as well as the consumable material used in the tear down and setup. The longer the production tears down and setup takes, the higher the variable costs. Vijayashree and Uthayakumar [29] have developed an integrated vendor and buyer inventory model with investment for quality improvement and setup cost reduction. Vijayashree and Uthayakumar [27] developed an integrated inventory model with controllable lead time and setup cost reduction for defective and non-defective items.

In the context of Economic Order quantity EOQ model, Porteus [21] primary considered a situation where the production process can go 'out-of-control' with a given probability θ each time it produces another item. Once the process is 'out-of-control', it remains that until the remainder of the lot has been produced. Rosenblatt et al. [22] analyzes the case when the system deteriorates during the production process and produces some proportion of defective items. Yang and Pan [31] considered variable lead time and quantity improvement investment with normal distributional insist in the model. In addition, Rosenblatt et al. [22] assume that the elapsed time until the production process shift is a random variable and is exponentially distributed, and derive an approximated optimal manufacture run time in their models, showed that the resulting production lot size should be smaller than that of the classical EPQ formula, and thus there would be an incentive to produce smaller lots. Moreover, Porteus [21] initiated the notion of a joint investment in process quality improvement and setup cost reduction in the EOQ model. Porteus [21], Hong et al. [10] considered the economic benefits of reducing setup cost and improving process quality by joint capital investment under a budget constraint.

Vijayashree and Uthayakumar [28] have considered integrated inventory model with controllable lead time involving investment for quality improvement in supply chain system. Vijayashree and Uthayakumar [24] have presented inventory models involving lead time crashing cost as an exponential function. Vijayashree and Uthayakumar [26] have presented a two stage supply chain model with selling price dependent demand and investment for quality improvement. Vijayashree and Uthayakumar [25] have discussed vendor-buyer integrated inventory model with quality improvement and negative exponential lead time crashing cost. Vijayashree and Uthayakumar [30] have developed two-echelon supply chain inventory model with controllable lead time.

To best our knowledge, we develop an integrated inventory model system consisting of a vendor and buyer under investment for quality improvement and setup cost reduction. The objective of this paper is to maximize the total profit for the vendor and buyer. We analyze how the coordination between two stage supply chain models is affected when the customer demand is price sensitive.

The paper is organized as follows: In section 3, notations are discussed. In section 4, assumptions are given. Section 5 is discussed with model development for the buyer and the vendor integrated model and investment for quality improvement and setup cost reduction. In section 6, solution procedure is presented. In section 7, an algorithm procedure is developed to find the optimal solution to the integrated inventory model. In section 8, a numerical example is offered. Finally, we draw conclusions and further researches are summarized in Section 9.

3. NOTATIONS

To establish the mathematical model, the following notations are used as follows

D Demand rate as a function of unit selling price

P Production rate of the vendor

Q Optimal order quantity (Decision Variable)

A_v Vendor’s setup cost per setup (Decision variable).

A_{v0} Original ordering cost (before any investment is made)

A_b Buyer’s ordering cost

δ The buyer unit selling price

c	The buyer unit purchasing price
α	Mark-up percentage
h_v	Inventory holding cost for the vendor per year
h_b	Inventory holding cost for the buyer per year
g	Cost incurred by producing a defective item (for rework and related operations)
θ_0	Original percentage of defective products produced once the system is in the out of control state prior to investment
θ	Percentage of defective products produced once the system is in the out of control state (Decision Variable)
$q(\theta)$	The investment required to reduce the out-of-control probability θ to θ_0
$q(A_v)$	Capital investment required to achieve setup cost A_v to A_{v0}
i	The fractional per unit time opportunity cost of capital (the opportunity cost rate)
ε	Percentage decrease in θ per dollar increase investment in $q(\theta)$ and $q(A_v)$.
ITP	Integrated total profit for the vendor and the buyer

4. ASSUMPTIONS

To establish the mathematical model, the following the assumptions of the model are summarized as follows

