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Supply Chain Inventory Model for Deteriorating Items with Multiple Buyers Single Vendor under Time Dependent Demand and Variable Holding Cost

Jiten Patel ¹, R.D. Patel ²

Statistical Assistant, Jilla Panchayat Office, Valsad, Gujarat, India¹

Visiting Professor, M.Sc.(IT) Programme, Veer Narmad South Gujarat University, Surat, Gujarat, India²

ABSTRACT: An optimal policy for vendor and buyer is developed for items having deterioration and demand is linear function of time. A single vendor and multiple buyers system model is developed as profit maximization to determine the system's optimal cycle time (strategy). We also determine the profit of buyer-vendor jointly. Numerical illustrations show that both buyers and vendor earn significant profit in supply chain inventory system. Post-optimality analysis is also carried out for parameters.

KEYWORDS: Different Deterioration, Multiple Buyers, Optimal strategy, Single Vendor, Supply chain, Time dependent demand, Time varying holding cost

I. INTRODUCTION

In supply chain inventory models many times a single buyer and single vendor manage collaborative inventory strategy to maximize joint profit or minimize total cost. But this strategy has limited global markets scenario. In recent times importance of supply chain inventory model develop memberships between the associated entities of supply chain. Buyer and vendor apply a strategy of business, generally, in classical methods of economic order quantity (EOQ) or Economic production quantity (EPQ). But according to today's business requirements, this concept is replaced by concept of integrated economic lot size (IELS) or supply chain strategy for improvement of market or demand of items. Supply chain inventory system is the collaborative process between individual business parties for achieving maximum joint profit or minimum joint cost.

An inventory model for purchaser and vendor under supply chain was derived by Banerjee [1]. He derived optimum quantity when vendor produce equal lot size under deterministic conditions. Hill [2] also derived supply chain model for global most favorable batching and delivery plan under manufacturing inventory strategy when single vendor and single buyer are considered in integrated system. Goyal [3] proposed and designed integrated inventory model that the consignment bulk would be estimated by first delivery amount. Wee and Yang [4] derived coordinated inventory model for buyer and vendor under deterministic demand when buyer and vendor worked together to minimize joint costs. Wee and Jong [5] formulated one buyer one producer collaborative inventory model where the influences of unit price, deterioration factor, producer's and buyer's unit cost was taken into consideration. Jauhari et al. [6] derived a supply chain inventory model where system leads to minimize joint cost of supply chain when single retailer and single purchaser is considered and adopted probabilistic demand. Seifert et al. [7] investigated two models such as without collaboration between various systems and with collaboration between two members only from entire supply chain. A time dependent coordinated inventory model for single seller and single purchaser derived by Gaobo [8] and computed expressions for optimal total cost for optimal order quantity and price discount. A collaborative inventory model was developed by Vijayashree and Uthayakumar [9] for single manufactured goods when the system consists of single retailer and single consumer. They assumed that manufacture rate is fixed/constant and lead time follows normal distribution. Ghiami and Williams [10] delivered two levels production inventory models with multiple buyers and one manufacturer when deteriorating items has fixed production rate and the order quantities are dispatched by the manufacturer to the consumers for definite period and the surplus inventory supplies for successive deliveries. Srinivas and Reddy [11] determined the integrated inventory model with consignment strategy when multiple buyers and single



vendor included in supply chain inventory. The integrated inventory model optimized the order quantity and determined minimum joint cost. Saha [12] developed an inventory model for deteriorating items in a supply chain management system under fuzzy environment. Gani and Dharik [13] developed multiple buyers and single vendor supply chain inventory model based on a shipment stock and vendor followed inventory policy suggested by management where demand and manufacture rate of the vendor are considered trapezoidal fuzzy numbers. EOQ and EPQ inventory model derived by Jonrinaldi et al. [14] under supply chain strategy considered multiple buyers and single vendor with multiple items and determine the vendor's optimal lot size and buyers' number of orders for shipment policy by considering discrete and continuous demand. For multiple products when single supplier and multiple buyers consist in inventory model and derived integrated model by Powar and Nandurkar [15] under supply chain policy determined the optimal joint reorder point, shipments and order quantity for each buyer subject to decrease the co-ordinated cost of buyers and vendor. Three-tier supply chains inventory management models including supplier sector, a manufacturer and retailer was formulated by Ghourchiany and Bafrouei [16]. Expressions for obtaining optimal amount of raw material order, optimal amount of the production and optimal order of retailers was also derived. An algorithm was provided for obtaining these units.

