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An EOQ Model with a Random Defective Supply Batch and Backorder Policy

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ABSTRACT : *This paper deals with an EOQ model with backorder at a constant rate and rejection of defective supply batches. The number of defective item is assumed follows a negative binomial distribution. An exact model for the system expected cost and convexity aere studied for authenticity of the proposed model, a case study, and a numerical example are provided, and the sensitivity analysis is also carried out.*

Keywords -*Inventory, EOQ, Backorder, Negative Binomial.*

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I. INTRODUCTION

Inventory is an unused resource (iddle resource) waiting for further processing [7]. Generaly, the supply shipping of companies will be through backordering, where batch are supplied to the customer have been delayed or failnes to be sent. This is usually due to the company a shortage of inventory during the period of sale (out of stock). According [5], EOQ (Economic Order Quantity) is the first method introduced by Ford Haris in 1915. EOQ method is an inspiration for inventory experts to develop other inventory control methods. [3] examine, that the EOQ method is the method used to determine optimal production and control strategies to minimize total cost of quality and maximize total profits. [8], has obtained an optimal model of EPQ (Economic Production Quantity) with independent properties in each cycle, with the normal distribution. They has reviewed the inventory using the classic EOQ to overcome a number of inventories that have rejected of defective merchandise and backorder occurrences. In this study, geometry distribution is used to represent the number of defective items on a shipment and delivery of batch at one period with another time period is independent [6]. An EOQ classic of inventory has a random inventory model in optimizing defects compared to EOQ correlated with binomial distribution of inventory and EOQ correlated with processes of inventory used the markovian supply system and porposional stochastic stock [4]. We found study about the effective management of denomination inventory to compensate for unmet demand often lost and unobserved. Then the request is assumed to use a poisson distribution or distributed normally, and negative binomial distribution [1]. The results of [1], indicate that the preparation of negative binomial distribution is interesting to be examined on distributions that have significant results with other discrete and an effective method. Then, in the study using the geometry of distribution to be researched [6] and developed by combining [1] research. Therefore, based [6] and [1], in this article has been studied about the EOQ with backorder model on defective of batch by using a negative binomial distribution. In this case, a negative binomial distribution is used because it has almost the same properties as the geometry distribution, and in this study will have two assumptions of success or failure which are the defects in every shipment of batch.

Based on this ddiscussion, the contribution of this paper is summariezed as follow: (i) we present an exact expected cost model of the system which is shown jointly convex in both decision variabeles (i.e order quantity and planned backorders); (ii) we show that the model optimal solution and the respective optimizer can be obtained in closed form and they all reduce those of the clasisical EOQ model under perfect supply quality; (iii) we provide analytical result which demonstrate that always the optimal expected cost incrases and the optimal order quantity decreases with decreasing supply quality; (iv) we provide numerical result demonstating the sensitivity of the optimal expected cost on changes in supply quality.

The remainder of this paper is organized follows. Section 2 gives the model assumptions and totation used. Section 3 present the exact expected cost model and the analysis leading to the optimal solution which is obtained in closed form. Section 4 provides numerical results and a discussion of theor implications in terms of system cosy performance. Finally, Section 5 summarizes the findings and provides directions for future research.

II. PRELIMIARIES

The opretaing assumptions underlying the model are as follows:

2.1 Notation

The following notations are used in order to model the problem:

$\boldsymbol{Q}$	Planned order quantity (in unit)[decision variable]
$\boldsymbol{J}$	Planned backorders [decision variable]
$\boldsymbol{T}$	Time between two successive supply deliveries (delivery interval)
$\boldsymbol{T'}$	Time between two successive acceptable deliveries. ($\boldsymbol{T'} = (\boldsymbol{X}+\mathbf{1})\boldsymbol{T}$)
$\boldsymbol{X}$	Number of successive defective supply deliveries.
$\boldsymbol{D}$	Demand rate (units per unit of time)
$\boldsymbol{B}$	Fixed cost per delivery
$\boldsymbol{k}$	Number of successive delivery
$\boldsymbol{h}$	Holding cost (per unit per unit time)
$\boldsymbol{b}$	Shortage cost (per unit per unit time)
$\boldsymbol{p}$	Probability that a supply batch is deffective
$*$	Superscript representing an optimal value
$\boldsymbol{o}$	Superscript representing variables of classical EOQ with backorder model.