1. The integrated system of single–vendor and single-buyer for a single product is considered.
2. The buyer faces a linear demand as a function of the selling price $D(\alpha) = a - b\delta$, $(a > b > 0)$.
3. Selling price is set based on the unit purchasing price plus a constant percentage mark-up, $\delta = (1+\alpha)c$
4. The inventory is continuously reviewed and replenished.
5. Shortage is not allowed.
6. A finite production rate for the vendor is considered, which is greater than the demand rate.
7. The logarithm investment cost function employed to describe the relationship between $q(\theta)$ and θ that is $q(\theta) = q_1 \ln\left(\frac{\theta_0}{\theta}\right)$ $(0 < \theta \le \theta_0)$ where θ_0 is the original out-of-control probability; $q_1 = \left(\frac{1}{\varepsilon}\right)$ with ε denoting the percentage decrease in θ per dollar increase in $q(\theta)$.

8. We assume that the capital investment $q(A_v)$, in reducing setup cost is a logarithm function of the setup cost A_v, that is for $q(A_v) = q_2 \ln\left(\frac{A_{vo}}{A_v}\right)$, for $0 < A_v \le A_{v0}$, where $q_2 = \left(\frac{1}{\varepsilon}\right)$ with ε denoting the percentage decrease in A_v per dollar increase in $q(A_v)$.

9. The inventory holding cost at the buyer is higher than that at the vendor, i.e. $h_b > h_v$.

10. All defective items produced are detected after the production cycle is over, and rework cost for defective items will be incurred.

11. Defective item revise cost per unit time, the anticipated number of defective items in a run of size Q with a given probability of θ that the procedure can go out of control is $\frac{Q^2\theta}{2}$. Thus, the defective cost per unit time is given $\frac{SDQ\theta}{2}$.

12. Investment cost required for quality improvement $iq_1 \ln\left(\frac{\theta_0}{\theta}\right)$.

13. Opportunity cost of setup cost reduction $= iq_2 \ln\left(\frac{A_{v0}}{A_v}\right)$.

5. MODEL DEVELOPMENT

The optimal order quantity and profit margin of the incorporated system is derived in this section. We first obtain the optimal policies if each supply chain member tries to maximize its benefit. Then, the policies and profits are compared with the case of an integrated system when they cooperate with each other.

We assume that the buyer faces a linear demand, $D(\delta) = a - b\delta$ (a > b > 0), as a function of his/her unit retail price, which increases as the price decreases. Moreover, we employ a mark-up pricing policy where the selling price is set based on the unit purchasing price, c, plus a constant percentage mark-up, i.e. $\delta = (1+\alpha)c$. Since $D(\alpha) = a - bc - \alpha bc$ the maximum percentage mark-up is $a/bc - 1$.

The total profit for the vendor and the buyer is equal to the gross revenue minus the sum of the purchasing cost, the order processing cost, and inventory holding cost, defective cost and opportunity investment cost for quality improvement and investment for setup cost. Consequently the total profit is going to be maximized, i.e.

$$\underset{(\alpha,Q,\theta,A_v)}{\text{maximize}}\, ITP(\alpha,Q,\theta,A_v) = (1+\alpha)c(a-bc-\alpha bc) - \frac{(a-bc-\alpha bc)(A_v+A_b)}{Q}$$
$$-\frac{Q}{2}\left[h_b + g\theta(a-bc-\alpha bc) + h_v(a-bc-\alpha bc)/P\right]$$
$$-iq_1\ln\left(\frac{\theta_0}{\theta}\right) - iq_2\log\left(\frac{A_{v0}}{A_v}\right) \quad (1)$$

for $0<\theta\le\theta_o$ and $0<A_v\le A_{v0}$, where i is the unfinished opportunity cost of capital per unit time.

6. SOLUTION PROCEDURE

It can effortlessly be shown that the total organization profit is concave in Q for the known values of the buyer percentage mark-up α.