A one vendor multiple buyers combined inventory models for varying deterioration for buyers and time varying holding cost for vendor buyer both under time dependent demand is considered in this chapter. We assume that vendor has better preservation technology, so preservation technology cost is included for vendor and therefore there is no deterioration cost for vendor.

II. ASSUMPTIONS AND NOTATIONS

NOTATIONS:

The first objective of this section is to list all the used notations in the subsequent sections for easy reference.

$D(t) : a_i + b_i t$, where $a_i > 0$, $0 < b_i < 1$

$I_{bi}(t) : i^{\text{th}}$ buyer's inventory size at time t

$I_v(t) : \text{Vendor's inventory size at time } t$

$A_{bi} : \text{Ordering cost of } i^{\text{th}} \text{ buyer's per order}$

$A_v : \text{Ordering cost of vendor per order}$

$c_b : \text{Unit purchasing cost of buyer}$

$\theta_i : i^{\text{th}}$ buyer's deterioration rate during $t_1 \leq t \leq t_2$, $0 < \theta_i < 1$

$\theta_{it} : i^{\text{th}}$ buyer's deterioration rate during, $t_2 \leq t \leq (T/n_i)$, $0 < \theta_i < 1$

$x_{bi} : i^{\text{th}}$ Buyer's fixed holding cost

$y_{bi} : i^{\text{th}}$ Buyer's varying holding cost

$x_v : \text{Fixed holding cost of vendor}$

$y_v : \text{Varying holding cost of vendor}$

$p_i : \text{Selling price of } i^{\text{th}} \text{ buyer's per unit}$

$m : \text{Preservation technology cost for vendor (fixed)}$

$n_i : \text{Number of time orders placed by } i^{\text{th}} \text{ buyer during cycle time.}$

$TP_{bi} : \text{Total profit of } i^{\text{th}} \text{ buyer}$

$TP_v : \text{Vendor's total profit}$

$TP : \text{Integrated total profit for both vendor and buyers per time unit.}$

$t_1 = v_1 * (T/n_i)$, $t_2 = v_2 * (T/n_i)$, where $T_b = T/n_i$

$T : \text{Cycle time of vendor (a decision variable).}$

ASSUMPTIONS:

Further we present the assumptions related to the work.

- The demand is declining function of time.
- One vendor multiple buyers are considered.
- Stock out is not permitted.
- Lead time is zero.
- During the cycle time, no repairing or replacement of deteriorated units and deterioration is dependent on time for buyer's inventory.
- For buyer and vendor both, time varying holding cost is considered.



III. MATHEMATICAL MODEL AND ANALYSIS

Level of inventory of i^{th} buyer's at time t be given by $I_{bi}(t)$ ($0 \leq t \leq T/n_i$) is shown below:
Buyer's Inventory

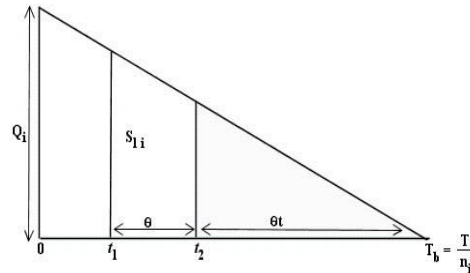


Fig. 1. Inventory size of buyer

Two situations are discussed. In the first situation, there is no collaboration between vendor and buyers, while in the second situation there is collaboration of buyers and vendor. Considering time and price dependent demand, inventory size is given for buyers and vendor.

