Advances in Management & Applied Economics, vol.1, no.2, 2011, 59-75
ISSN: 1792-7544 (print version), 1792-7552 (online)
International Scientific Press, 2011

# Economic order quantity with imperfect quality, destructive testing acceptance sampling, and inspection errors

**Muhammad Al-Salamah**[1]

## Abstract

This paper proposes another realistic application of the economic order quantity EOQ model. Researchers have studied EOQ models that assume the received lot contains items that are perfect and imperfect. All models in the literature assume that the received lot goes through a 100% inspection to separate acceptable items from the non-acceptable items. This paper argues that 100% inspection is not always a cheap option to the buyer; instead, the received lot is subjected to an acceptance sampling plan before the lot can be accepted. In addition, for real life cases, destructive testing of items in the acceptance sample must be performed to test the acceptability of the items in the lot, as in packaged food and electrical wires. This paper will develop an EOQ model when items are of perfect and imperfect quality and a single acceptance sampling plan with destructive testing and inspection errors is adopted. It is assumed that when the lot is rejected, items in the rejected lot are sold at a secondary market at a reduced price and the buyer will place another order. It is also assumed that there are inspection errors.

[1] Mechanical Engineering Department, College of Engineering,
Majmaah University, Majmaah, Saudi Arabia, email: salamah@kfupm.edu.sa

Article Info: *Revised*: June 23, 2011. *Published online*: October 31, 2011

**JEL classification numbers:** C51

**Keywords:** economic order quantity, imperfect quality, acceptance sampling, inspection errors, destructive testing

# 1 Introduction

Different products need different kinds of quality assessment tests, to insure a product meets the required specifications, such as electric current load, shear strength, fatigue, and heat tolerance. A destructive test results in either destruction of the product or failure of product's design margin, for the purpose of evaluating the quality and reliability of the product either during or after the normal operating conditions ([1], [2]). A 100% inspection plan with destructive testing requires testing all units in the lot and destroying all of them; hence this inspection plan does not provide a viable option to both the producer and the buyer, because when the lot is destroyed, the buyer will be in constant shortage and the producer will not gain enough on return on investment. Therefore, acceptance sampling when destructive testing is required provides a lot screening plan that will be more acceptable ([3], [4], [5]).

As it is well known, acceptance sampling is a screening strategy used to judge the acceptability of a received lot; that is, whether the lot contains an acceptable number of defects (read more in [6], [7], and [8]). Acceptance sampling plans are conveniently described by operating characteristic or OC curves, which estimate the probability of acceptance of a lot for a given incoming quality level. To fit various needs for different OC curves, a number of acceptance sampling plans have been developed, such as single, double, multiple, sequential, etc (see [9] and [10]). In this research, it is assumed that incoming lots will be subjected to a single acceptance sampling plan for attributes, which consists of taking a random sample of size $n$ drawn from a lot of size $Q$. A predetermined acceptance number $c \geq 0$ specifies the allowable number of nonconforming items within the selected items in the sample. If the number of non-conforming items is less than or equal to $c$, the lot will be accepted, otherwise it will be rejected.

As one of the parameters of the OC curves, the acceptance number $c$ has to be selected carefully that will result in an acceptable sampling plan. In expensive tests and in tests that require destructive testing in particular, $c$ becomes more critical. Even the selection of $c$ is arbitrary, when destructive testing is employed by the receiving agent, the acceptance number is commonly set to zero as in [11], [12], and [13] and implied in [14].

In the literature, there have not been studies that are involved in the determination of the optimal order quantity when items are with imperfect quality and a destructive testing policy is being followed by the buyer. This article intends to investigate and explore the relationship between the incoming quality level, on one side, and the optimal lot size and the sample size decisions, on the other side. The function that will be minimized is the difference between the expected total cost and total profit. The total cost consists of ordering cost, holding cost, destructive testing cost, shortage cost due to defective items in the accepted lot that cannot meet any of the demand, and rejection cost. The profit is the return from selling the items in the rejected lot in a secondary market. The shortage cost can be thought of as the cost of accepting a lot, which is associated with the buyer's risk.

