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# Calculating EOQ and ROP for Some Equipment

***E. Ebojoh*[a], *A.O. Jewo*[b] *and O.E. Ogbebor*[c]**
[a,c]Department of Production Engineering University of Benin, Benin City
[b]Department of Mechanical Engineering, Petroleum Training Institute, Effurun, Delta State
Email: voke.ebojoh@uniben.edu; andy_jewo@yahoo.com and osaowa.ogbebor@uniben.edu

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**Abstract**

*This paper presents the development and implementation of a software that calculates the Economic Order Quantity (EOQ) and the Re-Order Point (ROP) for some equipment in a servicing company. Appropriate software tool such as Visual Basic 6.0, Structure Query language and Microsoft Access was used. The software takes into account parameters such as the ordering cost, carrying or holding cost, annual demand, daily demand and lead time. A t-test which falls within the confidence interval of 0.05 was used to ascertain the superiority of the software calculation.*

## 1. Introduction

The concept of inventory theory involves the accumulation or stocking items (raw materials, purchased parts, semi-finished products, and finished goods) that is tangible in order to meet future demand [1].Inventory control can thus be defined as a planned approach of determining what to order, when to order, how much to order, and how much to stock so that the costs associated with buying and storing are optimal, without interrupting production and sales [1]. The goal of inventory control is to strike a balance between the loss due to non-availability of an item and the cost of carrying the stock of an item. This has led to two broad categories of inventory models: the Deterministic inventory models and the Probabilistic (or stochastic) inventory models.
The classical inventory model, also known as the Wilson's lot size formula or economic order quantity (EOQ) was developed by F.W Harris in 1913, but R.H Wilson, a consultant who applied it extensively, has been given credit for it [2]. This model is characterized by a steady or constant demand with no shortages. However, demand can vary either with time, or stock-level. The classical EOQ model has been extended to cover cases of irregular demand [3]. Further the Silver-Meal heuristic model was developed for the discrete time varying demand case [4] and could be adapted to give an approximate solution for continuous time-varying demand model [3]. An inventory model in which the demand rate is dependent on the instantaneous inventory level until a given inventory level is attained was presented [5], after

which the demand rate becomes constant. A simple and efficient algorithm for the determination of an optimal (r*, Q*) policy, which was restricted to the case where demands arise on a unit -by- unit basis was presented [6].

A probabilistic inventory model when delay in payment is permissible has been developed [7], while a deterministic inventory model for deteriorating items in which time and deterioration of units are treated as continuous variables and demand is a random variable was also modeled , [7], [8], [9] and [10] and presented in various work. A model in which the deterioration of inventory follows a three parameter Weibull distribution where the demand is assumed to be time varying and shortages are allowed in the system was proposed [11]. These models developed and researched by various scholars which include {[12], [13], [14], [15], [16], [17], [18], [19]} were however limited to analytical solutions and most times had algorithms that were somewhat cumbersome to compute manually. The main thrust therefore of this work is to incorporate these varied inventory models into software which will make computation and analysis simpler, faster and more accurate.

## 1.1 Related Mathematical Formulae

The following parameters will be defined:

### 1.1.1 Carrying or Holding Cost

The carrying or holding cost is the cost of keeping spares in warehouse or inventory unit.

Total carrying cost = $\frac{Q}{2}$ x $C_h$ (1)

Where Q = quantity of inventory item

$C_h$ = Unit carrying cost of inventory item

### 1.1.2 Ordering Cost

This is the cost of placing order for inventory item or the cost of purchasing inventory item.

Total ordering cost = $\frac{Q}{2}$ x $C_0$ ` (2)

Where $C_o$ = ordering cost for unit inventory item

### 1.1.3 Economic Order Quantity (Q*)

This is the optimal order quantity, it is quantity ordered that minimizes the total cost. It is achieve when total ordering cost equals total carrying cost.

$$Q^* = \sqrt{\frac{2DCo}{Ch}} \quad (3)$$

Where D = annual demand in units of inventory item

### 1.1.4 Re-Order Point (ROP)

This is the point at which order is placed to prevent stock out

$$ROP = d \times L \quad (4)$$

Where d = daily demand of inventory item

L = lead time in days

## 2.0 Methodology

### 2.1 Data Collection

Data was collected from a petrochemical company by means of a sample questionnaire. This data entails information about the annual demand, usage of spares, ordering cost, holding cost and lead time of the spares for both rotating and static equipment used.

