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# APPLICATION OF MULTI-ITEMS INVENTORY MODELS IN COURSE MATERIALS MANAGEMENT: TOWARDS BUILDING A DECISION SUPPORT SYSTEM FOR THE NATIONAL OPEN UNIVERSITY OF NIGERIA.

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**Abstract:**

The classic multi-item inventory model with space, number of inventory and monetary constraints were applied in this research to solve the Course Materials inventory management problem of the National Open University of Nigeria (NOUN). The Kuhn-Tucker necessary and sufficient condition of determining optimum Economic Order Quantities (EOQ) which uses the Lagrange multiplier trial-and-error method was replaced in this work with a simple trimming method to speed up the process. Python programming was used to code the resultant model to give a flexible interface that will be easy to use by all users. Numerical illustrations were given for the three different models to validate the performance of the model on the test data. The trimming method used in this work was tested by comparing results obtained using the method with those obtained using the Lagrange trial-and-error method. When implemented, the proposed model will improve decision making in Course Material inventory management and reduce the difficulty encountered by staff in utilization of stored data for basic scientific analysis using manual computational processes.

**Keywords:** Course Materials, Decision Support System, Economic Order Quantity, Multi-Item Inventory Models, Inventory Constraint, Python Programming, Space Constraint

## Introduction

Managing the complex processes involved in production and Inventory control using human intuitive judgment and manual processes is undoubtedly daunting with too many associated challenges. More so, these manual processes most times produce unreliable outputs which lead to wastages, extra costs and other disadvantages compared with automated systems. The National Open University of Nigeria is faced with the challenge of managing its over one thousand eight hundred different Course Materials (CM) which they are obligated to print and distribute to students every semester after registration. NOUN offers wide range of programmes across its eight faculties with over Five Hundred Thousand students. These students are spread across over one hundred Study Centres nationwide. Every Semester, there is need to distribute over One Thousand Eight Hundred distinctive printed Course materials to these students at their different locations to enable them study and prepare for examination.

A study of the system of Course Materials production planning and inventory management in the National Open University of Nigeria shows that a lot of problem-solving and decision-making processes are manually carried out. This has effect on the overall productivity and efficiency of the resultant system as evident in the non-availability of some Course Materials at the Study Centres when demanded by students. There is need therefore, to develop a comprehensive decision support system (DSS) for problem solving and decision making in the entire processes of production and inventory management of Course Materials in NOUN. Such decision support system must consists of relevant models and tools for forecasting students population, determining demand for each Course Material, managing production and inventory of the Course Materials. Adoga et al. (2022) discussed the demand forecast module and the Economic production module of the proposed DSS, in this paper, we present the inventory management module of the decision support system which will be used for the Course Materials inventory management.

Inventory management problems exist in many organizations that rely on inventory items for day to day running of the organizations. Such organizations are usually faced with the problem of how much items to order so as to service their demands for a certain period of time and when to place such orders for each inventory item in order not to go out of stock. Inventory Management is important for the successful operations of most organizations due to the amount of money inventory represents. Efficient inventory and production planning hinges on the right decision being made at the right time as each wrong decision may cost the firm very heavily in terms of money, labour and other resources (Russel & Taylor, 1995). To avoid wasteful spending on inventory, a firm must establish an inventory policy that specifies when an order for additional items should be placed and how many items should be ordered at each time. In this regard, different types of inventory models have been developed to provide effective directional guidance for inventory management (Masood, 1998). This research therefore presents three specialized inventory models to help NOUN Decision Makers determine the optimum order quantities and when to place orders for each Course Material to ensure all year availability of the Materials.

The Economic Order Quantity model is generally used to determine an optimal order size by balancing the setup cost and inventory holding cost (Jonrinaldi et al., 2018). Kasthuri et al. (2011) developed a multi-item inventory model with constraints of storage space, number of orders and production cost in both crisp and fuzzy environment. The Kuhn-Tucker conditions method was employed in solving the model. The developed model can be modified to accommodate constraints such space, inventory level and budget. Rohatgi & Agrawal (2016) applied multi-item inventory models in the area of pharmacy inventory management. The problem was derived as nonlinear programming problem under limited budget and number of orders in a fixed period of time constraints. The results proved effective in the computation of EOQ, Optimum cost and optimum number of orders for a list of pharmaceutical inventory items with different yearly demand. Miranda et al. (2015) presented an alternative approach for the calculation of the multi-item EOQ in presence of space restrictions. The model introduced an exit condition to stop the algorithm quickly when there is the certainty that the optimal solution has been found.

Hariga (2000) developed an efficient iterative procedure to determine the near optimal lot size, reorder point and setup time. The reduction in setup time proposed by the model is efficient in reduction of the total inventory costs and results in a smaller lot size and a shorter lead time. Ouyang et al. (1999) investigated the impact of ordering cost reduction on the modified continuous review inventory systems involving variable lead time with a mixture of backorders and lost sales. An algorithm procedure to find the optimal order quantity, ordering cost, reorder point and lead time simultaneously was finally developed. Lin & Hou (2005) proposed an inventory system with random yield in which both the setup cost and yield variability can be reduced through capital investment. The paper discussed a procedure to find the optimal order quantity, reorder point, optimal setup cost and yield standard deviation. Results showed that significant cost savings can be achieved by adopting capital investments.