The economic order quantity with imperfect incoming quality and destructive testing has not been investigated by researchers. In the literature, nondestructive acceptance sampling plans have been proposed for lot acceptance; which have been designed to fit certain OC curves. This paper will further advance the study of the economic order quantity for the practical case when the single acceptance sampling plan for attributes and destructive testing are implemented. Specifically, this paper will develop a cost function for optimal determination of the lot size and sample size when items are with imperfect quality and the buyer will impose a destructive testing plan on the received lot. The total cost has the following components:

- Ordering cost
- Holding cost
- Destructive testing cost
- Shortage cost
- Profit from selling unacceptable lot.

The acceptance number $c$ will be taken as zero, as it was argued before (see the introduction). To further limit the scope of this research, the following assumptions are made:

- The demand rate is constant and known,
- The replenishment is infinite and instantaneous,
- There is a single product,
- Shortages are not back-ordered (lost sales case),
- The buyer will place a new order when the received lot is rejected.

For the inspection process, the following are assumed:

- The number of nonconforming items follows the binomial distribution,
- The inspection time is negligible,
- The inspection plan is without replacement of destroyed items,
- The inspection process is not perfect.

## 2 Literature Review

The literature dealing with the economic order quantity with imperfect incoming quality has exclusively been based on a screening, 100% inspection strategy; none of the studies on this topic have applied some form of acceptance sampling. The literature proposes a number of strategies on how imperfect quality can be treated within the classical economic order quantity methodology. The first study that includes imperfect quality in the economic order quantity model is [15], which is based on profit maximization. [16] present a simple approach for determining the economic order quantity for an item with imperfect quality. [17] have treated the proportion of the imperfect items as random variable and affirmed that a profit maximization model will lead to the same solution drawn from a cost minimization model. [18] consider defective products and Taguchi's cost of poor quality in the economic order quantity model, where the product quality follows a normal distribution function.

[19] present an inventory model for imperfect items under a one-time-only discount, where the defectives can be screened out by a screening process and then can be sold in a single batch by the end of the screening process. [20] has developed an inventory model for items with imperfect quality and quantity discounts in response to the request of the powerful buyer.

[21] analyze the effect of screening speed and variability of the supply process on the order quantity when items are imperfect and extend the model by allowing for several batches of imperfect quality items to be consolidated and shipped in one lot. [22] apply the concept of entropy cost to extend the classical EOQ model under the assumptions of perfect and imperfect quality.

Stochastic analysis of the economic order quantity with imperfect quality has been developed. [23] investigate the economic order quantity with imperfect quality items, where the percentages of defective items and poor-quality items in each delivered lot are assumed to be random variables, and the inspection cost, holding cost, ordering cost are characterized as fuzzy variables, respectively. [24] consider items to be of different qualities, perfect and imperfect, and the percentage of the yield rate from the perfect items is assumed to be a random variable with known probability distribution.

Some studies have included imperfect quality as a form of shortage that has to be carried to future orders. [24] and [26] have assumed bad items can be back-ordered and developed the total profit function per cycle. [27] develop an EOQ model in which each received lot contains some defective items and shortages backordered. It has been assumed that 100% of the items in each lot are inspected to separate good from defective items, which are imperfect quality and scrap items. The effect of percentage defective on optimal solution is studied. [28] have developed an economic order quantity model with defective items and shortages in fuzzy random environment; where the percentage of defective items is a random variable and the defective items contain imperfect quality items and scrap items; the rate of scrap items in defective items is a fuzzy variable. They have written an expression for the expected profit, which has been proven to be concave.

There are studies that examine the effect of learning on the economic order quantity with imperfect quality items. The first study on the learning effects was presented by [29]. They have developed models in which the percentage defective per lot is assumed to decline according to a learning curve. Based on previous studies, [30] present the optimal lot sizes for an item with imperfect quality when different holding costs for the good and defective items are considered. They have studied two situations: without a learning effect and with learning effect. They have noted that when there is learning effects, the lot size with different holding costs for the good and defective items is more than the one with same holding costs for the good and defective items. [31] consider learning in inspection with three cases: partial transfer of learning, total transfer of learning, and no transfer of learning. [32] examine a case when the screening process is imperfect and errors can happen during inspection. The probability of misclassification errors is assumed to be known.

In the literature review, it has been highlighted the advancements in the design of realistic economic order quantity models when items in the received lot are classified as either defective or non-defective. All proposed models assume a screening, 100% inspection of the lot; unacceptable items are either backordered or sold at a discounted price. These assumptions not necessarily hold for all real life cases; usually buyers do not have the resources to examine every item in the lot, so they are apt to adopt an acceptance sampling plan. For certain types of products, a destructive testing is required to ensure the items meet certain requirements.

