Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA
Published: February 18, 2025

DOI: 10.46254/AN15.20250105

Inventory Management Improvements by Applying the Theory of Determining the Optimal Order Size

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Abstract

Currently, the criteria for determining the optimal order quantity and the holding quantity to achieve maximum cost-effectiveness have not yet been applied in the inventory management of the factory in the case study. Therefore, to reduce the factory's costs and improve the efficiency of raw material management to meet demand, this research aims to study the improvement of inventory management in the factory by applying the theory of different order quantity methods and comparing them with the actual inventory costs from April 2022 to March 2023 using three heuristic methods: 1. Economic Order Quantity (EOQ) 2. The Periodic Order Quantity (POQ) method, as per the Silver-Meal approach, found that all three heuristic order size determination methods had lower inventory costs than the actual inventory costs. The method that provided the lowest cost for this case study was the POQ method, which reduced the factory's inventory costs by 79.59%. Additionally, the calculation mechanism of the POQ method is not complex and is easy to implement in practice.

Keywords

Economical ordering, the quantity of raw materials remaining in the warehouse at the reorder point, Safe Inventory, Time-based ordering

1.Introduction

Currently, many businesses emphasize the importance of material planning and control for production or various services, incorporating technology to assist in management. This involves planning and preparing materials, known as Material Requirements Planning (MRP). However, due to the relatively high cost of MRP systems, which are often complex, different businesses face various problems and limitations in their usage. This necessitates the continuous development of MRP systems to ensure they are easy to use, convenient, and highly efficient for each business's needs.

A company that manufactures car compressors in Thailand is a business engaged in the production of automotive parts. By producing **100%** of automotive air conditioning compressors for export, due to an increase in customer orders over the past **1-2** years and a significant rise in new models, driven by the global expansion of engine usage. This makes production planning and sourcing of raw materials increasingly important and significant.

The researcher studied the general conditions of the case study company and found that the ordering of raw materials used in production is controlled by an MRP system for ordering, storing, and supplying raw materials into the production process. However, the raw materials still rely on outdated information that has not been updated in the MRP system for ordering. This has led to issues where the raw materials are insufficient to meet production demands, resulting in delays in delivering products to customers. At times, there have been excessive orders of raw materials into the warehouse, leading to insufficient storage space. These problems occur frequently. Additionally, it was found that the criteria for determining the appropriate and economical order quantity in the MRP system of the case study company have not been correctly and clearly applied; instead, the experience and guesses of the person responsible for ordering are still being used. Therefore, the researcher proposes the results of the study to improve the planning of raw material orders within the case study company, aiming to prevent production line stoppages, avoid missed sales opportunities, and reduce inventory costs**.**

1.1 Objectives of the thesis

This research aims to improve raw material demand planning for the company in the case study. Make sure that the procurement of raw materials and various materials used in production meets the requirements. and propose methods for managing stock ingredients to achieve the lowest possible purchasing and storage costs.

2. Literature Review

2.1 Production Planning

Production planning refers to the planning involved in managing various production factors such as labor, machinery, raw materials, and production processes, or the 4Ms (Man, Machine, Material, Method), in order to achieve production results that meet the goals set according to customer demand (Anurat Rayabphan, 2016).

2.2 Material Requirements Planning: MRP

The concept of the MRP system focuses on ordering materials accurately enough to meet the required quantity and at the right time. To achieve this goal, effective coordination within the system is essential, involving the needs of customers, manufacturers, and suppliers. A central unit, such as the planning department, assists in coordinating and gathering information from various parties to process and create a material requirements plan for each item. (Boonrasak Madmaai, 2013).

2.3 EOQ (Economic Order Quantity)

EOQ, or Economic Order Quantity, refers to the optimal quantity or amount of product orders that is most cost-effective or economical in order to avoid sunk costs from inventory in warehouses, such as handling, storage, and depreciation costs, among others. Calculating EOQ helps businesses determine how much to order based on product demand before producing or stocking items (Figure 1- Figure 3).

