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Proposing Multi-item Replenishment model for an Inventory Management System of Malaysia's SMEs

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Abstract

The present study describes a modified Economic Order Quantity (EOQ) for multi-item replenishment model with the deterministic demand nature of an inventory management. The function is subjected to the available financial and space constraints in the organization. If the constraints are not satisfied under the given conditions, then Lagrange technique is applied to obtain the optimal order quantity of the multi-items. The purpose of this study is to empower the manufacturing sector of Malaysia's SMEs with the advantages of the inventory model that controls the overproduction and underproduction inventories to meet their customer's demand on the right time. From this study, 90.9% of the optimum quantities of products had been achieved by using the multi-item inventory replenishment model as compared to the EOQ. This model is able to control the total cost of inventory efficiently for the optimum space availability.

Keywords: Inventory Model; Economic Order Quantity;Multi-ItemInventory Replenishment;Lagrange Technique; Inventory Cost; Constraints.

1. Introduction

Inventory Management (IM) is an important management issue for most organizations as such large, medium-sized and small organizations [1]. IM as a set of policies, includes the physical infrastructure, control form, the planning, the management data engineering as well as the organizational implanting in the inventory system [2]. In addition, IM policy is primarily concerned with two conventional decisions: (i) How much to order (produce or purchase) to replenish an item's inventory, and (ii) When to order[3]. To respond to these two questions, several inventory models have been produced. The prime assumption of classical Economic Order Quantity (EOQ) is the optimal order quantity. However, due to the vast number of unavoidable variables, this assumption may not always be true for most production ergonomics. Pakhira et al. [4], added an inventory modelling manages the amount of inventory that must be kept up to guarantee the continuous production of a product. Therefore, to accomplish the concerned of IM's policy, a model is needed to adjust the cost occurring from carrying an excessive amount of stock against the penalty expenses occurring due to stock deficiency. There is a variety of decisions in product recovery activities[5]. Many inventory models are based on EOQ or Economic Production Quantity (EPQ), due to its simplicity and robustness[6]. The EOQ model is used to determine an optimal order size by balancing the setup cost and inventory holding cost [7]. While, EPQ model is used to determine the optimal replenishment of lot size to be produced[8]. For several years, the subject of classical EOQ has been discussed in a variety of ways, and several studies have attempted to resolve it. It progresses from a single-item model with demand tied to unit price to multi-item models with a variety of constraints. These two models are fully analytical, requiring a substantial amount of arithmetic to arrive at the best solution[6]. In the case of price competitive environment, planning in sales and marketing are not sufficient to sustain the profit margin. Therefore, it needs to minimize the production cost [9].

In many nations, the retailing industries comprises of a critical number of businesses, particularly in the Small Medium Enterprises (SMEs) sector. For instance, 50% of the SMEs practically come from wholesale and retail enterprises in Malaysia. Out of this part, 80% of the establishments fall into the classification of smallscale enterprises [10]. Table 1 shows the distribution of SMEs in Malaysia by sectors, which represents 89.2% (service), 5.3% (manufacturing), 4.3% (construction) and 1.1%

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(agriculture). The remaining 0.1% is in mining and quarrying sector [11]. Ahmad and Zabri [10]had shown that most of the bigger firms are applying the concepts and strategies of inventory control which have fewer financial restrictions for the adoption of advanced management approach. However, in present, the IM practices implemented by the firms have been designed following to their requirements [12]. Moreover, Ngubane at el. [13], expressed that the absence of IM practices has denied the manufacturing sector of SMEs to become the incredible rivals within the manufacturing organizations. In Malaysia, for instance, the most widely recognized issue facing by SMEs is poor IM strategies that would influence the performance of manufacturing firm [14].

The objective of this study is to introduce a modified EOQ of multi-item replenishment model using the deterministic demandsfor an inventory management system. The proposed model is subjected to determine the optimal quantity of multi-items within the limits of allowable financial and space constraints within the manufacturing sector of Malaysia's SMEs to reduce the total cost of inventory and control the over production as well as underproduction.

Table 1: Distribution of SMEs in Malaysia by sector [11]

Sector	Percentage	Number of SMEs
Service	89.2%	809,126
Manufacturing	5.3%	47,698
Construction	4.3%	39,158
Agriculture	1.1%	10,218
Mining and Quarrying	0.1%	865

The modified EOQ model will be used to prevent shortages and the required numerical in the model equations are solved manually.