## 3 The mathematical Model

The article will develop an economic order quantity model for the case when items are classified as defective and nondefective and the received lot is subjected to a single acceptance sampling plan and destructive testing and inspection errors. The cost function of the model is equal to the total costs minus total profits. Total costs include the costs of ordering, holding, destructive testing, and lot acceptance. Profits include revenue from selling the remaining items of the rejected lot. The variables of the model are the lot size and the sample size. The acceptance number will be assumed zero, as commonly used in destructive tests that are based on acceptance sampling.

Consider a buyer who places orders of size $Q$ from a supplier with a fixed ordering cost $A$ and unit variable ordering cost $C_o$ and faces a constant demand rate $D$. The inventory holding cost is $h$ and the cycle length is $T$. When a lot is received, the buyer uses a destructive testing acceptance sampling plan to decide if the lot should be accepted and placed in inventory or rejected. A sample of size $n$ units is taken from the lot and inspected. The probability that an item is defective is $p$. The buyer accepts a lot when the number of defective items in the sample is equal to or less than $c$, the acceptance number. The destructive testing cost is $g(n)$. The shortage cost is $C_a$ per unit. The probability of classifying a defective item as nondefective is $m$, with probability distribution function $f(m)$ and cumulative distribution function $F(m)$. When the result of destructive testing acceptance plan is to reject the lot, the buyer can sell the remaining items in the rejected lot for $K$ per unit and place a new order. The behavior of the inventory level is illustrated in Figure 1.

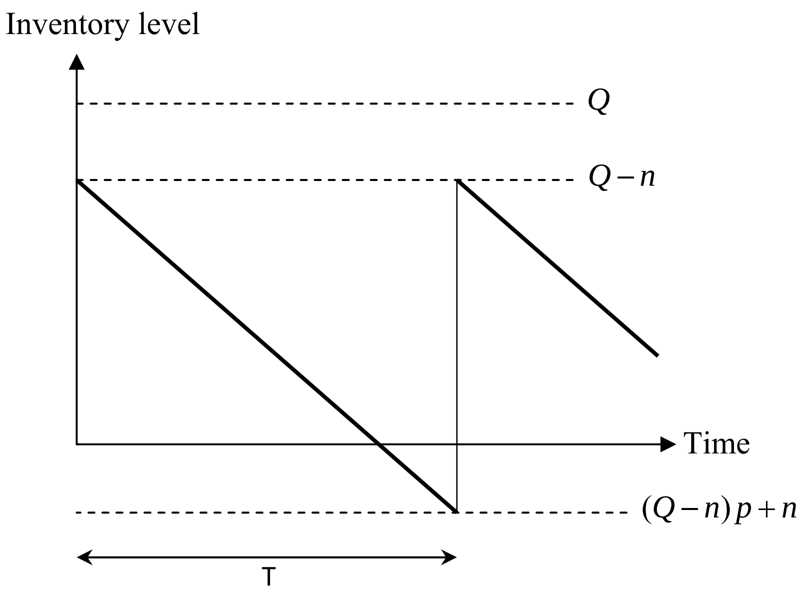


Figure 1: Behavior of the inventory level over time

The aim is to find an optimal ordering quantity and optimal sample size with zero acceptance number that will minimize the average total cost with an acceptable inspection service level:

$$\min E[TC(Q,n)] \quad \text{subject to} \quad P(\text{inspection yield}) \geq p_1 \tag{1}$$

The service level $p_1$ is the least acceptable probability that the acceptance sampling plan can offset the effect of inspection errors. The service level value is specified by the buyer.

The probability that a lot is accepted is equal to the probability that there are $c$ or less defective parts in the lot:

$$p_a = P(x \leq c) = \sum_{x=0}^{c} \binom{n}{x} p^x (1-p)^{n-x} \tag{2}$$

The received lot is rejected when the number of defects in the sample exceeds the acceptance number *c*.