## 2.2 Data Analysis

The data presented in Tables 1 to 8 were analyzed to determine the Economic Order Quantity (EOQ) and the Re-Order Point by using the relations in Eq. 1 to Eq. 4

Table 1: Compressor (Air Blower)

| Stockable Spare part | Year | Annual Demand in units of spares | Quantity of Spares used quarterly | Order cost (₦) | Carrying cost (₦) | Average daily demand in units of spare | Lead time in days |
|---|---|---|---|---|---|---|---|
| Bearing | 2013 | 8 | 2 | 1200 | 720 | 0.02 | 14 |
| | 2014 | 16 | 4 | 1300 | 840 | 0.04 | 15 |
| | 2015 | 16 | 4 | 1300 | 880 | 0.04 | 14 |
| | 2016 | 8 | 2 | 1500 | 890 | 0.02 | 18 |
| | 2017 | 8 | 2 | 2500 | 1200 | 0.02 | 16 |
| | 2018 | 8 | 2 | 2800 | 1220 | 0.02 | 18 |

Table 2: Pump 1 (Oil)

| Stockable spare part | Year | Annual Demand in Units of Spares | Quantity of spares used quarterly | Ordering cost (₦) | Carrying cost (₦) | Average daily demand in unit of spare | Lead time in days |
|---|---|---|---|---|---|---|---|
| Mechanical seal | 2013 | 4 | 1 | 1200 | 750 | 0.01 | 16 |
| | 2014 | 2 | 0 | 1500 | 800 | 0.01 | 15 |
| | 2015 | 2 | 1 | 1500 | 800 | 0.01 | 14 |
| | 2016 | 2 | 0 | 1800 | 900 | 0.01 | 17 |
| | 2017 | 2 | 1 | 3600 | 1500 | 0.01 | 18 |
| | 2018 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 3: Pump 2 (Fuel Gas)

| Stockable Spare part | Year | Annual Demand in units spares | Quantity of Spares used quarterly | Ordering cost (₦) | Carrying cost (₦) | Average daily demand in unit of spare | Lead time in days |
|---|---|---|---|---|---|---|---|
| Mechanical seal | 2013 | 4 | 1 | 1200 | 750 | 0.01 | 16 |
| | 2014 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015 | 2 | 0 | 1500 | 800 | 0.01 | 14 |
| | 2016 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2017 | 4 | 1 | 3600 | 1500 | 0.01 | 18 |
| | 2018 | 2 | 0 | 4000 | 1700 | 0.01 | 17 |

Table 4: Pulverizer

| Stockable Spare part | Year | Annual Demand in units spares | Quantity of Spares used quarterly | Ordering cost (₦) | Carrying cost (₦) | Average daily demand in unit of spare | Lead time in days |
|---|---|---|---|---|---|---|---|
| Sieve/Basket | 2013 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2014 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2016 | 2 | 1 | 1000 | 250 | 0.01 | 15 |
| | 2017 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2018 | 2 | 1 | 1500 | 300 | 0.01 | 14 |

Table 5: Dryer

| Stockable Spare part | Year | Annual Demand in units spares | Quantity of Spares used quarterly | Ordering cost (₦) | Carrying cost (₦) | Average daily demand in units of spare | Lead time in days |
|---|---|---|---|---|---|---|---|
| Bearing | 2013 | 8 | 2 | 1200 | 720 | 0.02 | 14 |
| | 2014 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015 | 8 | 2 | 1300 | 880 | 0.02 | 14 |
| | 2016 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2017 | 8 | 2 | 2500 | 1200 | 0.02 | 16 |
| | 2018 | 8 | 2 | 2800 | 1200 | 0.02 | 15 |

Table 6: Bucket Elevator

| Stockable Spare part | Year | Annual Demand in units spares | Quantity of Spares used quarterly | Ordering cost (₦) | Carrying cost (₦) | Average daily demand in units of spare | Lead time in days |
|---|---|---|---|---|---|---|---|
| Cups | 2013 | 24 | 12 | 1200 | 350 | 0.07 | 15 |
| | 2014 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2016 | 20 | 10 | 1500 | 500 | 0.06 | 16 |
| | 2017 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2018 | 26 | 13 | 2400 | 1200 | 0.07 | 14 |