2. Literature review

In the last few decades, a number of mathematical models for inventory problems have been created, the first and most basic of which is the EOQ, which was established by Wilson[15]. And today, the establishment of increasingly advanced and complex inventory models has been based on this EOQ model. In terms of demand distributions, certain factors that have been integrated in models including multi-item, quantity discount, deterioration rate, deterministic or probabilistic models[16]. Over the time, the literature on production and inventory models had been modified. Several scholars have contributed to the discussion by modifying inventory model assumptions and incorporating multiple dimensions of inventory management, making it more useful[17]. A mathematical model for controlling a production system for a single item with an unknown deterioration rate has been proposed [18]. A two-level inventory model was established to optimize the cost of inventory management, and a distributed multi-level inventory control strategy for automobile maintenance spare parts[19]. Zhang and Wang [20]have developed a multi-item inventory problem with storage capacity restriction, while a joint inventory model to determine the optimal inventory replenishment product assortment, shelf space and display area. Kasrhuri et al., [21]developed a fuzzy multi-item inventory model by incorporating storage space and production cost. Furthermore, Zhang and Du [22] conducted the study of multi-product newsboy problem for uncertain demand. Also, Ould-Louly and Dolgui[23]introduced a dynamic single stage multi-item inventory control model with the goal of determining the average holding cost and stockout probability for the components under a certain service level for customer demands and lead time uncertainties. Ertogral, [24] solved a multi-item single source ordering problem using the Lagrange technique, which included transportation costs. Multi item inventory control issues may have the multiple conflicting objectives in addition to a single goal. While, Roy and Maiti[25] proposed a multi-objective inventory model of decaying items with stock-dependent demand with limited storage facility and a total cost budget. Taleizadeh et al., [26]proposed a Pareto and genetic algorithm hybrid method to optimize multi-product, multi-constraint inventory control systems, taking into account both continuous and periodic reviews, as well as fuzzy replenishments and demand. Again, storage capacity and material size limit the number of distinct materials that can be stored in the plant. Pasandideh et al. [27] used a non-dominated sorting genetic algorithm and multi-objective particle swarm optimization to solve a bi-objective economic manufacturing quantity problem for defective items. The problem was stated as a multi-objective nonlinear programming model, with the aim of minimizing both the overall inventory cost and the required warehouse space by determining the order quantities of the product. Balkhi et al., [28] developed a number of inventory models in which demand, output, and deterioration rates are all arbitrary functions of time, and in some of which shortages are permitted but entirely backlogged. Ben-Daya and Raouf[29] proposed a more realistic and general single period solution for multi-item with the restricted budgetary and floor/shelf space constraints, in which, the item demand follows the uniform probability distribution which is subject to space and budget limits.

3. Methodology

The methodology adopted in this paper is a quantitative research design. To utilize this model for optimal order quantities of multiple items that need to be replenished, the flow chart of the procedure is shown in Figure 1.

The model requires the necessary data, while solving different equations; in essence the available investment and the space capacity of the organization, demand rate, ordering cost, holding cost, purchase price per unit and the size of individual item.

The optimal order quantities of multiple items have been calculated by EOQ. After calculating the quantities, it is required to solve both the financial and space constraints. Once the constraints have been determined, then its validity check is required. If the left-hand side value of the equations is less than the right-hand side, so constraints are feasible, no further work is needed. However, if the constraints are not feasible, the Lagrange technique should be utilized. These constraints will affect the size of orders quantities for each type of item.

3.1. Economic Order Quantity

According to [30], a stock managing method to minimize the overall holding cost and ordering cost is known as Economic Order Quantity (EOQ). EOQ model is concerning the tradeoff between the holding cost and ordering cost by choosing the right quantity for replenishing the inventory of different type of materials. The ordering frequency will be diminished by a colossal order quantity; subsequently there will be decreased in the cost per unit time. Anyway, it prompts the expanding of warehouse holding cost.

In general, the following assumptions are made for the EOQ model.

1. Demand is known and constant.
2. The replenishment is instantaneous and complete.
3. The lead time is known and consistent.
4. Shortage is not allowed.

3.2. Equation of EOQ

When perusing the existing study in inventory modeling, one of the noteworthy troubles is the standard arrangement of factors and notations [31].