Zhang & Wang (2011) explored the structural properties of deteriorated multi-item EOQ model and proposed an algorithm for solving the optimal solution by proving that the studied problem is a special convex separable nonlinear knapsack problem. The result is also applicable to solving the classical constrained multi-item EOQ problem with suitable modification. Ophokenshi et al. (2019) proposed a mathematical model of an inventory system with time-dependent, three-parameter Weibull deterioration and a stochastic type demand in the form of a negative exponential distribution. The optimal inventory policy for the proposed model was derived and the necessary and sufficient condition for the optimal policy was also established. The objective of Kotb & Fergany (2011) was to derive the analytical solution of the EOQ model of multiple items with both demand-dependent unit cost and lead time using geometric programming approach. The optimal order quantity, the demand rate and the lead time were determined and used to obtain the optimal total cost.

Yen et al. (2019) presented a model that considers the holding costs of raw materials under conditions of two-level trade credit and limited storage capacity. Four theorems were developed in the work to characterize the optimal solutions according to a cost minimization strategy. Ukil & Uddin (2016) developed a time dependent inventory model on the basis of constant production rate and market demands which are exponentially decreasing. The model developed an algorithm to determine the optimal demand, optimal order interval, optimal time cycle and the optimum total cost. Skowron & Styczen (2016) considered a complex autonomous inventory coupled system that can take the form of a network of chemical or biochemical reactors for example and where the inventory interactions perform the recycling of by-products between the subsystems. A multi-frequency second-order test for complex multi-periodic systems including the boundary optimal steady-state process and an arbitrary large number of harmonics used to verify its improvement by the multi-periodic operation was also proposed.

Sharma (2005) discussed extensively the Lagrange method of solving Multi-Item Deterministic Inventory Models (The classical EOQ with Constraints models). The method of Lagrange's multiplier was used to minimize the cost equations considering limitations of storage, finance and inventories in separate cases. The systematic trial and error method was used to find $\lambda^*$ (the optimum value of λ), by trying successive value of λ, the values of $\lambda^*$ should result in simultaneous values of $q_i^*$ satisfying the given constraint equations.

**Materials and Methods**

Here we present the steps followed in applying the classic multi-items inventory models to the data of NOUN course material inventory. The classic multi-item inventory models with space, monetary and inventory limitations discussed in Sharma (2005) were adopted with modifications in the slow trial-and-error method which were replaced with faster trimming methods in this work.

The Classical EOQ Model is constructed based on the conditions that goods arrive the same day they are ordered and no shortages allowed. Figure 1 show the classic inventory cycle. The cycle begins at time 0 with an arriving order. The amount of the order is the lot size, q. The lot is delivered all at one time causing the inventory to shoot from 0 to Q instantaneously. Materials are withdrawn from inventory at a constant demand rate, R. After the inventory is depleted, the time for another order of size Q arrives, and the cycle repeats (Taha, 2007). Figure 1 shows the cycle of a single item but there are many real life situations where multiple items are required to run an organization. These multiple items most times compete for space, monetary and other limited resources of the organization making the inventory problem more complex to deal with. In such situations, the EOQ models are first applied without constraints. Then the results are subjected to constraints depending on the nature of the problem.

Sharma (2005) gave the unconstraint equation for the order quantity $q_i$ as:

$$q_i = \sqrt{\frac{2C_3^{(i)}R_i}{C_1^{(i)}}}\ ,\ i = 1,2,\ldots,n. \tag{1}$$

While the equation for the limitation on floor space (Storage space) was given as:

$$q_i^* = \sqrt{\left(\frac{2C_3^{(i)}R_i}{C_1^{(i)}+2\lambda^* a_i}\right)}\ ,\ i = 1,2\ldots,n. \tag{2}$$

Subject to $\sum_{i=1}^{n} a_i q_i^* \leq A$ (3)

The equations for limitation on investment, was given as:

$$q_i^* = \sqrt{\left(\frac{2C_3^{(i)}R_i}{C_1^{(i)}+2\lambda^* C_4^{(i)}}\right)} \tag{4}$$

Subject to $\sum_{i=1}^{n} C_4^{(i)} q_i^* \leq M$ (5)

Similarly, the equation for limitation of Inventories was given as:

$$q_i^* = \sqrt{\left(\frac{2C_3^{(i)}R_i}{C_1^{(i)}+\lambda^*}\right)}, \quad i = 1,2\ldots,n. \tag{6}$$

Subject to $\sum_{i=1}^{n} q_i^* \leq N$ (7)

Finally, P, d and C(t) are given by:

$$P = \frac{R_i}{q_i^*} \tag{8}$$

$$d = \frac{365}{P} \tag{9}$$

$$C(t) = \frac{R_i}{q_i^*} C_3 \tag{10}$$

***Notations and Assumptions of the Models***

n = number of items

$R_i$ = demand rate for the i[th] item (i= 1,2….,n).