Change in inventory sizes are given by following differential equations for buyers and vendor:

$$\frac{dI_{bi}(t)}{dt} = -(a_i + b_i t), \quad 0 \leq t \leq t_1 \quad (1)$$

$$\frac{dI_{bi}(t)}{dt} + \theta_i I_{bi}(t) = -(a_i + b_i t), \quad t_1 \leq t \leq t_2 \quad (2)$$

$$\frac{dI_{bi}(t)}{dt} + \theta_i t I_{bi}(t) = -(a_i + b_i t), \quad t_2 \leq t \leq \frac{T}{n_i} \quad (3)$$

$$\frac{dI_v(t)}{dt} = - \sum_{i=1}^N (a_i + b_i t), \quad 0 \leq t \leq T \quad (4)$$

initially taken conditions are: $I_{bi}(0) = Q_i$, $I_{bi}(t_1) = S_{1i}$, $I_{bi}\left(\frac{T}{n_i}\right) = 0$ and $I_v(T) = 0$.

Solving equations (1) to (4) we have,

$$I_{bi}(t) = Q_i - (a_i t + \frac{1}{2} b_i t^2), \quad (5)$$

$$I_{bi}(t) = \left[a_i (t_1 - t) + \frac{1}{2} a_i \theta_i (t_1^2 - t^2) + \frac{1}{2} b_i (t_1^2 - t^2) \right] + S_{1i} [1 + \theta_i (t_1 - t)] + \left[\frac{1}{3} b_i \theta_i (t_1^3 - t^3) - a_i \theta_i t (t_1 - t) - \frac{1}{2} b_i \theta_i t (t_1^2 - t^2) \right] \quad (6)$$

$$I_{bi}(t) = \left[a_i \left(\frac{T}{n_i} - t \right) + \frac{1}{2} b_i \left(\frac{T^2}{n_i^2} - t^2 \right) + \frac{1}{6} a_i \theta_i \left(\frac{T^3}{n_i^3} - t^3 \right) + \frac{1}{8} b_i \theta_i \left(\frac{T^4}{n_i^4} - t^4 \right) - \frac{1}{2} a_i \theta_i t^2 \left(\frac{T}{n_i} - t \right) - \frac{1}{4} b_i \theta_i t^2 \left(\frac{T^2}{n_i^2} - t^2 \right) \right]. \quad (7)$$

$$I_v(t) = \sum_{i=1}^N \left[a_i (T - t) + \frac{1}{2} b_i (T^2 - t^2) \right]. \quad (8)$$

(by not considering higher powers of θ)

Substituting $t = t_1$, in (5) gives

$$Q_i = S_{1i} + \left(a_i t_1 + \frac{1}{2} b_i t_1^2 \right). \quad (9)$$



From equations (6) and (7), putting $t = t_2$, we have

$$I_{bi}(t_2) = \left[\begin{aligned} &a_i(t_1 - t_2) + \frac{1}{2}a_i\theta_i(t_1^2 - t_2^2) + \frac{1}{2}b_i(t_1^2 - t_2^2) \\ &+ \frac{1}{3}b_i\theta_i(t_1^3 - t_2^3) - a_i\theta_i t_2(t_1 - t_2) - \frac{1}{2}b_i\theta_i t_2(t_1^2 - t_2^2) \end{aligned} \right] + S_{i1} [1 + \theta_i(t_1 - t_2)] \tag{10}$$

$$I_{bi}(t_2) = \left[\begin{aligned} &a_i \left(\frac{T}{n_i} - t_2 \right) + \frac{1}{2}b_i \left(\frac{T^2}{n_i^2} - t_2^2 \right) + \frac{1}{6}a_i\theta_i \left(\frac{T^3}{n_i^3} - t_2^3 \right) \\ &+ \frac{1}{8}b_i\theta_i \left(\frac{T^4}{n_i^4} - t_2^4 \right) - \frac{1}{2}a_i\theta_i t_2^2 \left(\frac{T}{n_i} - t_2 \right) - \frac{1}{4}b_i\theta_i t_2^2 \left(\frac{T^2}{n_i^2} - t_2^2 \right) \end{aligned} \right]. \tag{11}$$