Figure 3(a) represents the ordering cost of inventory. When the order quantity increases, the cost associated with it will decrease and vice versa. While Figure 3(b) shows the holding cost of inventory. When the order quantity increases, the holding cost will increase due to high number of inventories that are kept in the warehouse. And finally, Figure 3(c) represents the optimal order quantity occurring at the point where the ordering cost and the holding cost curve intersect. Thus, in EOQ model, the optimal order quantity will occur at a point when the total of ordering cost and holding cost are similar. Thus, the optimal order quantity will be the quantity that minimizes the total costs of inventory. Furthermore, a decrease in either ordering cost or holding cost will reduce the total cost curve as of Figure 3(c) [30]. Therefore, the equation Qt of optimal order quantity is derived from Figure 3(c) [30].

$$Qt = \sqrt{\frac{2AD}{h}} \quad (1)$$

Where:

D = the demand rate per units per year,

A =ordering cost/ per order,

h is inventory holding cost/ per unit andtime = $i \times c$,

C = unit cost of each item,

i =the inventory holding cost percentage.

3.3. Description of the Multi-item Inventory Model

The study is concentrated on the deterministic single item inventory model. EOQ equation with the above assumption where the demand and lead-time are constant, replenishment is instantaneous and complete, and shortages are not allowed.

This study will extend the fundamental concept into a multi-item inventory replenishment model for SMEs in Malaysia with the similar supposition but focusing on the existence of financial and space constraints. These constraints will certainly, affect the size of the order quantities for each type of item.

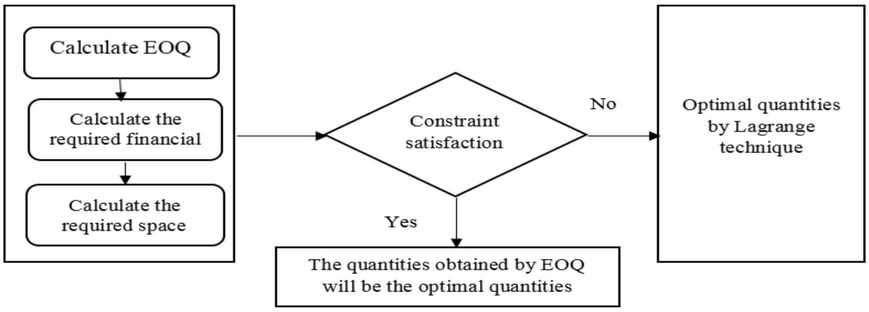

Figure 1: Flow diagram of multi-item inventory model

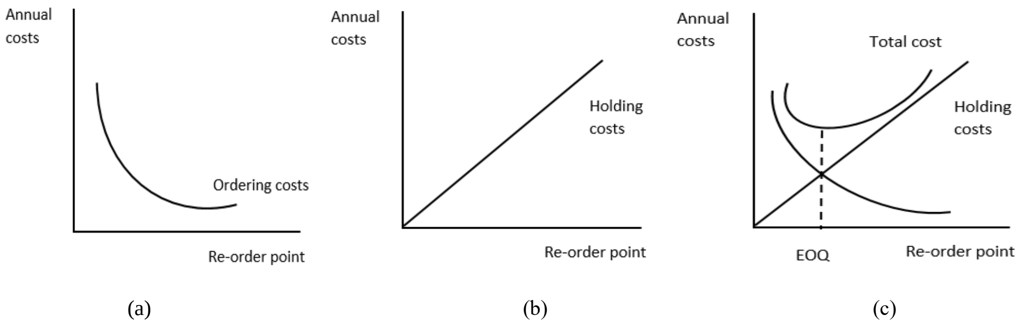

Figure 3: (a) Ordering cost; (b) Holding cost and (c); Optimal order quantity [30].

The total cost of a multi-item inventory system is determined as the sum of the total cost of every item independently. We assume the shortage of a *n* item of inventory model is not allowed. Now, the equations for financial and space constraints can be shown as follow [30]:

$$\sum_{n=1}^{m} C_n Q_n \le F \qquad (2)$$

$$\sum_{n=1}^{m} S_n Q_n \le T.S \qquad (3)$$

where:

Q is the number of units per order,

S_n is the required space for every item, $n = 1, 2, 3 \ldots m$,

C_n is the capital for every item, $n = 1, 2, 3 \ldots m$,

F is maximum allowed financial for inventory,

$T.S$ is maximum storage allowed for each item.

3.4. Lagrange Technique

In this study, the nonlinear programming problem has been dealt with by using Lagrange procedure. The Lagrange procedure assumes implicitly that the orders are received simultaneously and does not consider phasing order for the various items.