$C_1^{(i)}$ = holding (or carrying) cost per unit of the quantity of i[th] item.

$C_3^{(i)}$ = Ordering cost per unit order for the i[th] item.

$C_4^{(i)}$ = unit price of the i[th] item

C(q) = Total inventory cost

C(t) = Total annual ordering cost

$q_i$ = the amount of quantity ordered of the i[th] item.

$q_i^*$ = Economic Order Quantity (EOQ) of the i[th] item.

λ = Lagrange Multiplier

P = number of Orders per year

d = Number of days' supply per optimum order

T = trimming constant

A = the maximum storage area (in sq. meter) available for the n items.

$a_i$ = Storage area required per unit of the i[th] item

M = The Amount of money available for investment on inventory at a particular time.

N = Maximum number of stock at a given time.

The models have the same assumptions with the classic inventory models as follows:

i. The demand is deterministic and supply is instantaneous.
ii. Shortages are not allowed.
iii. The order of each item is not dependent on the other.

***Applying the inventory model with limitation in space***

In this model, the inventory system includes n >1 items which are competing for a limited storage space. An interaction between the different items occurring due to this limitation is considered as a constraint. The classical multi-item inventory model uses the Kuhn-Tucker necessary and sufficient condition which uses the Lagrangian multiplier and trial-and-error methods to find the constrained optimum order quantities of each item from equation 2 and 3. The trial-and error method is a slow algorithm considering the number of iterations that may occur before arriving at a solution. To fasten the process, this study determined $q_i^*$ for each item using the steps below:

i. Determine the unconstrained value of $q_i$ using equation 1
ii. Compute the value of $\sum_{i=1}^{n} a_i q_i$
iii. If the value of $\sum_{i=1}^{n} a_i q_i \leq A$ stop and set the obtained values $q_i$ to $q_i^*$ (optimum values)
iv. If $\sum_{i=1}^{n} a_i q_i > A$, we compute a trimming constant (T) given by $T = \frac{A}{\sum_{i=1}^{n} a_i q_i}$ (11)
v. $q_i^*$ (optimum values) = $Tq_i$ for i = 1,2…., n. (12)
vi. Check if $\sum_{i=1}^{n} Tq_i^* \leq A$

***Applying the inventory Model with limitation in investment (monetary constraint)***

In this case we consider an upper monetary limit M (in Naira) on the amount available for investment on the entire inventory items. To achieve the objective in equation 5, we apply our trimming method to obtain the optimum value of $q_i^*$ after determining the unconstrained value of $q_i$ using equation 1. The steps involved in executing the model are:

i. Compute the value of $\sum_{i=1}^{n} C_4^{(i)} q_i$
ii. If the value of $\sum_{i=1}^{n} C_4^{(i)} q_i \leq M$ stop and set the obtained values $q_i$ to $q_i^*$ (optimum values)
iii. If $\sum_{i=1}^{n} C_4^{(i)} q_i > M$, we compute a trimming constant (T) given by $T = \frac{M}{\sum_{i=1}^{n} C_4^{(i)} q_i}$ (13)
iv. $q_i^*$ (optimum values) = $Tq_i$ for i = 1,2…., n.
v. Check if $\sum_{i=1}^{n} C_4^{(i)} q_i^* \leq M$

***Applying the inventory Model with limitation in Inventories items***

In this case we intend to limit the number of all units of the stocks to N,

i.e $\sum_{i=1}^{n} q_i \leq N$, i = 1,2…., n.

Again we apply our trimming method to obtain the optimum value of $q_i^*$ after determining the unconstrained value of $q_i$ using equation 1. The steps involved in executing the model are:

i. Compute the value of $\sum_{i=1}^{n} q_i$
ii. If the value of $\sum_{i=1}^{n} q_i \leq N$ stop and set the obtained values $q_i$ to $q_i^*$ (optimum values)
iii. If $\sum_{i=1}^{n} q_i > N$, we compute a trimming constant (T) given by $T = \frac{N}{\sum_{i=1}^{n} q_i}$ (14)
iv. $q_i^*$ (optimum values) = $Tq_i$ for i = 1,2…., n.
v. Check if $\sum_{i=1}^{n} q_i^* \leq N$

A flowchart of the model selection process is shown in figure 1.