Taking the first order partial derivatives of $TC(Q,\theta,m,A_v)$ with respect to Q, θ and A_v equating them to zero, we get

$$\frac{\partial ITP}{\partial Q} = \frac{(a-bc-\alpha bc)(A_b+A_v)}{Q^2} - \frac{1}{2}\left[h_b + g\theta(a-bc-\alpha bc) + \frac{h_v(a-bc-\alpha bc)}{P}\right] \quad (2)$$

$$\frac{\partial ITP}{\partial \theta} = -\frac{QS(a-bc-\alpha bc)}{2} + \frac{iq_1}{\theta} \quad (2)$$

$$\frac{\partial ITP}{\partial A_v} = -\frac{(a-bc-\alpha bc)}{Q} + \frac{iq_2}{A_v} \quad (3)$$

$$Q^* = \sqrt{\frac{2(a-bc-\alpha bc)(A_b+A_v)}{\left[h_b + g\theta(a-bc-\alpha bc) + \frac{h_v(a-bc-\alpha bc)}{P}\right]}} \quad (4)$$

$$\theta^* = \frac{2iq_1}{QS(a-bc-\alpha bc)} \quad (5)$$

$$A_v^* = \frac{Qiq_2}{(a-bc-\alpha bc)} \quad (6)$$

Substituting expression (4), (5) and (6) into the cost function (1), we get

$$TP(Q,\theta,A_v)=(1+\alpha)c(a-bc-\alpha bc)-\sqrt{2(a-bc-\alpha bc)(A_b+A_v)\left[h_b+g\theta(a-bc-\alpha bc)+\frac{h_v(a-bc-\alpha bc)}{P}\right]}$$
$$-iq_1\ln\left(\frac{\theta_0 Qg(a-bc-\alpha bc)}{2iq_1}\right)-iq_2\ln\left(\frac{A_{v0}(a-bc-\alpha bc)}{Qiq_2}\right) \qquad (7)$$

Further, based on the convexity and concavity behavior of the objective function with respect to the decision variable, the following algorithm is designed to find the optimal values of order quantity Q, process quality θ and setup cost A_v which maximize the integrate total profit $ITP(Q,\theta,A_v)$.Therefore we establish the following iterative algorithm to obtain the optimal solution.

7. ALGORITHM

Step 1. Begin with $\theta=\theta_0$ and $A_v=A_{v0}$.

(i).Substitute θ and A_v into equation (4) estimate Q.

(ii).Utilizing Q find out θ and A_v from equations (5) and (6).

(iii).Repeat step (i) - (ii) until no modify occurs in the values of, Q,θ, and A_v. Denote the solution by $(Q^{'},\theta^{'},A_v^{'})$.

Step 2. Compare $\theta^{'}$ & θ_0, and $A_v^{'}$ & A_{v0}, correspondingly.

If $\theta^{'}<\theta_0$ and $A_v^{'}<A_{v0}$, then the key found in step 1 is optimal solution.

` We indicate the optimal solution by (Q^*,θ^*,A_v^*). If $(Q^*,\theta^*,A_v^*).=(Q^{'},\theta^{'},A_v^{'})$, then go to step (7), otherwise go to step (3).

Step 3. If $\theta^*<\theta_0$ and $A_v^*\geq A_{v0}$ go to step 4. If $\theta^*\geq\theta_0$ and $A_v^*<A_{v0}$ go to step 5. If $\theta^*\geq\theta_0$ and $A_v^*\geq A_{v0}$, then go to step 6.

Step 4. Let $A_v^*=A_v$ and exploit equations (4) and (5) to find out the new $(Q^{'},\theta^{'})$ by a procedure similar to the one in Step 1, the result is denoted by $(\dot{Q},\dot{\theta})$. If $\dot{\theta}<\theta_0$, then the optimal solution is obtained, i.e., if $(Q^*,\theta^*,A_v^*).=$ $(\dot{Q},\dot{\theta},A_{v0})$. then go to step (7), otherwise go to step (iv).