This technique is initially used to solve the inventory problems by ignoring the financial and space constraints in Equations (2) and (3) respectively. The optimal ordered quantities are obtained by assuming that $Qt = Qt_n$ by Equation (1) [31].

$$Qt_n = \sqrt{\frac{2A_n D_n}{h_n}} \qquad (4)$$

This is accomplished by developing a Lagrange expression (LE), which is given by:

$$LE(Q_n, \pi) = \left\{ \left(\sum_{n=1}^{m} \frac{A_n D_n}{Q_n} \right) + \pi \left(\sum_{n=1}^{m} C_n Q_n \right) - F \right\} \qquad (5)$$

Where π is the Lagrange multiplier. Equation (6) obtained by taking derivative of Equation (5) with respect to Q_n. QLt_n represents the optimal quantity obtained by using the Lagrange technique.

$$QLt_n = \left\{ \sum \sqrt{\frac{2A_n D_n}{C_n (i + \pi)}} \right\} \qquad (6)$$

Equation (7) obtained by taking derivative of Equation (5) with respect to π.

$$\pi = \left\{ \frac{1}{2} \left(\frac{1}{F} \sum \sqrt{2A_n D_n C_n} \right)^2 - \frac{i}{2} \right\} \qquad (7)$$

Substituting Equation (7) into Equation (6) and rearranging gives;

$$QLt_n = \left(\frac{F}{\sum_{n=1}^{m} C_n Q_n} \right) Qt_n = \left(\frac{F}{E} \right) Qt_n \qquad (8)$$

Equation (8) represents the optimal quantity by Lagrange technique and F represents the maximum available financial. Similarly, E represents left hand sides of Equations (2) and (3). Such as; $\sum_{n=1}^{m} C_n Q_n \le F$ and $\sum_{n=1}^{m} S_n Q_n \le T.S$.

By repeating the same steps, equation of optimal quantity by Lagrange technique for space constraint and other constraints if available can be obtained. Equation (9) represents the optimal order quantity by Lagrange technique regarding space constraint below;

$$QLt_n = \left(\frac{T.S}{\sum_{n=1}^{m} S_n Q_n} \right) Qt_n = \left(\frac{T.S}{E} \right) Qt_n \qquad (9)$$

4. Result and Discussion

This study has been carried out in one of the SME in Melaka, Malaysia. The organization is producing several numbers of items. The problem faced by the company is the uncontrollable of over production. It incurred the increment in total cost of inventory. The company also has enough amounts of inventory and space for these items.

The available financial and space measurements have been provided by the company in Table 2.

And on the other hand, because of the economic crises, a company cannot invest all of its capital in one place. So, basically the selected company is in search of an optimal solution to control the inventories within the constraints of available financial and the capacity of space in the warehouse for inventories. The data collection was done by interview technique in the selected company. The interviews were conducted to study the manufacturing operations for the accurate information on the current situation of IM with the supply chain officers. Table 2 represents the collected data of the proposed optimal policy for multi-item inventory replenishment. Based on the company recommendations, the most critical five items have been selected to manage its quantities required per year with the available financial and space on hand.

Table 2. Data collected from the interview made at SME

		Items				
		A	B	C	D	E
Cost (purchase price/ unit)	C	12	12	13	15	13
Inventory caring cost rate	i	0.18	0.18	0.18	0.18	0.18
Demand rate (unit per year)	D	261,402	65,349	914,910	676,040	518,300
Set up cost	A	80,000	71,000	83,000	85,000	77,000
caring cost per unit per year	h	2.16	2.16	2.34	2.7	2.34
Item size	S_n	1.33	1.33	1.33	1.33	1.33
Available financial (Malaysian ringgit RM)	32,693,342					
Available space (cubic meter m^3)	102,500					

Table 3 shows the optimal quantities of five different items which is obtained by the values of A_n, D_n and h_n for all five items from Table 2 and putting these values in Equation (4).

Table 3: Optimal quantities by EOQ

Optimal order quantities (Qt_n)	
Qt_1	139,151
Qt_2	65,545
Qt_3	254,762
Qt_4	206,314
Qt_5	184,690

4.1. Financial Constraint

Financial constraint represents the possible combinations of items and services that a buyer can purchase with the available financial on hand. The overall inventory cost of multi-item has been estimated as the sum of total cost of each item independently. The overall cost of the inventory system for all items is obtained by Equation (2). The feasibility of financial constraint will be checked by putting the values of C_n for all items from Table 2 and the values of Qt for all items from Table 3 in Equation (2).

$$12 \times 139{,}151 + 12 \times 65{,}545$$
$$+12 \times 254{,}762 + 12 \times 206{,}314$$
$$+12 \times 184{,}690 \leq 32{,}693{,}342$$
$$10{,}205{,}544 \leq 32{,}693{,}342$$

The total cost of items obtained is RM11,269,941, which is less than the available financial that is RM 32,693,342 in Table 2. So, constraint is not violated and it is feasible. This implies that the quantities of five items obtained in Table 3 are optimum for the available financial to be purchased.