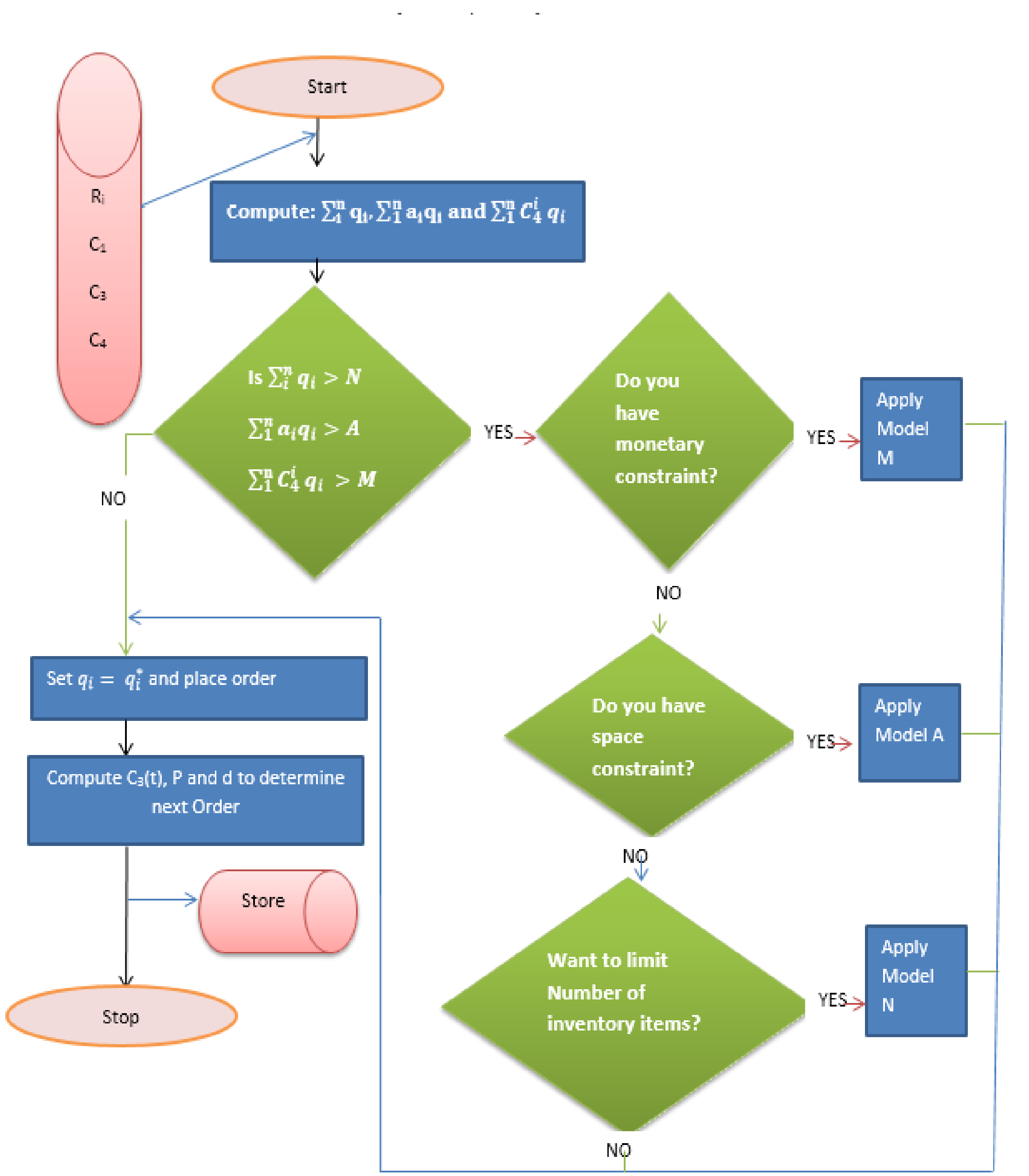


**Figure 1: A flowchart of the model selection process**

***System Implementation***

Jupyter notebook Integrated Development Environment (IDE) was used to develop the DSS prototype using python programming language. The inventory module of the Decision Support System was tested to determine the performance and accuracy of the developed system.

The inputs in table 2 – 4 were used to illustrate the performance of the three multi-items inventory models discussed in this research. The values of A, M and N in equations 11, 13 and 14 were given as 12m$^2$, ₦2, 500,000 and 1800 units respectively. The Trimming factor for each model was computed from the respective constraint equations as follows:

$T = \frac{A}{\sum_{i=1}^{n} a_i q_i}$=**0.5737659877159055**, $T = \frac{M}{\sum_{i=1}^{n} C_4^{(i)} q_i}$= **0.5341247129251392,** and

, $T = \frac{N}{\sum_{i=1}^{n} q_i}$ = **0.860648981573858**

for the space, monetary and inventory constraint models respectively. The performance of the trimming method used in this work was evaluated relative to the Lagrange multiplier parameter method found in literature. An example of each constraint model solved using trial and error Lagrange multiplier method (Sharma, 2005) was reworked using the inbuilt trimming factor of our DSS. Results of both methods were compared as shown in table 1.