(i) let $\theta^*=\theta_0$ and exploit equation (4) to find out the new $Q^{'}$, then go to step (7).

Step 5. Let $\theta^* = \theta_0$ and utilize equations (4) and (6) to find out the new $(Q^{'}, A_v^{'})$ by a method similar to the one in Step 1, the result is denoted by $(\dot{Q}, \dot{A}_v)$. If $\dot{A}_v < A_{v0}$, then the optimal solution is obtained, i.e., if $(Q^*, \theta^*, A_v^*) = (Q^*, \theta^*, \dot{A}_v)$. then go to step (7), otherwise go to step (v).

(ii) $A_v^* = A_{v0}$ And utilize equation (4) to find out the new $Q^{'}$, then go to step (7).

Step 6. Let $A_v^* = A_{v0}$ and $\theta^* = \theta_0$, and utilize equation (4) to find out the new $Q^{'}$, then go to step (7).

Step 7. Utilize equation (1) to calculate the corresponding integrated to compute the integrated total profit $ITP(Q, \theta, A_v)$. Then go to step 8.

Step 8. Set $(Q^*, \theta^*, A_v^*) = (Q^*, \theta^*, A_v^*)$, then (Q^*, θ^*, A_v^*) is the optimal solutions.

8. NUMERICAL EXAMPLE

Consider an inventory system with the following characteristics $P = 3200/\text{year}$ $A_v = \$\ 400/\text{unit}$, $A_b = \$\ 25/\text{unit}$, $h_b = \$5/\text{unit}$, $h_v = \$4/\text{unit}$, $S = 15/unit$

$i = \$0.2/\text{year}$, $\theta = 0.0002$ $q(\theta) = 400\ln\left(\frac{\theta_0}{\theta}\right)$. $\alpha = \$0.50/\text{unit}$, $q(A_v) = 1500\ln\left(\frac{A_{v0}}{A_v}\right)$. Beside we take, $a = 1500$, $b = 10$, $c = \$\ 60/\text{unit}$, applying the solution procedure we have optimal order quantity $Q^* = 284$ units, $A_v^* = \$70$, $\theta^* = 0.000012790$, Total profit $TP = \$52224$.

9. CONCLUSION

The main purpose of this paper is to present the vendor and the buyer optimizing integrated inventory model with investment for quality improvement and effectively rising investment to reduce the setup cost. We developed an integrated inventory model for integrated optimization.

The buyer faces a linear demand as a function of the selling price. Selling price is set based on the unit purchasing price plus a constant percentage mark-up. The paper assumes a single product that flows along a two-level supply chain (vendor–buyer). The buyer faces a linear demand, which is assumed to be sensitive to price and mark-up percentage performance.

In this paper, we have used the logarithmic function to obtain the investment for quality improvement and setup cost reduction. In the analysis, we assumed that the setup cost and process quality are functions of capital expenditure, respectively. In addition, we offer a method to find the optimal production run time, setup cost and process quality improvement level. By the logarithm investment function, the optimal quality improvement and setup cost reduction investment also are obtained. In the present work we have developed an integrated production, inventory model in which the objective is to maximize the total profit of the buyer and the vendor by optimizing the optimal order quantity, setup cost reduction and investment for quality improvement. A mathematical model is developed and solved to determine the optimal solution. Developing the model to the multi-supplier case is also proposed for the future research.

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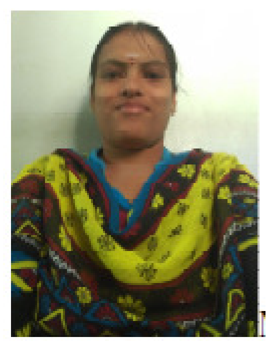
BIOGRAPHICAL NOTES



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