When the lot is accepted, the expected number of short units that otherwise must meet part of the demand is equal to $(Q-n)p+n$, and these units will cause the buyer to incur shortage cost. Therefore, the cost of accepting a lot is:

$$C_a\left((Q-n)p+n\right)P(x\le c)=C_a\left((Q-n)p+n\right)p_a \tag{3}$$

The average expected total cost in a cycle consists of the difference between the total costs and the total benefits. The costs are the fixed ordering cost, the variable ordering cost, holding cost, cost of destructive testing, cost of lot rejection, and cost of lot acceptance; and the benefits are equal to the revenue from selling the remaining items in the rejected lot:

$$TC(Q,n)=\begin{cases} \dfrac{AD}{Q}+C_0D+g(n)\dfrac{D}{Q}+\dfrac{h(Q-n)^2}{2Q}+\dfrac{DC_a\left((Q-n)p+n\right)}{Q}, & p_a \\ 2\left(\dfrac{AD}{Q}+C_0D+g(n)\dfrac{D}{Q}\right)-\dfrac{KD(Q-n)}{Q}+\dfrac{h(Q-n)^2}{2Q}+\dfrac{DC_a\left((Q-n)p+n\right)}{Q}, & (1-p_a)p_a \\ 3\left(\dfrac{AD}{Q}+C_0D+g(n)\dfrac{D}{Q}\right)-2\dfrac{KD(Q-n)}{Q}+\dfrac{h(Q-n)^2}{2Q}+\dfrac{DC_a\left((Q-n)p+n\right)}{Q}, & (1-p_a)^2p_a \\ \vdots & \vdots \end{cases} \tag{4}$$

The expected total cost can be written as

$$E[TC(Q,n)]=p_a\sum_{i=0}^{\infty}[(i+1)(\frac{AD}{Q}+C_0D+\frac{g(n)D}{Q})-i\frac{KD(Q-n)}{Q}+h\frac{(Q-n)^2}{2Q} \\ +\frac{DC_a\left((Q-n)p+n\right)}{Q}](1-p_a)^i \tag{5}$$

In the expression of the expected total cost, $p_a$ is a function of the sample size $n$ and the acceptance number $c$.

**Theorem 3.1**

*The infinite series*

$$\sum_{i=0}^{\infty}[(i+1)(\frac{AD}{Q}+C_0D+\frac{g(n)D}{Q})-i\frac{KD(Q-n)}{Q}+h\frac{(Q-n)^2}{2Q}+\frac{DC_a\left((Q-n)p+n\right)}{Q}](1-p_a)^i$$

*converges*.

**Proof.** We can begin by expanding the expression of the series:

$$\begin{aligned}&\sum_{i=0}^{\infty}[(i+1)(\frac{AD}{Q}+C_0D+\frac{g(n)D}{Q})-i\frac{KD(Q-n)}{Q}+h\frac{(Q-n)^2}{2Q}+\frac{DC_a\left((Q-n)p+n\right)}{Q}](1-p_a)^i\\ &=(\frac{AD}{Q}+C_0D+\frac{g(n)D}{Q})\sum_{i=0}^{\infty}[(i+1)(1-p_a)^i]-\frac{KD(Q-n)}{Q}\sum_{i=0}^{\infty}i(1-p_a)^i\\ &+[h\frac{(Q-n)^2}{2Q}+\frac{DC_a\left((Q-n)p+n\right)}{Q}]\sum_{i=0}^{\infty}(1-p_a)^i\end{aligned}$$

The three resulting infinite series are convergent:

$$\sum_{i=0}^{\infty}[(i+1)(1-p_a)^i]=\frac{1}{p_a^2}$$

$$\sum_{i=0}^{\infty}i(1-p_a)^i=\frac{1-p_a}{p_a^2}$$

$$\sum_{i=0}^{\infty}(1-p_a)^i=\frac{1}{p_a}$$

Hence, the series converges and it is equal to

$$(\frac{AD}{Q}+C_0D+\frac{g(n)D}{Q})\frac{1}{p_a^2}-\frac{KD(Q-n)}{Q}\frac{1-p_a}{p_a^2}+[h\frac{(Q-n)^2}{2Q}+\frac{DC_a\left((Q-n)p+n\right)}{Q}]\frac{1}{p_a}$$

Substituting out the infinite series, the expected cost becomes:

$$\begin{aligned}E[TC(Q,n)]=(\frac{AD}{Q}+C_0D+\frac{g(n)D}{Q})\frac{1}{p_a}-\frac{KD(Q-n)}{Q}\frac{1-p_a}{p_a}+h\frac{(Q-n)^2}{2Q}\\ +\frac{DC_a\left((Q-n)p+n\right)}{Q}\end{aligned} \tag{6}$$