**Results and Discussion**

Tables 2 – 4 also show the outputs of the inventory module of the developed DSS prototype. The inventory module has three inbuilt inventory models; the models with space, monetary and inventory constraints. The values of EOQ ($q_i$*) of each item shown in tables 2 – 4 represents the optimum number of items required per order so as to meet the projected yearly demand without stock out . (P) Represents the optimum number of orders per year that will satisfy the total yearly demand while C(q) represents the cost of ordering the EOQ of each item per order made. These results provide answers to basic question such as when to Order, how much to Order and the cost of each Order. For every Order, the EOQ of each item is ordered and received. The results are in line with the inventory cycle discussed by Taha (2007) and will serve as a basis for formation of an inventory policy for the institution. Table 1 show the results obtained when the trimming method used in this research was compared with the trial and error Lagrange multiplier method presented in Sharma (2005). The EOQ obtained from our DSS inventory module and that obtained by Sharma (2005) from the same inputs were compared. The variations from the two methods were relatively small and negligible. Our proposed trimming method is therefore recommended for its speed over the slow trial and error method which in some cases took up to seven trials before the final result. The interface of the developed DSS prototype allows users to select an input file for an inventory model and then provide tools for execution of the chosen model. Upon execution, the model outputs consisting of the economic order quantities (EOQ) of each course material, optimum number of orders per year and the total ordering cost are displayed in the model output window. The results of this module will help Decision Makers to decide on when to place orders and how much quantity of each item to order at a given time.

**Table 1: Validation of the Space Model**

| Item code (Inventory item) | Annual Forecast Demand (Ri) | Ordering Cost per Unit item (C3) | Holding Cost per unit item (C1) | Storage area reserve for the ith item (ai) | $q_i$ | EOQ (qi* = $Tq_i$) | EOQ computed from Lagrange Multiplier method | Positive difference |
|---|---|---|---|---|---|---|---|---|
| 1 | 20 | 100 | 30 | 1 | 11.54701 | 5.5 | 6.7 | 1.2 |
| 2 | 40 | 50 | 10 | 1 | 20 | 9.5 | 7.6 | 1.9 |
| 3 | 30 | 150 | 20 | 1 | 21.2132 | 10.0 | 10.6 | 0.6 |
| Grand Total | | | | | 52.76021 | 25 | 24.9 | 0.1 |

**Table 2: Inputs and Outputs of the multi-item EOQ model with space limitation**

| Course code (items) | Annual Forecast Demand (Ri) | Ordering Cost per Unit item (C3) | Holding Cost per unit item (C1) | Storage area reserve for the ith item (ai) | Unconstraint Order Quantity $q_i = \sqrt{\frac{2C_3^{(i)}R_i}{C_1^{(i)}}}$ | EOQ (qi* = $Tq_i$) | Number of Orders per year (P) | C3(t) |
|---|---|---|---|---|---|---|---|---|
| CIT101 | 1506 | 400 | 200 | 0.01 | 77.61443 | 44.532 | 33.81798 | 13527.19 |