Table 7: Magnetic Separator

| Stockable Spare part | Year | Annual Demand in units spares | Quantity of Spares used quarterly | Ordering cost (₦) | Carrying cost (₦) | Average daily demand in units of spare | Lead time in days |
|---|---|---|---|---|---|---|---|
| Bearing | 2013 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2014 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2016 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2017 | 8 | 2 | 2500 | 1200 | 0.02 | 14 |
| | 2018 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 8: Bag Filter

| Stockable Spare part | Year | Annual Demand in units spares | Quantity of Spares used quarterly | Ordering cost (₦) | Carrying cost (₦) | Average daily demand in units of spare | Lead time in days |
|---|---|---|---|---|---|---|---|
| Filter | 2013 | 3000 | 750 | 1200 | 350 | 8.22 | 14 |
| | 2014 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2015 | 4000 | 1000 | 1500 | 500 | 10.96 | 14 |
| | 2016 | 0 | 0 | 0 | 0 | 0 | |
| | 2017 | 0 | 0 | 0 | 0 | 0 | |
| | 2018 | 9000 | 2500 | 2400 | 1200 | 16.44 | 13 |

Based on the parameters presented in Tables 1- 8 the Economic Order Quantity (Q*) and the Re-order Point (ROP) are computed for the various equipment as follow: The computed results are tabulated in Tables 10.

For Bag Filter (filter);
Using appropriate parameters in Table 8 and Eq. 3 and Eq. 4
(In 2013, D = 3000, $C_o$ = ₦1200, $C_h$ = ₦350, d = 8.22, L = 14)

$$Q^* = \sqrt{\frac{2\times3000\times1200}{350}} = 144, \quad ROP = 8.22 \times 14 = 115$$

(In 2015, D = 4000, $C_o$ = ₦1500, $C_h$ = ₦500, d = 10.96, L = 14)

$$Q^* = \sqrt{\frac{2\times4000\times1500}{500}} = 155, \quad ROP = 10.96 \times 14 = 154$$

(In 2018, D = 9000, $C_o$ = ₦2400, $C_h$ = ₦1200, d = 24.66, L = 13)

$$Q^* = \sqrt{\frac{2\times9000\times2400}{1200}} = 190, \quad ROP = 24.66 \times 13 = 321$$

Table 9: Bag Filter

| Stockable Spare part | Year | Reorder point | Economic Order quantity |
|---|---|---|---|
| Bearing | 2013 | 115 | 144 |
| | 2014 | 0 | 0 |
| | 2015 | 144 | 155 |
| | 2016 | 0 | 0 |
| | 2017 | 0 | 0 |
| | 2018 | 321 | 190 |

In the calculations done above, any fraction for Q* and ROP is rounded up to one unit. This is so because decimal fraction of spares cannot be obtained. However, the actual value of ROP is the safety stock unit together with the calculated value obtained.

## 2.3 Development of Software

Software for Spare Part Inventory Module (SPIM) was developed. In the development of the SPIM, appropriate software tool such as Visual Basic 6.0, Structure Query language and Ms Access was used. This is to ensure that the system will support good interface facilities with external programs and systems. The SPIM was designed with a good graphical user interphase (GUI). The forms allow the user to select required parameters from a predefined list. The user enters only the values of parameters and the system automatically generates the required result on the user interface. It also provides a user-friendly interface consisting of menu bars and buttons to help user during data input to the system and facilities to explicitly display results