2.2 Assumptions

The following assumptions are used in order to model the problem:

(1) Demand rate is known and constant.
(2) Shortages are allowed and fully backordered.
(3) There is fixed delivery schedule, where supply batches are delivered at equally spaced delivery intervals T.
(4) Incidents of delivery of defective batch are mutually independent of each other.
(5) Each batch is checked on arrival and, if the batch is broken, the inventory is rejected. Thus, the system operates with an "all or nothing" supply policy system.
(6) There is no emergency shipping and the total amount of each rejected batch is routinely added to the next planned batch of shipment.
(7) The batch sent by suppliers to distributors who will be checked before being sent to the buyer.

III. MODEL AND ANALYSIS

In this section, an exact model for the cost expectation system will be followed and then sought for optimization of the system and determines the optimal variable and cost. Modeling and optimization follows the classic EOQ (with backorder), with the Q booking plan and the J backorder plan as the decision variable.

3.1 Exact Cost Model

In this supply model there is a shortage of batches and backorders, where orders from consumers will be received even though at thetime there is no supply, demand will be met after new supply. shortage of batch that occur due to defects in the supply batch, resulting in delayed delivery to consumers. At the expense expected can be modeled by understanding the operating system over time. First, consider the case of a perfect supply where all supply shipments are received. This is because demand is constant and remains operating under a fixed delivery schedule (Assumption 3). All supply cycles are identical to the length of time ie $T' = T = \frac{Q}{D}$ (such as the time taken to consume unit Q with rate D). Thus, at each cycle has begun supply Q-J level and ends with a backorder ie J.

This paper considered an imperfect supply case ($p > 0$) where there are several batches of defects that result in the length of the supply cycle being random variables that depend on successive defect shipments with the chance of occurrence of defective batches being p and random variables indicating the number of deliveries defect is x. Therefore, the length of each supply cycle can be directly expressed as $Tx = (x + 1)\,T$. Since inefficient delivery is independent (Assumption 4), then x is a random variabel negative binomial with parameter p and with an opportunity function in Eq. (2.21). At each cycle, can be directly determined initial and final supply levels. The total number of defective items sent successively available with successful initial delivery (Assumption 6), with the initial supply cycle ie $Q-J$ (for each cycle). The final supply cycle (which indicates the backorder), depends on the length of the cycle ie $J + xQ$. The length of the final supply cycleincludes the backorder plan and the total number of x representing the defect delivery (xQ).

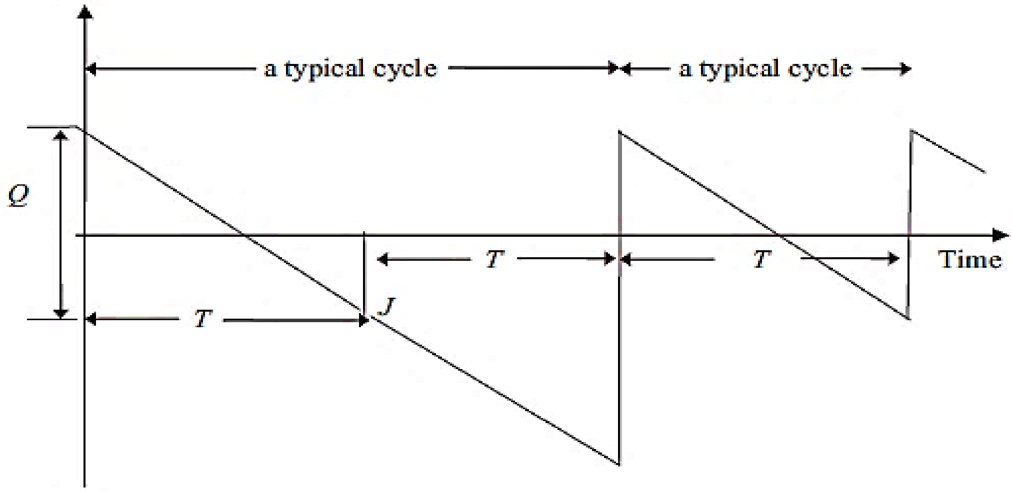

Figure 1. Inventory Realization with Two Consecutive Cycles.