So from equations (10) and (11), we have

$$S_{i1} = \frac{1}{[1 + \theta_i(t_1 - t_2)]} \left[\begin{aligned} &a_i \left(\frac{T}{n_i} - t_2 \right) + \frac{1}{2}b_i \left(\frac{T^2}{n_i^2} - t_2^2 \right) + \frac{1}{6}a_i\theta_i \left(\frac{T^3}{n_i^3} - t_2^3 \right) + \frac{1}{8}b_i\theta_i \left(\frac{T^4}{n_i^4} - t_2^4 \right) - \frac{1}{2}a_i\theta_i t_2^2 \left(\frac{T}{n_i} - t_2 \right) \\ &- \frac{1}{4}b_i\theta_i t_2^2 \left(\frac{T^2}{n_i^2} - t_2^2 \right) - a_i(t_1 - t_2) - \frac{1}{2}a_i\theta_i(t_1^2 - t_2^2) - \frac{1}{2}b_i(t_1^2 - t_2^2) - \frac{1}{3}b_i\theta_i(t_1^3 - t_2^3) \\ &+ a_i\theta_i t_2(t_1 - t_2) - \rho_i p_i \theta_i t_2(t_1 - t_2) + \frac{1}{2}b_i\theta_i t_2(t_1^2 - t_2^2) \end{aligned} \right]. \tag{12}$$

Substituting from (12), value of S_{i1} in (6) gives

$$I_{bi}(t) = \frac{[1 + \theta_i(t_1 - t)]}{[1 + \theta_i(t_1 - t_2)]} \left[\begin{aligned} &a_i \left(\frac{T}{n_i} - t_2 \right) + \frac{1}{2}b_i \left(\frac{T^2}{n_i^2} - t_2^2 \right) + \frac{1}{6}a_i\theta_i \left(\frac{T^3}{n_i^3} - t_2^3 \right) + \frac{1}{8}b_i\theta_i \left(\frac{T^4}{n_i^4} - t_2^4 \right) \\ &- \frac{1}{2}a_i\theta_i t_2^2 \left(\frac{T}{n_i} - t_2 \right) - \frac{1}{4}b_i\theta_i t_2^2 \left(\frac{T^2}{n_i^2} - t_2^2 \right) - a_i(t_1 - t_2) - \frac{1}{2}a_i\theta_i(t_1^2 - t_2^2) \\ &- \frac{1}{2}b_i(t_1^2 - t_2^2) - \frac{1}{3}b_i\theta_i(t_1^3 - t_2^3) + a_i\theta_i t_2(t_1 - t_2) + \frac{1}{2}b_i\theta_i t_2(t_1^2 - t_2^2) \end{aligned} \right] \\ + \left[a_i(t_1 - t) + \frac{1}{2}a_i\theta_i(t_1^2 - t^2) + \frac{1}{2}b_i(t_1^2 - t^2) + \frac{1}{3}b_i\theta_i(t_1^3 - t^3) - a_i\theta_i t(t_1 - t) - \frac{1}{2}b_i\theta_i t(t_1^2 - t^2) \right]. \tag{13}$$

Using (12) in (9), we have

$$Q_i = \frac{1}{[1 + \theta_i(t_1 - t_2)]} \left[\begin{aligned} &a_i \left(\frac{T}{n_i} - t_2 \right) + \frac{1}{2}b_i \left(\frac{T^2}{n_i^2} - t_2^2 \right) + \frac{1}{6}a_i\theta_i \left(\frac{T^3}{n_i^3} - t_2^3 \right) + \frac{1}{8}b_i\theta_i \left(\frac{T^4}{n_i^4} - t_2^4 \right) \\ &- \frac{1}{2}a_i\theta_i t_2^2 \left(\frac{T}{n_i} - t_2 \right) - \frac{1}{4}b_i\theta_i t_2^2 \left(\frac{T^2}{n_i^2} - t_2^2 \right) - a_i(t_1 - t_2) - \frac{1}{2}a_i\theta_i(t_1^2 - t_2^2) \\ &- \frac{1}{2}b_i(t_1^2 - t_2^2) - \frac{1}{3}b_i\theta_i(t_1^3 - t_2^3) + a_i\theta_i t_2(t_1 - t_2) + \frac{1}{2}b_i\theta_i t_2(t_1^2 - t_2^2) \end{aligned} \right] + \left(a_i t_1 + \frac{1}{2}b_i t_1^2 \right) \tag{14}$$