**Fig. 1: Screenshot of SPIM startup interface**

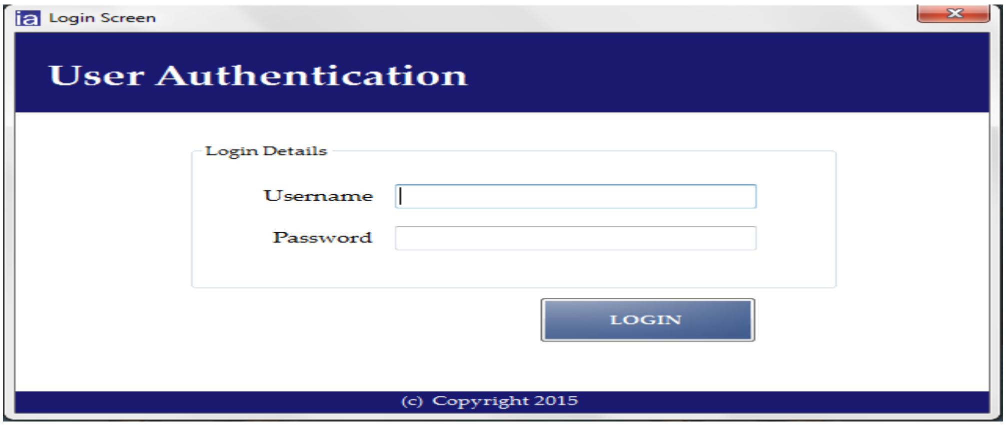


**Fig. 2: Screenshot of SPIM authentication interface**

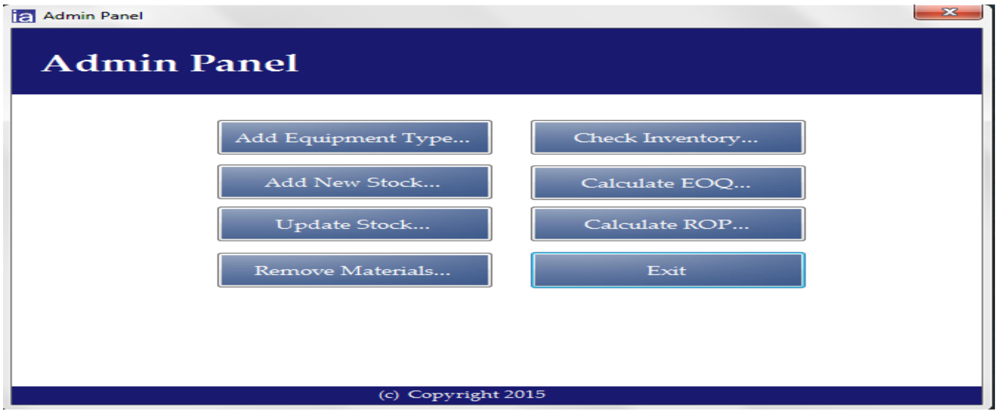


**Fig. 3: Screenshot of SPIM main menu**

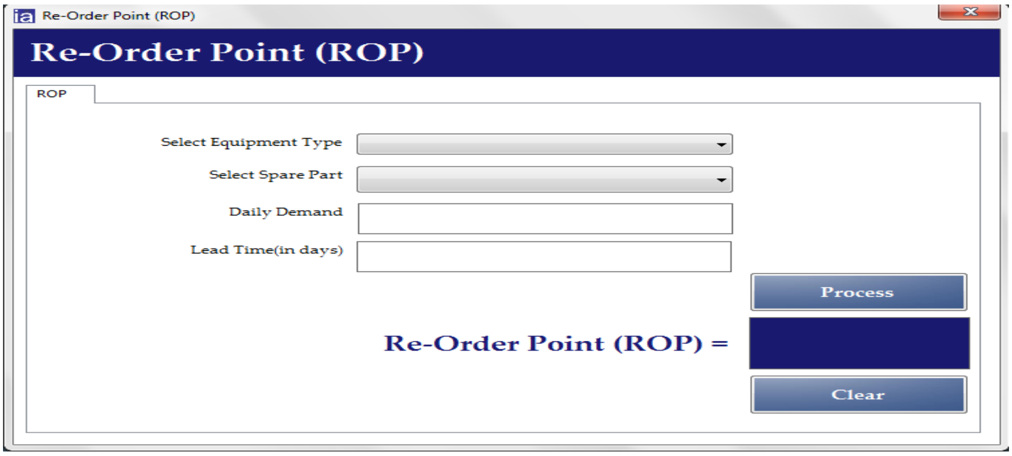


**Fig. 4: Screenshot of SPIM ROP computation interface**

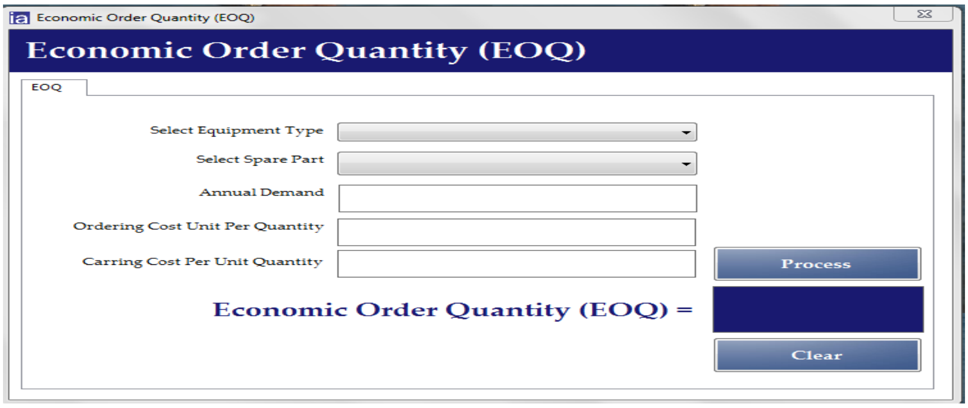


**Fig. 5: Screenshot of SPIM EOQ computation interface**

## 2.4 Model of Flow Chart

A flowchart is a diagrammatic representation that illustrates the sequence of operation to be performed to get the solution of a problem. Flowcharts are generally drawn in the early stages of formulating computer solutions by the use of standard symbols which are in form of rectangle circle, diamond, etc. They are usually connected by arrows which indicate the order in which the system is being developed. The flowchart shown in Fig. 6 is the model on which the spare parts inventory management system software was built.

### 2.4.1 Algorithm for Spare Parts Inventory Module

An algorithm is a specific set of instruction for carrying out a procedure or solving a problem, usually with the requirement that the procedure terminate at some point. The algorithm developed for the spare parts inventory module is based on the flowcharts and consists of the sequence of determining the Economic Order Quantity.

## 3.0 Results and Discussion

A software for optimizing inventory control system in a petrochemical carbon black plant was developed and named SPIM. During the verification of the software, the following areas were of concern: correctness, consistency and completeness of the model.

## 3.1 The Spare Part Inventory Module Result

Using test cases the result generated using the SPIM verified against manual calculation.
Test case 1: Bag Filter
Significant input:
Spare part type = Bearing
Annual demand = 3000
Holding cost = 350
Ordering cost = 1200
Output (EOQ) = 144