Figure 1 shows the possibilities that occur from two different cycles [6].. The first cycle has a length of $T' = 2T$ where the defect delivery at time T follows cycle length $T' = T$. Dispatch batch delivery is available at time $2T$, so the two cycles have the same start cycle. Then, at the end of the first cycle the backorder occurs because it sends a defective batch at time T to $J + Q$. Therefore, given the corresponding supply cost $c\ (Q,J)$ is given as follows:

$$c(Q,J,X) = (x+1)B + \frac{h(Q-J)^2}{2D} + \frac{bJ^2}{2D} + \frac{BJXQ}{D} + \frac{bX^2Q^2}{2D}.$$

As defined before, X is a negative binomial random variable. With parameter p; thus the expected value and second moment of X given by $E(X) = \frac{k}{p}$ and $E(X^2) = Var\ (X) + \left[\left(E(X)\right)\right]^2$ .Therefore, the expected value of eq(1) is given by:

$$C(Q,J) = \frac{k+p}{p}B + \frac{h(Q-J)^2}{2D} + \frac{bJ^2}{2D} + \frac{BJkQ}{Dp} + \frac{bQ^2(k^2+k-kp)}{2Dp^2}$$

considering the length of any inventory cycle $T' = (X + 1)\,T$, the expected length of each supply cycle given by:

$$E(T') = [E(X)+1]T = [E(X)+1]\left(\frac{Q}{D}\right) = \frac{(k+p)Q}{pD}$$

Therefore, the total cost is given by:

$$TC(Q,J) = \frac{c(Q,J)}{E(T')} = \frac{BD}{Q} + \frac{ph(Q-J)^2}{2Q(k+p)} + \frac{bJ^2p}{2Q(k+p)} + \frac{bJk}{k+p} + \frac{bQ(k^2+k-kp)}{k+p}$$

3.2 Model Optimization

Using the total cost of Equation (4) is minimized by $J \geq 0$. The first derivative of $TC\ (Q,J)$ to Q and J is obtained:

$$\frac{\partial TC(Q,J)}{\partial Q} = -\frac{BD}{Q^2} + \frac{ph(Q-J)}{Q(k+p)} - \frac{1}{2}\frac{ph(Q-J)^2}{Q^2(k+p)} - \frac{1}{2}\frac{bJ^2p}{Q^2(k+p)} + \frac{b(k^2+k-kp)}{k+p}.$$

$$\frac{\partial TC(Q,J)}{\partial J} = \frac{p(bk-2ph)}{k+p} + \frac{(2p^2h+bp)J}{Q(K+p)}.$$

Since the minimization problem is limited by non-negativity to J, then Equation (6) indicates to have two cases to check: (1) $p\ (bk - 2ph)\ /\ (k + p) \leq 0$ and (2) $p\ (bk - 2ph)\ /\ (k + p) > 0$

Case 1. $p \leq \frac{bk}{2h}$

By settings Equations (5) and (6) equal to zero give is:

$$Q^* = \sqrt{\frac{2BD(k+p) + (b+h)J^2p}{Ph + 2bk^2}}$$

$$J^* = \frac{(2ph + bk)Q^*}{2h + b}$$

For determine the nature of (Q^*, J^*), it is have to review the second derivative as follows:

$$\frac{\partial^2 TC(Q,J)}{\partial Q^2} = \frac{2BD}{Q^3} + \frac{ph}{Q(k+p)} - \frac{2ph(Q-J)}{Q^2(k+p)} + \frac{ph(Q-J)^2}{Q^3(k+p)} + \frac{bJ^2p}{Q^3(k+p)} > 0.$$