| CIT102 | 1297 | 400 | 200 | 0.01 | 72.02777 | 41.327 | 31.38378 | 12553.51 |
| CSS111 | 1342 | 400 | 200 | 0.01 | 73.26664 | 42.037 | 31.92357 | 12769.43 |
| CSS112 | 1297 | 400 | 200 | 0.01 | 72.02777 | 41.327 | 31.38378 | 12553.51 |
| CSS121 | 1342 | 400 | 200 | 0.01 | 73.26664 | 42.037 | 31.92357 | 12769.43 |
| CSS132 | 1297 | 400 | 200 | 0.01 | 72.02777 | 41.327 | 31.38378 | 12553.51 |
| CSS133 | 1342 | 400 | 200 | 0.01 | 73.26664 | 42.037 | 31.92357 | 12769.43 |
| CSS134 | 1297 | 400 | 200 | 0.01 | 72.02777 | 41.327 | 31.38378 | 12553.51 |
| CSS136 | 1297 | 400 | 200 | 0.01 | 72.02777 | 41.327 | 31.38378 | 12553.51 |
| CSS152 | 1297 | 400 | 200 | 0.01 | 72.02777 | 41.327 | 31.38378 | 12553.51 |
| ECE110 | 273 | 400 | 200 | 0.01 | 33.04542 | 18.960 | 14.39848 | 5759.39 |
| ECE112 | 273 | 400 | 200 | 0.01 | 33.04542 | 18.960 | 14.39848 | 5759.39 |
| ECE113 | 271 | 400 | 200 | 0.01 | 32.92416 | 18.890 | 14.34564 | 5738.255 |
| ECE120 | 273 | 400 | 200 | 0.01 | 33.04542 | 18.960 | 14.39848 | 5759.39 |
| ECE121 | 271 | 400 | 200 | 0.01 | 32.92416 | 18.890 | 14.34564 | 5738.255 |
| ECE123 | 271 | 400 | 200 | 0.01 | 32.92416 | 18.890 | 14.34564 | 5738.255 |
| ECO121 | 1342 | 400 | 200 | 0.01 | 73.26664 | 42.037 | 31.92357 | 12769.43 |
| EDU111 | 435 | 400 | 200 | 0.01 | 41.71331 | 23.933 | 18.17523 | 7270.091 |
| EDU112 | 441 | 400 | 200 | 0.01 | 42 | 24.098 | 18.30014 | 7320.057 |
| EDU114 | 441 | 400 | 200 | 0.01 | 42 | 24.098 | 18.30014 | 7320.057 |
| ENG111 | 164 | 400 | 200 | 0.01 | 25.6125 | 14.695 | 11.15982 | 4463.927 |
| ENG113 | 164 | 400 | 200 | 0.01 | 25.6125 | 14.695 | 11.15982 | 4463.927 |
| ENG114 | 168 | 400 | 200 | 0.01 | 25.92296 | 14.873 | 11.29509 | 4518.038 |
| ENG121 | 164 | 400 | 200 | 0.01 | 25.6125 | 14.695 | 11.15982 | 4463.927 |
| ENG122 | 168 | 400 | 200 | 0.01 | 25.92296 | 14.873 | 11.29509 | 4518.038 |
| ENG141 | 164 | 400 | 200 | 0.01 | 25.6125 | 14.695 | 11.15982 | 4463.927 |
| ENG162 | 168 | 400 | 200 | 0.01 | 25.92296 | 14.873 | 11.29509 | 4518.038 |
| ENG172 | 168 | 400 | 200 | 0.01 | 25.92296 | 14.873 | 11.29509 | 4518.038 |
| GST101 | 1777 | 400 | 200 | 0.01 | 84.30896 | 48.373 | 36.7349 | 14693.96 |
| GST102 | 1738 | 400 | 200 | 0.01 | 83.37865 | 47.839 | 36.32956 | 14531.82 |
| GST105 | 1777 | 400 | 200 | 0.01 | 84.30896 | 48.373 | 36.7349 | 14693.96 |
| GST107 | 1777 | 400 | 200 | 0.01 | 84.30896 | 48.373 | 36.7349 | 14693.96 |
| PCR111 | 1342 | 400 | 200 | 0.01 | 73.26664 | 42.037 | 31.92357 | 12769.43 |
| PCR114 | 1297 | 400 | 200 | 0.01 | 72.02777 | 41.327 | 31.38378 | 12553.51 |
| PED112 | 273 | 400 | 200 | 0.01 | 33.04542 | 18.960 | 14.39848 | 5759.39 |
| PED122 | 271 | 400 | 200 | 0.01 | 32.92416 | 18.890 | 14.34564 | 5738.255 |
| PED130 | 273 | 400 | 200 | 0.01 | 33.04542 | 18.960 | 14.39848 | 5759.39 |
| PED144 | 271 | 400 | 200 | 0.01 | 32.92416 | 18.890 | 14.34564 | 5738.255 |
| POL111 | 1342 | 400 | 200 | 0.01 | 73.26664 | 42.037 | 31.92357 | 12769.43 |
| POL126 | 1297 | 400 | 200 | 0.01 | 72.02777 | 41.327 | 31.38378 | 12553.51 |
| Grand Total | | | | | 2091.445 | 1200 | NA | 364511.8 |