When the acceptance number $c$ is set to zero, the lot acceptance probability becomes $p_a=(1-p)^n$, and the expected total cost reduces to

$$E[TC(Q,n)] = (\frac{AD}{Q} + C_0 D + \frac{g(n)D}{Q})\frac{1}{(1-p)^n} - \frac{KD(Q-n)}{Q}(\frac{1}{(1-p)^n} - 1) + h\frac{(Q-n)^2}{2Q} + \frac{DC_a\left((Q-n)p+n\right)}{Q} \tag{7}$$

In considering the inspection yield, the number of defects in the sample is equal to $pn$. But because of the error in inspection, the reported number of defects in the sample is only $pn(1-m)$. Therefore, we can define the yield of the inspection to be whether $pn(1-m) \geq c+1$. Therefore, the sample size *n* should be selected such that:

$$P(pn(1-m) \geq c+1) \geq p_1 \tag{8}$$

The probability of misclassification of a defective item $m$ is the only random variable in the inspection yield constraint; hence we can write:

$$P(1-m \geq \frac{c+1}{pn}) \geq p_1 \tag{9}$$

$$P(m \leq 1-\frac{c+1}{pn}) \geq p_1 \tag{10}$$

$$\int_0^{1-\frac{c+1}{pn}} f(m)dm \geq p_1 \tag{11}$$

The limits of the integration might exceed the permissible range of $m$, which can be defined as $\left[m_{\min}, m_{\max}\right]$. A better description of the integration can be:

$$\int_{m_{\min}}^{\ell} f(m)dm \geq p_1 \ , \quad \ell = \min\left\{1-\frac{c+1}{pn},\ m_{\max}\right\} \tag{12}$$

$$F(\min\left\{1-\frac{c+1}{pn},\ m_{\max}\right\}) \geq p_1 \tag{13}$$

The economic order quantity with destructive testing acceptance sampling and inspection errors is found by minimizing $E[TC(Q,n)]$, defined by Eq. (7), subject to the inspection yield constraint, defined by Eq. (13).

## 4 Numerical Analysis

Consider a buyer who replenishes the inventory from a production system that produces perfect and imperfect items. The relevant costs and parameters are:

$C_a = \$0.7$

$C_0 = \$2$ per unit

$A = \$50$

$h = \$0.5$

$D = 1000$ units per year

$p = 0.01$

$K = \$0.4$ per unit

$f(m)$ normal ($\mu = 0.002$, $\sigma = 1$)

$p_1 = 0.1$

$c = 0$

In this analysis of the model, the inspection cost function will be assumed to be linear; $g(n) = 5n + 10$. A linear inspection cost function reasonably describes the all costs associated with inspection, such as managerial cost, engineering cost, labor cost, etc. Examples of studies that assume linear inspection costs include [33] and [5]. The model is solved using GAMS-BARON solver. The optimal solution for the parameters selected above is $Q = 1{,}112$ and $n = 30$.

The sample size as determined by the inspection yield probability is shown in Figure 2. The sample size is calculated from Eq. (13) for the case of normal distribution as $n \geq \frac{1}{p(1-\Phi^{-1}(p))}$, where $\Phi^{-1}$ is the normal inverse cumulative distribution function, and $c = 0$. The plot of $n$ vs $p_1$ shows that the sample size increases when the inspection yield probability is raised. This result is consistent with a prior expectation that when the probability is high, we need a large sample in order for the number of defects in the sample which have been correctly classified as defective to exceed the critical number. The plot also shows that the sample size increases when the standard deviation declines. For example, for $p_1 = 0.1$, the sample size $n = 44$ when $\sigma = 1$, and $n = 53$ when $\sigma = 0.7$.

The effect of the selling price $K$ on the lot size, sample size, and the expected cost is illustrated in Table 1. The lot size $Q$ seems to increase only slightly with the increase in $K$, while the expected cost declines with the increase in the selling price.