Requirement:

$$\frac{2BD}{Q^3} + \frac{ph}{Q(k+p)} + \frac{ph(Q-J)^2}{Q^3(k+p)} + \frac{bJ^2p}{Q^3(k+p)} > \frac{2ph(Q-J)}{Q^2(k+p)}$$

Then,

$$\frac{\partial^2 TC(Q,J)}{\partial J^2} = \frac{(2p^2h + bp)}{Q(k+p)} > 0.$$

$$\frac{\partial^2 TC(Q,J)}{\partial Q \partial J} = -\frac{ph}{Q(k+p)} + \frac{ph(Q-J)}{Q^2(k+p)} - \frac{bJp}{Q^2(k+p)} < 0.$$

Since $\frac{\partial^2 TC(Q,J)}{\partial Q^2} > 0$, $\frac{\partial^2 TC(Q,J)}{\partial J^2} > 0$and the following condition:

$$\left(\frac{\partial^2 TC(Q,J)}{\partial J^2}\right)\left(\frac{\partial^2 TC(Q,J)}{\partial Q^2}\right) - \left(\frac{\partial^2 TC(Q,J)}{\partial Q \partial J}\right)^2 = \frac{2hp(Y)^2 + bp + ph}{Q(k+p)} + \frac{ph(J-Q) + bJp}{Q^2(k+p)} > 0.$$

with $Y = \frac{(J^2bp + J^2hp + 2BDk + 2BDp)}{Q^3(k+p)}$

So the above condition can be said $TC\ (Q,J)$ convex to both variables and variables (Q^*, J^*) is a unique global minimum. Therefore, by substitutingEquation (3), the optimal total cost expectation per unit time at $(Q,J) = (Q^*, J^*)$ is:

$$TC(Q^*, J^*) = \frac{DB}{\sqrt{V}} + \frac{1}{2}\sqrt{W}ph\left(\frac{\sqrt{V} + (2h + b^2ph + bk)}{2h+b}\right)^2 + \frac{1}{2}\frac{VAbp(2ph+bk)^2\sqrt{V}}{(2h+b)^2} - k\frac{b(2ph+bk)\sqrt{V}}{A(2h+b)} + \frac{Mb\sqrt{V}}{A}.$$

With:

$A = k + p,$

$$V = \frac{2BD(k+p) + (b+h)J^2p}{2bk^2 + ph},$$

$$W = \frac{2BD(k+p)^2 + Jp(b+h)(k+p)^4}{2bk(k+p)^2 + ph(k+p)}.V$$

Case 2. $p > \frac{bk}{2h}$

In Equation (6), $\frac{\partial TC\ (Q,J)}{\partial J}$ is positive for all $J \geq 0$ and since $TC\ (Q,J)$ increases on J. Thus, since the minimum value at the boundary of part $J = 0$, then the first derivative for the minimum condition is:

$$\frac{\partial TC(Q, J=0)}{\partial Q} = -\frac{BD}{Q^2} + \frac{1}{2}\frac{ph}{k+p} + \frac{b(k^2 + k - kp)}{p(k+p)}.$$

Then evaluated from the order quantity obtained:

$$Q^* = \sqrt{\frac{BDp(k+p)}{\frac{1}{2}p^2h + b(k^2 + k - kp)}}.$$

Therefore $J = 0$, then the value $J^* = 0$. Then, a concavity test on the second derivative is obtained $\left(\frac{\partial^2 TC(Q,J=0)}{\partial Q^2}\right) = \frac{2BD}{Q\hat{}3} > 0$ which is a unique global minimum, then using Eq. (2) obtained the expected total optimal cost per unit time:

$$TC(Q^*, J^* = 0) = \frac{BD}{\sqrt{\frac{BDAp}{\frac{1}{2}p^2h+Mb}}} + \frac{BDAp^2h}{\sqrt{\alpha}(hp^2+2Mb)} + \frac{b}{2\sqrt{\alpha}} + \frac{bk+Mb\sqrt{\beta}}{A}.$$

With:

$$\alpha = \frac{BDp(k+p)^2}{\frac{1}{2}ph(k+p)^3 + b(k^2+k-kp)(k+p)},$$

$$\beta = \frac{BDp(k+p)}{\frac{1}{2}p^2h + b(k^2+k-kp)}.$$

The above results can be summarized in the following propositions

Proposition 1.