**Table 3: Inputs and Outputs of the multi-item EOQ model with monetary limitation**

| Course code (Inventory item) | Annual Forecast Demand (Ri) | Ordering Cost per Unit item (C3) | Holding Cost per unit item (C1) | unit price of the ith item (C4) | $q_i = \sqrt{\frac{2C_3^{(i)}R_i}{C_1^{(i)}}}$ | EOQ (qi* = $Tq_i$) | Number of Orders per year (P) | C(t) |
|---|---|---|---|---|---|---|---|---|
| CIT101 | 1506 | 400 | 200 | 2000 | 77.61443 | 41.45579 | 36.32786 | 14531.14 |
| CIT102 | 1297 | 400 | 200 | 2000 | 72.02777 | 38.47181 | 33.71299 | 13485.2 |
| CSS111 | 1342 | 400 | 200 | 2500 | 73.26664 | 39.13352 | 34.29285 | 13717.14 |
| CSS112 | 1297 | 400 | 200 | 2500 | 72.02777 | 38.47181 | 33.71299 | 13485.2 |
| CSS121 | 1342 | 400 | 200 | 2500 | 73.26664 | 39.13352 | 34.29285 | 13717.14 |
| CSS132 | 1297 | 400 | 200 | 2500 | 72.02777 | 38.47181 | 33.71299 | 13485.2 |
| CSS133 | 1342 | 400 | 200 | 2500 | 73.26664 | 39.13352 | 34.29285 | 13717.14 |
| CSS134 | 1297 | 400 | 200 | 2500 | 72.02777 | 38.47181 | 33.71299 | 13485.2 |
| CSS136 | 1297 | 400 | 200 | 2500 | 72.02777 | 38.47181 | 33.71299 | 13485.2 |
| CSS152 | 1297 | 400 | 200 | 2500 | 72.02777 | 38.47181 | 33.71299 | 13485.2 |
| ECE110 | 273 | 400 | 200 | 2000 | 33.04542 | 17.65038 | 15.46709 | 6186.837 |
| ECE112 | 273 | 400 | 200 | 2000 | 33.04542 | 17.65038 | 15.46709 | 6186.837 |
| ECE113 | 271 | 400 | 200 | 2000 | 32.92416 | 17.5856 | 15.41033 | 6164.133 |
| ECE120 | 273 | 400 | 200 | 2000 | 33.04542 | 17.65038 | 15.46709 | 6186.837 |
| ECE121 | 271 | 400 | 200 | 2000 | 32.92416 | 17.5856 | 15.41033 | 6164.133 |
| ECE123 | 271 | 400 | 200 | 2000 | 32.92416 | 17.5856 | 15.41033 | 6164.133 |
| ECO121 | 1342 | 400 | 200 | 2500 | 73.26664 | 39.13352 | 34.29285 | 13717.14 |
| EDU111 | 435 | 400 | 200 | 2000 | 41.71331 | 22.28011 | 19.52414 | 7809.657 |
| EDU112 | 441 | 400 | 200 | 2000 | 42 | 22.43324 | 19.65833 | 7863.332 |
| EDU114 | 441 | 400 | 200 | 2000 | 42 | 22.43324 | 19.65833 | 7863.332 |
| ENG111 | 164 | 400 | 200 | 2000 | 25.6125 | 13.68027 | 11.98807 | 4795.228 |
| ENG113 | 164 | 400 | 200 | 2000 | 25.6125 | 13.68027 | 11.98807 | 4795.228 |
| ENG114 | 168 | 400 | 200 | 2000 | 25.92296 | 13.8461 | 12.13338 | 4853.354 |
| ENG121 | 164 | 400 | 200 | 2000 | 25.6125 | 13.68027 | 11.98807 | 4795.228 |
| ENG122 | 168 | 400 | 200 | 2000 | 25.92296 | 13.8461 | 12.13338 | 4853.354 |
| ENG141 | 164 | 400 | 200 | 2500 | 25.6125 | 13.68027 | 11.98807 | 4795.228 |
| ENG162 | 168 | 400 | 200 | 2000 | 25.92296 | 13.8461 | 12.13338 | 4853.354 |
| ENG172 | 168 | 400 | 200 | 2500 | 25.92296 | 13.8461 | 12.13338 | 4853.354 |
| GST101 | 1777 | 400 | 200 | 2000 | 84.30896 | 45.0315 | 39.46127 | 15784.51 |
| GST102 | 1738 | 400 | 200 | 2000 | 83.37865 | 44.5346 | 39.02584 | 15610.33 |
| GST105 | 1777 | 400 | 200 | 2000 | 84.30896 | 45.0315 | 39.46127 | 15784.51 |
| GST107 | 1777 | 400 | 200 | 2000 | 84.30896 | 45.0315 | 39.46127 | 15784.51 |
| PCR111 | 1342 | 400 | 200 | 2500 | 73.26664 | 39.13352 | 34.29285 | 13717.14 |
| PCR114 | 1297 | 400 | 200 | 2500 | 72.02777 | 38.47181 | 33.71299 | 13485.2 |
| PED112 | 273 | 400 | 200 | 2000 | 33.04542 | 17.65038 | 15.46709 | 6186.837 |
| PED122 | 271 | 400 | 200 | 2000 | 32.92416 | 17.5856 | 15.41033 | 6164.133 |
| PED130 | 273 | 400 | 200 | 2000 | 33.04542 | 17.65038 | 15.46709 | 6186.837 |
| PED144 | 271 | 400 | 200 | 2000 | 32.92416 | 17.5856 | 15.41033 | 6164.133 |
| POL111 | 1342 | 400 | 200 | 2500 | 73.26664 | 39.13352 | 34.29285 | 13717.14 |
| POL126 | 1297 | 400 | 200 | 2500 | 72.02777 | 38.47181 | 33.71299 | 13485.2 |
| Grand Total | | | | | 2091.445 | 1117.092 | NA | 391564.9 |