4.2. Space Constraint

Space constraint refers to the available space for stock in the organization. The feasibility of space constraint will be checked by putting the values of S_n for all items fromTable 2 and the values of Qt for all items from Table 3 in Equation (3).

$$1.33 \times 139{,}151 + 1.33 \times 65{,}545$$
$$+1.33 \times 254{,}762 + 1.33 \times$$
$$206{,}314 + 1.33 \times 184{,}690 \leq 102{,}500$$
$$1{,}131{,}115 \leq 102{,}500$$

In this manner, the space required for the items to be ordered is 1,131,115 m^3. The space is greater than the available space at the SMEs' warehouse, which is only 102,500 m^3 available. Therefore, constraint is not feasible. This implies that the quantities obtained in Table 3 are not the required quantities. The optimal quantities, for which both the constraints will be satisfied, are obtained by Lagrange techniques in Table 4. Table 4 are obtained by putting the optimal quantity Qt for each item from table 3, the value of available space $T.S$ and the value of E in equation (9).

Table 4: Optimal quantities by Lagrange technique

Optimal Order quantities QLt_n	
QLt_1	12,610
QLt_2	5,940
QLt_3	23,086
QLt_4	18,636
QLt_5	16,736

To check whether space constraint is satisfied, the quantities of obtained in Table 4 and the values of S_n for all items from Table 2 put in Equation (3).

$$1.33 \times 12{,}610 + 1.33 \times 5{,}940$$
$$+133 \times 23{,}086 + 1.33 \times 18{,}636$$
$$+1.33 \times 16{,}736 \leq 102{,}500$$
$$102{,}420.64 \leq 102{,}500$$

The feasibility of space constraint can be seen, because the left-hand side value is less than the right-hand side of equation 3 above. Comparing the values of both Table 3 and 4, there is a substantial difference among the values of optimal quantities determined by EOQ and Lagrange technique. The optimal quantities determined by Lagrange technique in Table 4 are minimum from that of determined by EOQ in Table 3.

It is derived from the results that the optimal order quantities in Table 4 have a positive impact on the financial performance of SMEs in the manufacturing sector. SMEs will control and manage high operating cost by holding excess stocks as well as stock out situation. Larger storage costs, handling charges, and interest from short-term borrowings are the result of more stock in the company than it is required. Stock-outs typically occur when there is a high demand for a product and there is a scarcity of inventory for fast-moving commodities, resulting in lost sales and customer loyalty. Sometimes loss is also incurred, when the products are sold at a lower price than normal[32].The findings show that the Lagrange Technique is used to find the optimal value of an objective function when space and financial limitations are present. In the case of SMEs in Malaysia, collected data is used to demonstrate the validity of the suggested model. The implications of the multi-item replenishment model are evident from the results, and provide a useful framework for reducing the inventory overall cost and deliver the ability to the organization to take right decision in controlling underproduction and overproduction[33].

Conclusion

This study has introduced a multi-item inventory replenishment model with the deterministic demand nature to be applied at SMEs in Malaysia. The numeric advantages of utilizing the equations are significant and important, initially, when the quantities cannot surpass the absolute finance and the overall allowed space, the new equation of the EOQ for optimum exploitation of the financial and storage should be removed. The findings show that the optimal quantities of different items were obtained by multi-item inventory replenishment model, within the allowed financial limit and capacity of storage in Table 4, are the optimized one as compared to the quantities obtained by EOQ in Table 3. This model has reduced the value of inventory up to 90.9 %. The result shows that in order to overcome overproduction or to eliminate underproduction, the selected SME needs to order/produce the quantities obtained in Table 4 for five items. The advantages of the proposed model are as follows:(i) Consideration of financial and space constraints make the model realistic as ignorance of these restriction results in infeasible solution, (ii) Providing trade credit strengthens to the supply chain coordination.

There are numerous ways to make the current model more realistic by extending it. And for the future work, it is suggested to find the new EOQ model by introducing constraints other than space and financial for instance, size of order. Additionally, the present study is carried without software, it is suggested for future work to formulate the same model with the application of inventory control software, for instance, application manager, Matrix Laboratory (MATLAB) etc. Furthermore, it is also suggested to utilize the same model with probabilistic demand with shortages and enhance the present work with the determination of total inventory cost.

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