The optimal total cost per unit of time depends on p, with (Q^*, J^*) can be given as follows:

a) **Case (1).** $\boldsymbol{p \leq \frac{2h}{bk}}$

$$Q^* = \sqrt{\frac{2BD(k+p)+(b+h)J^2p}{Ph+2bk^2}},$$

$$J^* = \frac{(2ph+bk)Q^*}{2h+b},$$

And

$$TC(Q^*, J^*) = \frac{DB}{\sqrt{V}} + \frac{1}{2}\sqrt{W}ph\left(\frac{\sqrt{V}+(2h+b^2ph+bk)}{2h+b}\right)^2 + \frac{1}{2}\frac{VAbp(2ph+bk)^2\sqrt{V}}{(2h+b)^2} - k\frac{b(2ph+bk)\sqrt{V}}{A(2h+b)} + \frac{Mb\sqrt{V}}{A}.$$

b) **Case(2).** $\boldsymbol{p > \frac{2h}{bk}}$

$$Q^* = \sqrt{\frac{BDp(k+p)}{\frac{1}{2}p^2h + b(k^2+k-kp)}},$$

$J^* = 0,$

And

$$TC(Q^*, J^* = 0) = \frac{BD}{\sqrt{\frac{BDAp}{\frac{1}{2}p^2h+Mb}}} + \frac{BDAp^2h}{\sqrt{\alpha}(hp^2+2Mb)} + \frac{b}{2\sqrt{\alpha}} + \frac{bk+Mb\sqrt{\beta}}{A}.$$

The above can be determined analytically the properties of Q^*, J^*, and $TC\ (Q^*, J^*)$ both for Case (1) and Case (2), regard the quality of supply p and can be connected from the model obtained with the classic EOQ model. Further, the properties of Q^*, J^*, and $TC\ (Q^*, J^*)$ can be described as follows:

Case (1) :

$$\frac{dQ^*}{dp} = \frac{1}{2}\frac{2D^2BA + J^2(b+h)}{\sqrt{V}\ (2bk^2+ph)} > 0,$$

$$\frac{dJ^*}{dp} = \frac{1}{2}\frac{(2ph+bk)(2BD^2A + J^2(b+h))}{\sqrt{V}(2h+b)(2bk^2+ph)} > 0,$$

$$\frac{dTC(Q^*, J^*)}{dp} = -\frac{B^2D^4A}{R\sqrt{V^2}} + \frac{3}{4}\frac{(BDL)}{R^2\sqrt{V^5}} + \frac{\frac{1}{2}hVZE^2 + \frac{1}{4}phV^2E^2}{C_1} - \frac{7}{2}bpAR^2\sqrt{V^3} - \frac{bkR\sqrt{V}}{AC_1} - \frac{bM\sqrt{V}}{A^2}.$$

Case ($\boldsymbol{B}$):

$$\frac{dQ^*}{dp} = \frac{2BD^2AMbp + hp(p^2D^2BA - 2BDpA)}{\sqrt{\beta}(p^2h+2Mb)^2} > 0,$$

$J^* = 0,$

$$\frac{dTC(Q^*,J^*)}{dp} = \frac{QBD}{\gamma\sqrt{\beta^3}} + \frac{DQp^2h^2}{\alpha\gamma^2} + \frac{1}{2}\left(\frac{(2p^2hDA^5 - phDA^2 - 2bDMA^3)BDp + hp^2BD^2A^2(phA^3 + 2bMA)B^2}{\sqrt{\alpha^3}(phA^3 + 2bMA)^2}\right) + \frac{b}{2\alpha} - \frac{1}{2}\left(\frac{(-2p^2hDA^4 - phDA^4 - 2bDMA^2)BDA^2bp^2 + bp^2BD^2A^2(phA^2 + 2BMA)}{\sqrt{\alpha^3}(phA^3 + 2bMA)^2}\right) + \frac{QMb}{A\gamma\sqrt{\alpha}} - \frac{Mb\sqrt{\alpha}}{A^2}.$$