Table 1. Selling price

| $K$ | $Q$ | $n$ | $E[TC(Q,n)]$ |
|---|---|---|---|
| 0.4 | 1,112 | 30 | 3,111.038 |
| 0.5 | 1,114 | 30 | 3,076.797 |
| 0.6 | 1,116 | 30 | 3,042.554 |

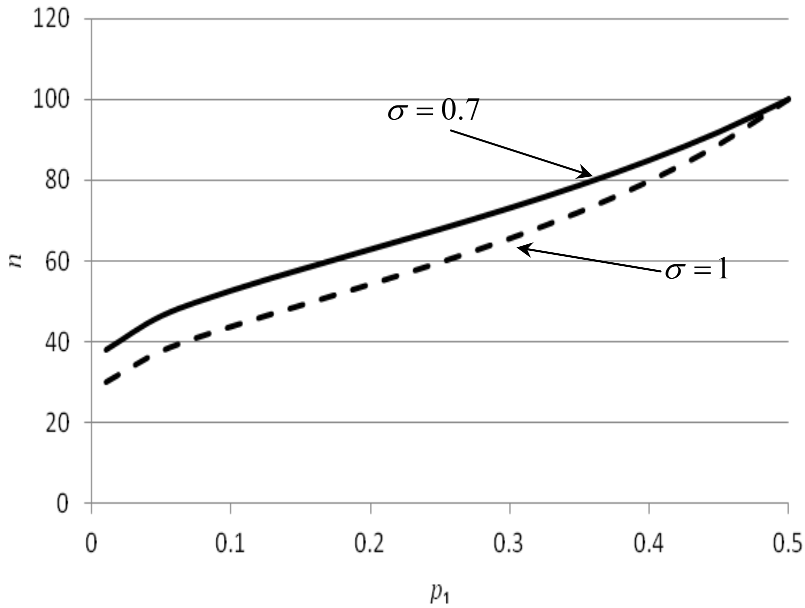


Figure 2: Sample size

Table 2 illustrates the effect of the probability of a defective item on the lot size, sample size, and the expected cost. With the increase in $p$, all variables decline. The decline in the lot size $Q$ with the increase in $p$ is consistent with the expectation that when the probability of defective is high, we better order less quantity to reduce the shortage cost per cycle.

Table 2. Probability of defective

| $p$ | $Q$ | $n$ | $E[TC(Q,n)]$ |
|---|---|---|---|
| 0.01 | 1,112 | 30 | 3,111.038 |
| 0.02 | 884 | 15 | 3,014.729 |
| 0.03 | 793 | 10 | 2,982.461 |

## 5 Conclusion

This article provides an economic order quantity model in which the buyer orders items from a production process that produces perfect and imperfect products. As a result, the buyer applies an acceptance sampling plan; because of the nature of the items, destructive testing is required to assess quality. The inspection process is not perfect; defective items can be still classified by the inspection as nondefective. If the received lot is rejected, the remaining items are sold in a secondary market for a reduced price and a new order is place. It has been found that the increase the selling price reduces the lot size, and that increase the probability of a defect item reduces both the lot size and the sample size.

**ACKNOWLEDGEMENTS.** I would like to acknowledge the support received from King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

# 6 References


[1] T. Pyzdek and P. Keller, *Quality Engineering Handbook*, CRC Press, 2003.

[2] F. Breyfogle, *Implementing Six Sigma: Smarter Solutions using Statistical Methods*, Second edition, Wiley, 2003.

[3] K.K. Aggarwal, *Reliability Engineering*, Kluwer Academic Publishers, 1993.

[4] M.J. Kowalewski, *Quality and Statistics: Total Quality Management*, American Society for Testing and Materials, 1994.

[5] F. Delgadillo and R. Bremer, The Development of A Destructive Sampling Method Designed For High Quality Production Processes (DSM-HQ), *Quality and Quantity*, **44**(3), 2010, 595-605.

[6] P. Pang, *The Essentials Of Quality Control Management*, Trafford Publishing, 2003.

[7] E.G. Schilling and D. V. Neubauer, *Acceptance Sampling In Quality Control*, CRC Press, 2009.

[8] J.L. Devore, *Probability and Statistics for Engineering and the Sciences*, Eighth edition, Duxbury Press, 2011.

[9] M.J. Kowalewski and J. B. Tye, *Statistical Sampling: Past, Present, and Future Theoretical and Practical*, ASTM International, 1990.

[10] K. Stephens, *The Handbook Of Applied Acceptance Sampling: Plans, Principles, and Procedures*, ASQ Quality Press, 2001.

[11] F. Wurnik, Sampling Analysis in the DPM Range, *Microelectronics and Reliability*, **30**(1), (1990), 35-38.