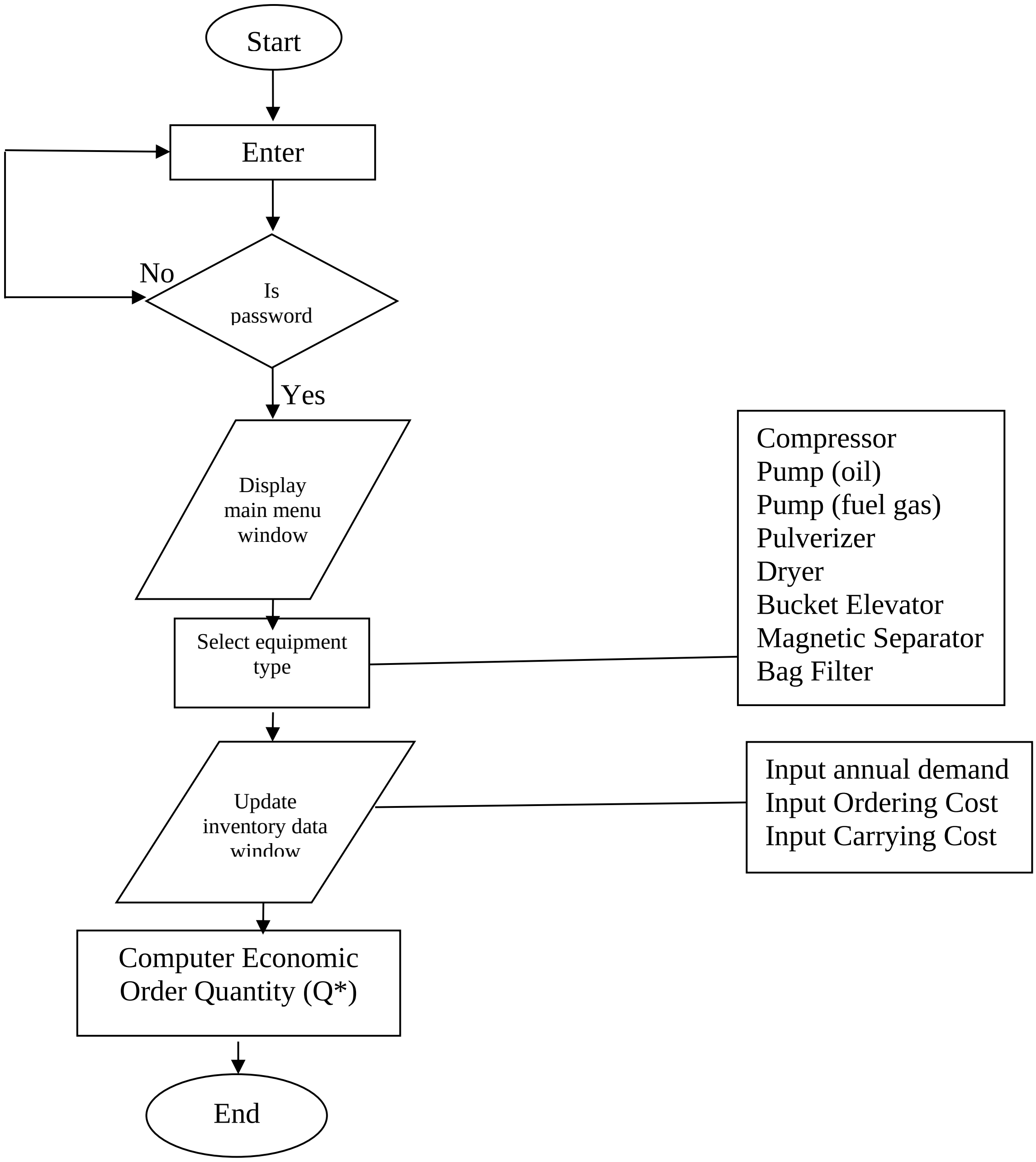


**Fig. 6: Spare Parts Inventory Module Flowchart.**

| | |
|---|---|
| 10 | Start |
| 20 | Enter password |
| 30 | Is password correct? |
| 40 | If yes, display main menu screen, Else 20 |
| 50 | Select equipment type |
| 60 | Input inventory data |
| 70 | Input annual demand |
| 80 | Input ordering cost per unit quantity |
| 90 | Input carrying cost per unit quantity |
| 100 | Compute Economic Order Quantity |
| 110 | End |

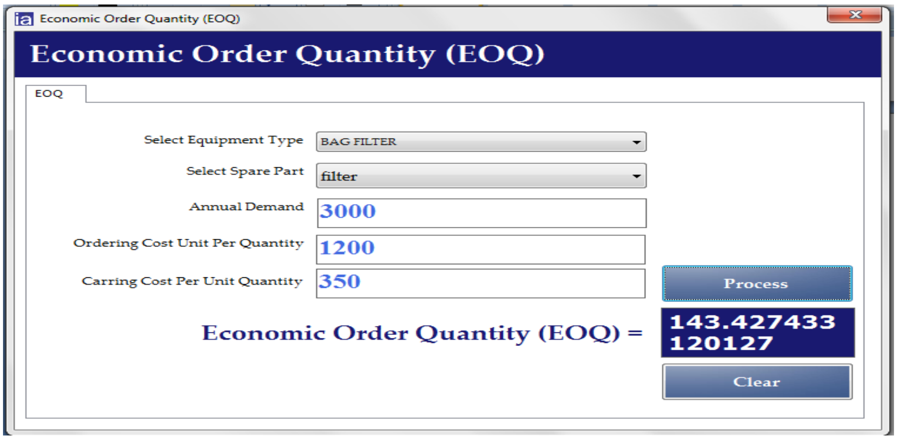


**Fig. 7: Screenshot of software result for EOQ of bag filter**

Test case 2 " Bag Filter
Significant input:
Daily Demand = 8.22
Lead time = 14 days
Output (ROP) = 115