With:

$A = k + p,$

$C = b + h,$

$C_1 = 2h + b,$

$E = 2h + b - 2ph + bk,$

$L = 2D^2BA + CJ^2,$

$M = k^2 + k - kp,$

$Q = D^2BpA\gamma - 2BDAp^2h,$

$R = 2bh^2 + bk,$

$V = \frac{2BDA + CJ^2p}{2bk^2 + ph},$

$Z = \frac{2BDA^2 + (b+h)A^4Jp}{2bkA^2 + phA},$

$\alpha = \frac{BDAp}{\frac{1}{2}phA^3 + bMA},$

$\beta = \frac{BDpA}{\frac{1}{2}p^2h + bM},$

$\gamma = p^2h + 2bM.$

Based on the previous description that decreasing quality or increasing p value, will always result in optimal cost increase. Furthermore, the deteriorating quality also affects the quantity and the optimal order ratethat should decrease. However, deteriorating quality has an effect on the optimal quantity and order rate. This is in contrast to the statement produced by [6], so that the increase in system uncertainty must be compensated simultaneously by reducing the delivery interval and introducing J supply. Therefore the case that matches the problem is Case (1) safety supplies.A supply is said to be of good quality when there is no defect in it or $p = 0$. Then, the optimal number of orders and safety supplies (Q^*, J^*) and the expected total supply cost of each unit of time are converted to classical EOQ (with backorder) as follows:

$$Q^* = Q_0^* = \sqrt{2}\sqrt{\frac{BDk}{2bk^2 + ph}},$$

$$J^* = J_0^* = \frac{bkQ}{b + 2h},$$

and

$$TC(Q^*,J^*) = \frac{DB}{\sqrt{\frac{2BD}{2bk^2}}} - \frac{kb^2\sqrt{\frac{2BD}{2bk^2}}}{2h + b} + b(k + 1 - p)\sqrt{\frac{2BD}{2bk^2}}.$$

Hence, by characterizing the nature of each case characteristic, the optimal cost of the EOQB model provides a minimum total cost estimate but if it can only be achieved with a perfect supply quality $p = 0$ and this is rarely encountered in real events due to some constraints still can not be overcome.

IV. CASE STUDY

The model has employed one of the pamps supplier as a real case. This supplier is PT. Famili Kita which is located in Balikpapan, East Kalimantan, Indonesia. A company that sells pumps in all kinds to all over Indonesia. This product has a relatively flat demand of 14.049 pieces per year. The company pays Rp $184.860.000$ per year to start and inspect each supply. The shortage has been booked at a cost of Rp $8.058.750$ per year and the storage cost is Rp $519.807.868$ per year . It is assumed that the supplier is not fully reliable, with 0,15 experiencing quality under standard or defect. The parameter value are summarized as follows:

$D = 14049$ units, $p = 0{,}15, b = Rp\ 8.058.750, h = Rp\ 519.807.868, B = Rp\ 184.860.000$

Since $p \leq \frac{2h}{bk}$, the solution given is Proposition 1 (Case A). Therefore, the optimal ordering plan and backorder (Q^*, J^*) can be given as follows

$Q^* = 7.648{,}266$ pieces and $J^* = 1.598{,}487$ pieces

Then, can be obtained expectation of total cost each year is
$TC(Q^*, J^*) = Rp\ 605.834.406.923{,}886$
to observe the impact of supply uncertainty, we have devised two relative performace measures :

(i) $\Delta_1^{TC} = \frac{[TC(Q^*,J^*) - TC_0(Q_0^*,J_0^*)]}{TC_0(Q_0^*,J_0^*)}$