[12] C. Raju and H. A. Raghottam, A Note on Optimum Chain Sampling (ChSP-1), *Economic Quality Control*, **20**(1), (2005), 21–30.

[13] F. Delgadillo, R. Bremer and J.J. Hoffman, A Destructive Sampling Method Designed For Outsourcing Situations Involving High Quality Production Processes, *Quality and Quantity*, **41**(3), (2007), 513-529.

[14] T.T. Allen, Introduction to Engineering Statistics and Lean Sigma, Second edition, Springer, 2010.

[15] M.K. Salameh and M.Y. Jaber, Economic Production Quantity Model for Items with Imperfect Quality, *International Journal of Production Economics*, **64**(1-3), (2000), 59-64.

[16] S.K. Goyal and L.E. Cardenas-Barron, Note On: Economic Production Quantity Model for Items with Imperfect Quality - A Practical Approach, *International Journal of Production Economics*, **77**(1), (2002), 85-87.

[17] S. Papachristos and I. Konstantaras, Economic Ordering Quantity Models for Items with Imperfect Quality, *International Journal of Production Economics*, **100**(1), (2006), 148-154.

[18] J. Tsou, Economic Order Quantity Model and Taguchi's Cost Of Poor Quality, *Applied Mathematical Modelling*, **31**(2), (2007), 283-291.

[19] W.K. Hsu and H. Yu, EOQ Model for Imperfective Items Under A One-Time-Only Discount, *Omega*, **37**(5), (2009), 1018-1026.

[20] T. Lin, An Economic Order Quantity With Imperfect Quality And Quantity Discounts, *Applied Mathematical Modelling*, **34**(10), (2010), 3158-3165.

[21] B. Maddah and M.Y. Jaber, Economic Order Quantity for Items with Imperfect Quality: Revisited, *International Journal of Production Economics*, **112**(2), (2008), 808-815.

[22] M.Y. Jaber, M. Bonney and I. Moualek, An Economic Order Quantity Model for An Imperfect Production Process with Entropy Cost, *International Journal of Production Economics*, **118**(1), (2009), 26-33.

[23] X. Wang, W. Tang and R. Zhao, Random Fuzzy EOQ Model with Imperfect Quality Items, *Fuzzy Optimization and Decision Making*, **6**(2), (2007), 139-153.

[24] B. Maddah, M.K. Salameh and G.M. Karame, Lot Sizing with Random Yield and Different Qualities, *Applied Mathematical Modelling*, **33**(4), (2009), 1997-2009.

[25] J. Rezaei, Economic Order Quantity Model with Backorder for Imperfect Quality Items, *Proceedings of the IEEE International Engineering Management Conference*, **2**, (2005), 466-470.

[26] H.M. Wee, J. Yu and M.C. Chen, Optimal Inventory Model for Items with Imperfect Quality and Shortage Backordering, *Omega*, **35**(1), (2007), 7-11.

[27] A. Eroglu and G. Ozdemir, An Economic Order Quantity Model with Defective Items and Shortages, *International Journal of Production Economics*, **106**(2), (2007), 544-549.

[28] X. Wang, W. Tang, Y. Sai and K. Zhang, Fuzzy Random EOQ Model with Defective Items and Shortages, *IEEE International Conference on Networking, Sensing and Control*, (2008), 107-110.

[29] M.Y. Jaber, S.K. Goyal and M. Imran, Economic Production Quantity Model for Items with Imperfect Quality Subject to Learning Effects, *International Journal of Production Economics*, **115**(1), (2008), 143-150.

[30] M.I.M. Wahab and M.Y. Jaber, Economic Order Quantity Model for Items with Imperfect Quality, Different Holding Costs, and Learning Effects: A Note, *Computers & Industrial Engineering*, **58**(1), (2010), 186-190.

[31] M. Khan, M. Y. Jaber and M.I.M. Wahab, Economic Order Quantity Model for Items with Imperfect Quality with Learning in Inspection, *International Journal Of Production Economics*, **124**(1), (2010), 87-96.

[32] M. Khan, M.Y. Jaber and M. Bonney, An Economic Order Quantity (EOQ) for Items with Imperfect Quality and Inspection Errors, *International Journal of Production Economics*, in press.

[33] C.H. Lie and Y.H. Chun, Optimum Single-Sample Inspection Plans for Products Sold Under Free And Rebate Warranty, *IEEE Transactions on Reliability*, **R-36**(5), (1987), 634 – 637.