**Table 4: Inputs and Outputs of the multi-item EOQ model with Inventory constraint**

| Course code (Inventory item) | Annual Forecast Demand (Ri) | Ordering Cost per Unit item (C3) | Holding Cost per unit item (C1) | Unconstraint Order Quantity ($q_i = \sqrt{\frac{2C_3^{(i)}R_i}{C_1^{(i)}}}$ ) | EOQ (qi* = $Tq_i$) | Number of Orders per year (P) | C(t) |
|---|---|---|---|---|---|---|---|
| CIT101 | 1506 | 400 | 200 | 77.61443 | 66.79878 | 22.54532 | 9018.129 |
| CIT102 | 1297 | 400 | 200 | 72.02777 | 61.99063 | 20.92252 | 8369.007 |
| CSS111 | 1342 | 400 | 200 | 73.26664 | 63.05686 | 21.28238 | 8512.952 |
| CSS112 | 1297 | 400 | 200 | 72.02777 | 61.99063 | 20.92252 | 8369.007 |
| CSS121 | 1342 | 400 | 200 | 73.26664 | 63.05686 | 21.28238 | 8512.952 |
| CSS132 | 1297 | 400 | 200 | 72.02777 | 61.99063 | 20.92252 | 8369.007 |
| CSS133 | 1342 | 400 | 200 | 73.26664 | 63.05686 | 21.28238 | 8512.952 |
| CSS134 | 1297 | 400 | 200 | 72.02777 | 61.99063 | 20.92252 | 8369.007 |
| CSS136 | 1297 | 400 | 200 | 72.02777 | 61.99063 | 20.92252 | 8369.007 |
| CSS152 | 1297 | 400 | 200 | 72.02777 | 61.99063 | 20.92252 | 8369.007 |
| ECE110 | 273 | 400 | 200 | 33.04542 | 28.44051 | 9.598984 | 3839.594 |
| ECE112 | 273 | 400 | 200 | 33.04542 | 28.44051 | 9.598984 | 3839.594 |
| ECE113 | 271 | 400 | 200 | 32.92416 | 28.33614 | 9.563758 | 3825.503 |
| ECE120 | 273 | 400 | 200 | 33.04542 | 28.44051 | 9.598984 | 3839.594 |
| ECE121 | 271 | 400 | 200 | 32.92416 | 28.33614 | 9.563758 | 3825.503 |
| ECE123 | 271 | 400 | 200 | 32.92416 | 28.33614 | 9.563758 | 3825.503 |
| ECO121 | 1342 | 400 | 200 | 73.26664 | 63.05686 | 21.28238 | 8512.952 |
| EDU111 | 435 | 400 | 200 | 41.71331 | 35.90052 | 12.11682 | 4846.727 |
| EDU112 | 441 | 400 | 200 | 42 | 36.14726 | 12.2001 | 4880.038 |
| EDU114 | 441 | 400 | 200 | 42 | 36.14726 | 12.2001 | 4880.038 |
| ENG111 | 164 | 400 | 200 | 25.6125 | 22.04337 | 7.439879 | 2975.952 |
| ENG113 | 164 | 400 | 200 | 25.6125 | 22.04337 | 7.439879 | 2975.952 |
| ENG114 | 168 | 400 | 200 | 25.92296 | 22.31057 | 7.530063 | 3012.025 |
| ENG121 | 164 | 400 | 200 | 25.6125 | 22.04337 | 7.439879 | 2975.952 |
| ENG122 | 168 | 400 | 200 | 25.92296 | 22.31057 | 7.530063 | 3012.025 |
| ENG141 | 164 | 400 | 200 | 25.6125 | 22.04337 | 7.439879 | 2975.952 |
| ENG162 | 168 | 400 | 200 | 25.92296 | 22.31057 | 7.530063 | 3012.025 |
| ENG172 | 168 | 400 | 200 | 25.92296 | 22.31057 | 7.530063 | 3012.025 |
| GST101 | 1777 | 400 | 200 | 84.30896 | 72.56042 | 24.48994 | 9795.975 |
| GST102 | 1738 | 400 | 200 | 83.37865 | 71.75975 | 24.2197 | 9687.882 |
| GST105 | 1777 | 400 | 200 | 84.30896 | 72.56042 | 24.48994 | 9795.975 |
| GST107 | 1777 | 400 | 200 | 84.30896 | 72.56042 | 24.48994 | 9795.975 |
| PCR111 | 1342 | 400 | 200 | 73.26664 | 63.05686 | 21.28238 | 8512.952 |
| PCR114 | 1297 | 400 | 200 | 72.02777 | 61.99063 | 20.92252 | 8369.007 |
| PED112 | 273 | 400 | 200 | 33.04542 | 28.44051 | 9.598984 | 3839.594 |
| PED122 | 271 | 400 | 200 | 32.92416 | 28.33614 | 9.563758 | 3825.503 |
| PED130 | 273 | 400 | 200 | 33.04542 | 28.44051 | 9.598984 | 3839.594 |
| PED144 | 271 | 400 | 200 | 32.92416 | 28.33614 | 9.563758 | 3825.503 |
| POL111 | 1342 | 400 | 200 | 73.26664 | 63.05686 | 21.28238 | 8512.952 |
| POL126 | 1297 | 400 | 200 | 72.02777 | 61.99063 | 20.92252 | 8369.007 |
| Grand Total | | | | 2091.445 | 1800 | NA | 243007.9 |

**Conclusion**

The classic multi-item inventory model with space, number of inventory and monetary constraints were applied in this research to solve the Course Materials inventory management problem of NOUN. The rather slow process of determining optimum Economic Order Quantities using the Lagrange multiplier trial-and-error method was replaced in this work with a trimming constant. The resultant model was coded using python programming for easy use by concerned staff of NOUN. Integrating a wide range of inventory models in a single Decision Support System provides the decision maker with a wide range of alternatives thereby enhancing the overall decision making process.

Effective modeling of the Production and Inventory Management system of Course Materials in the National Open University of Nigeria will solve the problem of non-availability of these important learning materials when demand is made for them by students. Also automating the processes involved in the production and management of these materials will enable staff and Managers to carry out their duties with minimal stress and technical requirement. Application of the models discussed in this work will significantly increase productivity, efficiency and give management enough time to budget and plan ahead towards meeting the demands for course materials and other services in a forecast year. Finally, the results of this research will breach significantly the dearth of knowledge in the area of application of model-driven Decision Support Systems in problem solving in Nigerian institutions.

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