Which effectively present the optimal cost incrase caused by imperfect supply quality (relative to the classical EOQ cost that represents perdect quality) and

(ii) $\Delta_2^{TC} = \frac{[TC(Q_0^*,J_0^*) - TC(Q^*,J^*)]}{TC(Q^*,J^*)}$

Which shows the increase in the expected cost, if the EOQ optimal variables values are used instead of those evaluates through Proposition 1. For the example proble we have $\Delta_1^{TC} = 46{,}506\%$ and $\Delta_2^{TC} = 3{,}045\%$. Therefore, evem if only 1 in 15 deliveries are defective, we have a quite large cost increase. On the other hand, the optimal solution appears quite robust in deviations of the system variable from their optimal settings.

To observe the quantitative effect of changing parameter values on Q^*, J^*, and $TC(Q^*, J^*)$, we haveconducted a sensitivity analysis by varying the basic non-cost and cost parameters of the :

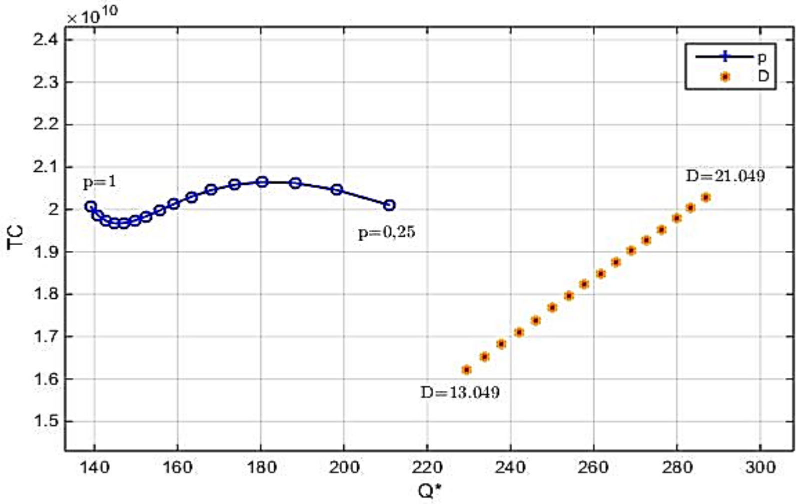

Figure 2. Sensitivity Analysis For Non-Cost Parameters.

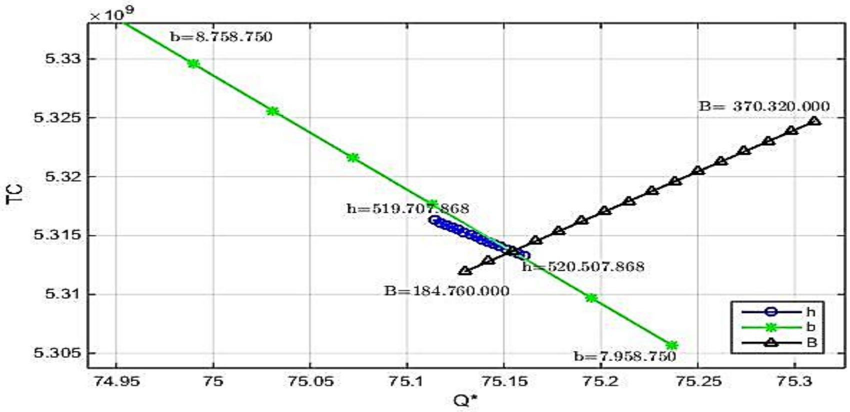

Figure 3. Sensitivity Analysis For. Cost Parameters

Figure (2) describes the optimal order quantity (Q^*) and the total cost expectancy (TC) is quite sensitive to variations in the quality of imperfect supply p and the demand rate D. When supply quality decreases (increases in supply probability of defects), order quantity Q^* drop. At the same time, the expected total cost of TC is relatively fluctuating. Then, as the demand level increases the order quantity increases, so does the total cost, this indicates that the demand rate is proportional to the order quantity and total supply cost. In the table for the non-cost parameter (Table 1) an increase in such cases becomes extremely extreme for the probability value of the number of batches damaged in the delivery period. The table shows the total cost increase of only Δ_1^{TC} (%) $= 46.506\%$. However, the demand change experienced a similar amount of Δ_1^{TC} for all numbers of parameter changes in which there was an increase in total cost of 34.626%.