Using value of Q in (5), we have

$$I_{bi}(t) = \frac{1}{[1 + \theta_i(t_1 - t_2)]} \left[\begin{aligned} &a_i \left(\frac{T}{n_i} - t_2 \right) + \frac{1}{2}b_i \left(\frac{T^2}{n_i^2} - t_2^2 \right) + \frac{1}{6}a_i\theta_i \left(\frac{T^3}{n_i^3} - t_2^3 \right) + \frac{1}{8}b_i\theta_i \left(\frac{T^4}{n_i^4} - t_2^4 \right) \\ &- \frac{1}{2}a_i\theta_i t_2^2 \left(\frac{T}{n_i} - t_2 \right) - \frac{1}{4}b_i\theta_i t_2^2 \left(\frac{T^2}{n_i^2} - t_2^2 \right) - a_i(t_1 - t_2) - \frac{1}{2}a_i\theta_i(t_1^2 - t_2^2) - \frac{1}{2}b_i(t_1^2 - t_2^2) \\ &- \frac{1}{3}b_i\theta_i(t_1^3 - t_2^3) + a_i\theta_i t_2(t_1 - t_2) - \rho_i p_i \theta_i \mu_2(\mu_1 - \mu_2) + \frac{1}{2}b_i\theta_i \mu_2(\mu_1^2 - \mu_2^2) \end{aligned} \right] \\ + \left(a_i t_1 + \frac{1}{2}b_i t_1^2 \right). \tag{15}$$



Total relevant profit consisted of following elements:

Buyers' relevant costs:

(i) Ordering cost (OC_b) = $\sum_{i=1}^N n_i A_{bi}$ (16)

(ii) Holding Cost:

$$\begin{aligned}
 (HC_b) &= \sum_{i=1}^N n_i \left[x_{bi} \left\{ \int_0^{\frac{T}{n_i}} I_{bi}(t) dt \right\} + y_{bi} \left\{ \int_0^{\frac{T}{n_i}} t I_{bi}(t) dt \right\} \right] \\
 &= \sum_{i=1}^N n_i \left[x_{bi} \left\{ \int_0^{t_1} I_{bi}(t) dt + \int_{t_1}^{t_2} I_{bi}(t) dt + \int_{t_2}^{\frac{T}{n_i}} I_{bi}(t) dt \right\} + y_{bi} \left\{ \int_{t_1}^{\frac{T}{n_i}} t I_{bi}(t) dt + \int_{t_1}^{t_2} t I_{bi}(t) dt + \int_{t_2}^{\frac{T}{n_i}} t I_{bi}(t) dt \right\} \right]
 \end{aligned}
 \tag{17}$$

(iii) Deterioration Cost:

$$(DC_b) = \sum_{i=1}^N n_i c_b \left[\int_{t_1}^{t_2} \theta_i I_{bi}(t) dt + \int_{t_2}^{\frac{T}{n_i}} \theta_i t I_{bi}(t) dt \right].
 \tag{18}$$

(iv) Sales Revenue:

$$(SR_b) = \sum_{i=1}^N n_i p_i \left[\int_0^{\frac{T}{n_i}} (a_i + b_i t) dt \right]
 \tag{19}$$

(v) Total Profit (buyers):

$$TP_{bi} = \frac{1}{T} [SR_b - OC_b - HC_b - DC_b]
 \tag{20}$$

Vendor's relevant costs:

(i) Ordering cost (OC_v) = Av (21)