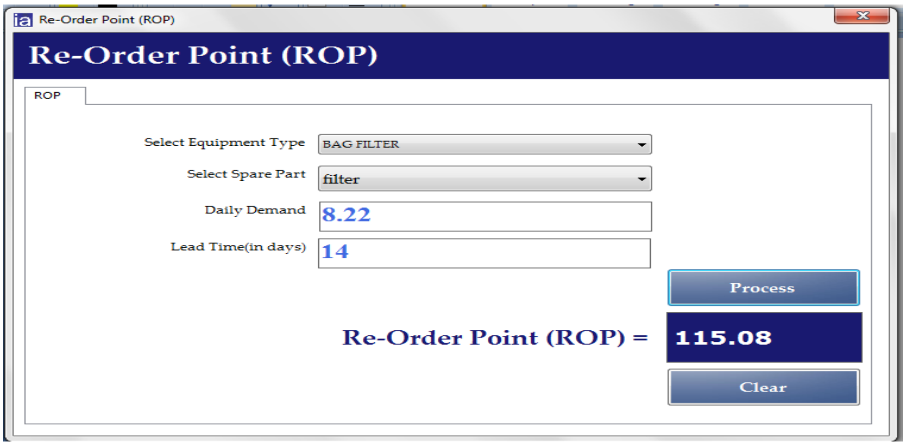


**Fig. 8:Screenshot of software result for ROP of Bag Filter**

A total of sixteen test cases were examined during the system's verification, eight tests each on the EOQ and ROP model respectively. A summary of the results obtained is presented in Table 10:

Table 10: Comparison of test results obtained for manual against software computation.

| s/n | Equipment (spare parts) | Manual computation | | Software computation | |
|---|---|---|---|---|---|
| | | ROP | EOQ | ROP | EOQ |
| 1 | Bag filter (filter) | 115 | 114 | 115.08 | 114 |
| 2 | Magnetic separator (bearing) | 0.28 | 6 | 0.28 | 6 |

| | | | | | |
|---|---|---|---|---|---|
| 3 | Bucket elevator (cups) | 1.05 | 13 | 1 | 13 |
| 4 | Dryer (bearing) | 0.28 | 5.16 | 0.28 | 6 |
| 5 | Pulverizer3 (sieve/basket) | 0.15 | 4 | 0.15 | 4 |
| 6 | Pump2 (fuel gas) (Mechanical seal) | 0.18 | 4.4 | 0.18 | 5 |
| 7 | Pump1(oil) (Mechanical seal) | 0.16 | 4 | 0.16 | 4 |
| 8 | Compressor (bearing) | 0.6 | 7.03 | 0.6 | 8 |

A t-test was carried out on the software and manual means. The test was carried out in succession at 95% confidence level to ascertain if there is significant difference in both means. The null hypothesis is that, there is no significant difference in the means of using manual computation and software computation. While the alternative hypothesis is that, there is a significant difference in both means. The significance level (α) is the probability of rejecting the null hypothesis when it is the true. If the t-test values are outside the range of confidence level, the assumption that the null hypothesis is true is rejected and the alternative hypothesis is accepted.

Difference = μ (ROP_s) - μ (ROP)
Estimate for difference: 0.0
95% CI for difference: (-43.8, 43.8)
t-Test of difference = 0 (vs ≠): t-Value = 0.00, p-Value = 1.000, DF = 13
Both use Pooled StDev = 40.5388

Difference = μ (EOQ_s) - μ (EOQ)
Estimate for difference: 0.3
95% CI for difference: (-40.9, 41.5)
t-Test of difference = 0 (vs ≠): t-Value = 0.02, p-Value = 0.988, DF = 13
Both use Pooled StDev = 38.1558

Since the value of t–calculated fall within the confidence level, the null hypothesis is accepted and the alternative rejected affirming the superiority of the software over the manual.

## 4.0 Conclusion

Table 10 presents the result obtained for manual computation and software computation of EOQ and ROP. From the results obtained, it is obvious that there is no significant difference between both means of computation. The software computation is very fast. It aids reduction and simplification of the computation process. Organizational performance can be improved with the use of this software as it eliminates the arithmetic process involve in computing inventory parameters (EOQ and ROP).

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