In Figure (3), it is explained that the optimal order quantity (Q^*) and the total cost expectation (TC) are quite sensitive to variations in the change of cost parameters as well as on non-cost parameters. Reduction in the stored supply from $h = 520{,}507{,}868$ to $519{,}707{,}686$ decreases the number of orders and increases the total cost is quite small. At backorder costs decreased on the number of bookings but experienced a strong increase in total cost. Furthermore, on shipping costs from $184{,}760{,}000$ to $370{,}320{,}000$ makes the total number of bookings and total costs increase. However, the increase in shipping costs does not affect any of the performance ofΔ_1^{TC} and Δ_2^{TC} which is clearly indicated in Table 1, where each action remains unchanged with B. It is explained that in this case storage costs have the properties which is equal to the backorder cost that is inversely proportional to the number of orders and is proportional to the total cost of supply. Then, the greater the shipping cost then the total order and the total cost of supply is also greater. This indicates that the shipping cost is proportional to the number of orders and the total cost of supply.

Table 1. Numerical Result for Different Base Example Parameters.

PARAMETER	Q^*	J^*	$TC(Q^*, J^*)$	Δ_1^{TC}	Δ_2^{TC}
p	210,833	53,925	2,011	46,876	0,828
	198,105	60,498	2,046	49,480	0,958
	188,167	66,799	2,062	50,655	1,094
	180,163	72,897	2,065	50,835	1,236
	173,561	78,837	2,058	50,343	1,384
	168,012	84,652	2,046	49,427	1,538
	163,275	90,367	2,030	48,283	1,695
	159,180	95,998	2,013	47,066	1,857
	155,601	101,560	1,997	45,906	2,020
	152,444	107,063	1,984	44,909	2,183
h	251,986	39,446	1,843	34,616	5,816
	251,976	39,444	1,843	34,621	5,817
	251,966	39,442	1,843	34,626	5,817
	251,956	39,441	1,843	34,631	5,817
	251,946	39,439	1,843	34,636	5,817
	251,936	39,437	1,843	34,641	5,818
	251,926	39,435	1,843	34,646	5,818
	251,916	39,434	1,843	34,651	5,818
	251,906	39,432	1,843	34,656	5,818
	251,896	39,430	1,843	34,661	5,819
b	252,234	39,464	1,840	35,269	5,813
	252,100	39,453	1,842	34,946	5,815
	251,966	39,442	1,843	34,626	5,817
	251,832	39,432	1,844	34,310	5,819
	251,699	39,421	1,846	33,997	5,821
	251,566	39,410	1,847	33,686	5,823
	251,432	39,399	1,848	33,379	5,825
	251,299	39,389	1,850	33,075	5,827
	251,167	39,378	1,851	32,774	5,829
	251,034	39,367	1,852	32,476	5,831
B	251,898	39,432	1,843	34,626	5,817
	251,932	39,437	1,843	34,626	5,817
	251,966	39,442	1,843	34,626	5,817
	252,000	39,448	1,843	34,626	5,817
	252,034	39,453	1,843	34,626	5,817
	252,068	39,458	1,844	34,626	5,817
	252,103	39,464	1,844	34,626	5,817
	252,137	39,469	1,844	34,626	5,817
	252,171	39,474	1,844	34,626	5,817
	252,205	39,480	1,845	34,626	5,817

V. CONCLUSION

In this article, have considered setting up EOQ (with backorders) to study the effect of imperfect supply quality on operating systems and costs. Focus on a simple form of imperfect quality in which a fraction of all supply deliveries are not perfect (below quality standards) and, under the "all or not" inspection policy, these shipments are rejected. The simplest form of the model contributes in showing that global optimum can be obtained in closed form, with expressions being a direct extension of the classical EOQ.

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