(ii) Holding Cost:

$$\begin{aligned}
 (HC_v) &= x_v \left[\int_0^T I_v(t) dt - \sum_{i=1}^N n_i \left[\int_0^{t_1} I_{bi}(t) dt + \int_{t_1}^{t_2} I_{bi}(t) dt + \int_{t_2}^{\frac{T}{n_i}} I_{bi}(t) dt \right] \right] \\
 &+ y_v \left[\int_0^T t I_v(t) dt - \sum_{i=1}^N n_i \left[\int_{t_1}^{\frac{T}{n_i}} t I_{bi}(t) dt + \int_{t_1}^{t_2} t I_{bi}(t) dt + \int_{t_2}^{\frac{T}{n_i}} t I_{bi}(t) dt \right] \right].
 \end{aligned}
 \tag{22}$$

(iii) Preservation Technology Cost (PTC_v) = m (23)

(iv) Sales Revenue:

$$(SR_v) = c_b \left(\sum_{i=1}^N \int_0^T (a_i + b_i t) dt \right) = c_b \left(\sum_{i=1}^N \left(a_i T + \frac{1}{2} b_i T^2 \right) \right)
 \tag{24}$$

(not considering higher powers of θ)

(v) Total Profit (vendor):

$$TP_v = \frac{1}{T} [SR_v - OC_v - HC_v - PTC_v]
 \tag{25}$$



Situation I: Buyer and vendor take independent decision:

Here the buyers and vendor make decision independently. For given value of n, TP_b can be maximized by solving

$$\frac{\partial TP_b(T_b)}{\partial T_b} = 0, \text{ where } T_b = \frac{T}{n_i} \tag{26}$$

provided it satisfies the second order condition

$$\frac{\partial^2 TP_b(T_b)}{\partial T_b^2} < 0. \tag{27}$$

This solution (n,T) maximizes TP_v.

Then the total profit without collaboration is given by:

$$TP = \max(TP_b + TP_v).$$

Situation-II: Joint decision of buyer and vendor:

Here joint decision is taken by buyers and vendor:

The optimum values of T must satisfy the following conditions which maximize total profit (TP) when buyers and vendor take joint decision. that T is expressed in terms of W and t_r, hence T_b is not a decision variable.

$$\frac{\partial TP_v(T)}{\partial T} = 0, \text{ where } T_b = \frac{T}{n_i}. \tag{28}$$

provided it satisfies the second order condition

$$\frac{\partial^2 TP_v(T)}{\partial T^2} < 0 \tag{29}$$

where total profit (TP) with collaboration is given by:

$$TP = TP_b + TP_v \tag{30}$$

IV. NUMERICAL EXAMPLE

Various parameter values in appropriate units are taken for numerical illustration, A_{b1} = 85, A_{b2} = 65, a₁ = 650, a₂ = 550, b₁=0.05, b₂ =0.05, θ₁=0.06, θ₂=0.04, c_b=40, p₁=77, p₂=73, x_{b1} =4.5 , x_{b2} =5.5, y_{b1}=0.04, y_{b2}=0.06, m = 5, A_v=2000, x_v=3, y_v=0.03, v₁=0.3, v₂=0.50, N=2 in appropriate units.

Table provides optimum independent and joint values of T and profits for buyers and vendor. The second order conditions given in equation (27) and equation (29) are also satisfied.

Table 1
Without collaboration and with collaboration optimum solution

	Independent Decision	Joint Decision
n ₁ , n ₂	n ₁ = 5, n ₂ = 5	n ₁ = 3, n ₂ = 3
T	1.0453	1.0225
Buyers Profit	88777.1911	88620.0355
Vendor's Profit	44572.8256	44809.9226
Total Profit	133350.0167	133429.9581

V. POST-OPTIMALITY COMPUTATIONS

Study of one parameter at a time, table below gives post-optimality computations.

Table 2
Sensitivity Analysis
Independent Decision

Parameter	%	n ₁	n ₂	Profit(b)	Profit(v)	Profit(bv)
a ₁ ,a ₂	+20%	5	5	106682.4052	53846.5450	160528.9502
	+10%	5	5	97728.2627	49205.9595	146934.2222
	-10%	5	5	79829.6649	39948.2784	119777.9433
	-20%	5	5	70886.2947	35333.7917	106220.0864
A _{b1} , A _{b2}	+20%	5	5	88640.1241	44595.1639	133235.2880



	+10%	5	5	88707.1252	44587.9335	133295.0587
	-10%	5	5	88850.7947	44547.2893	133398.0840
	-20%	6	6	88928.5449	44525.3209	133453.8658
x _{b1} , x _{b2}	+20%	5	5	88657.5352	44530.1876	133187.7228
	+10%	5	5	88716.1797	44553.3888	133269.5685
	-10%	5	5	88840.8765	44587.4166	133428.2931
θ ₁ , θ ₁	+20%	5	5	88907.6145	44595.5201	133503.1346
	+10%	5	5	88760.5288	44567.4290	133327.9578
	+10%	5	5	88768.8304	44570.1675	133338.9979
A _v	-10%	5	5	88785.6124	44575.3917	133361.0041
	-20%	5	5	88794.0957	44577.8210	133371.9167
	+20%	5	5	88777.1911	44190.1603	132967.3514
x _v	+10%	5	5	88777.1911	44381.4929	133158.6840
	-10%	4	4	88777.1911	44858.6907	133635.8818
	-20%	4	4	88777.1911	45050.0233	133827.2144
	+20%	4	4	88777.1911	44385.2627	133162.4538
	+10%	4	4	88777.1911	44526.3103	133303.5015
	-10%	5	5	88777.1911	44723.3117	133500.5028
	-20%	5	5	88777.1911	44873.7979	133650.9890

Table 3
Sensitivity Analysis
Joint Decision

Parameter	%	n ₁	n ₂	Profit(b)	Profit(v)	Profit(bv)
a ₁ , a ₂	+20%	3	3	106510.8479	54106.2987	160617.1466
	+10%	3	3	97563.7945	49454.5984	147018.3929
	-10%	3	3	79680.2547	40173.1818	119853.4365
	-20%	3	3	70745.1025	35545.7782	106290.8807
A _{b1} , A _{b2}	+20%	3	3	88520.3876	44822.3312	133342.7188
	+10%	3	3	88569.8309	44816.3139	133386.1448
	-10%	4	4	88803.9296	44679.6283	133483.5579
	-20%	4	4	88865.1698	44674.5836	133539.7534
x _{b1} , x _{b2}	+20%	4	4	88598.3719	44670.3827	133268.7546
	+10%	4	4	88670.1673	44677.5702	133347.7375
	-10%	3	3	88707.9214	44824.7561	133532.6775
	-20%	3	3	88798.9759	44838.6977	133637.6736
θ ₁ , θ ₁	+20%	4	4	88726.4291	44682.5544	133408.9835
	+10%	4	4	88735.1385	44683.3493	133418.4878
	-10%	3	3	88630.4966	44811.9672	133442.4638
	-20%	3	3	88640.9679	44814.0427	133455.0106
A _v	+20%	4	4	88714.0147	44358.8485	133072.8632
	+10%	4	4	88729.3590	44517.9434	133247.3024
	-10%	3	3	88649.1132	44980.5467	133629.6599
	-20%	3	3	88677.6573	45160.6565	133838.3138
x _v	+20%	3	3	88653.0600	44537.6375	133190.6975
	+10%	3	3	88637.4089	44671.4866	133308.8955
	-10%	4	4	88731.6427	44845.2559	133576.8986
	-20%	4	4	88716.9816	45013.6688	133730.6504

Based on the results of Table 2 and Table 3, we can observe about the optimal length of order cycle T* and maximum total profits for independent as well as joint decisions.

There will be increase or decrease in value of profits when parameters 'a₁, a₂' increase/ decrease independently as well as jointly, however, when A_{b1}, A_{b2}, x_{b1}, x_{b2}, x_v, A_v, and θ₁, θ₂ increase/decrease then total profit decrease/increase in independent and joint decision case.



VI. CONCLUSION

The result shows that the optimal cycle time is significantly decreased and total profit significantly increased when buyers and vendor take joint decision as compared to independent decision taken by buyers and vendor.

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