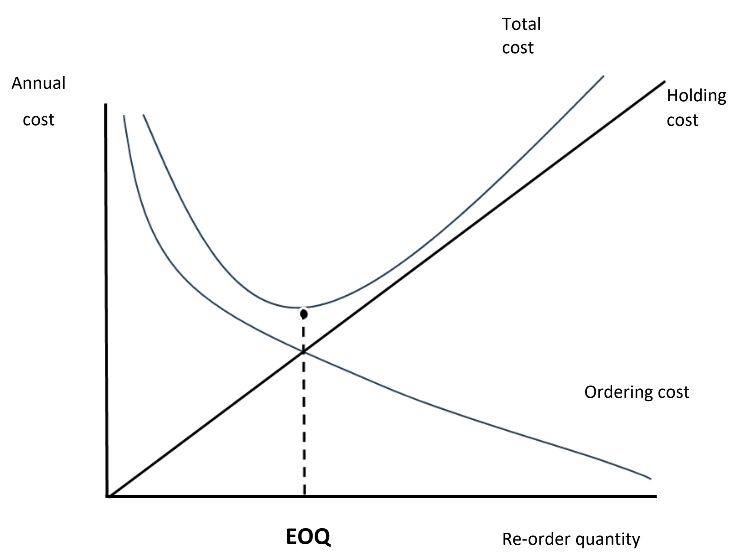


Figure 1. Show the EOQ point or the most economical order quantity

2.4 Periodic Order Quantity (POQ)

Periodic Order Quantity (POQ) is a method of inventory management used to determine the quantity of goods to be ordered at specified intervals. Orders are placed at predetermined times, such as every month or every week. This method helps make inventory management more flexible.

2.5 Silver-Meal Method

The Silver Meal (SM) method aims to minimize the average weekly inventory cost, denoted as C(i), which represents the average inventory cost. Per week, when the order quantity is set equal to the sum of the net demand from week i to week j (Heuanadi, et al., 2020).

2.6 Related Research

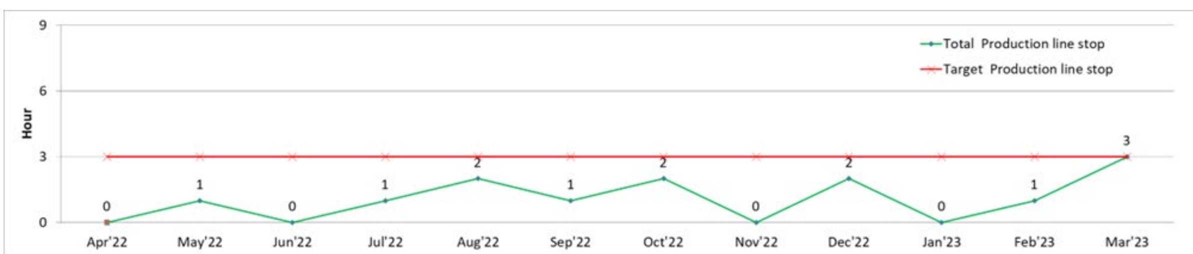
Nurprihatin, Rembulan, and Pratama (2022) The paper addresses the challenges faced by the processing industry due to improper inventory planning, which leads to increased operating costs, building costs, and product defects. The research focuses on a company experiencing lumpy demand and proposes a solution using Material Requirement Planning (MRP) with probabilistic Economic Order Quantity (EOQ) and Periodic Order Quantity (POQ) models. The demand for the coming period is forecasted using the Autoregressive Integrated Moving Average (ARIMA) method, and an aggregate plan is developed to determine the optimal production and subcontracting costs. The final analysis reveals that the POQ model produces the lowest cost for planning certain items, while the probabilistic EOQ model is more suitable for others.

Segerstedt, Jalbar and Samuelsson (2023) The paper discusses the limitations of the traditional Silver-Meal lot-sizing technique, particularly its inefficiency in handling periods with zero demand, which leads to unnecessary order replenishments and higher costs. The authors propose a reformulated version of the Silver-Meal technique that addresses these issues. The new formulation avoids the problems associated with zero demand periods and is more efficient in various demand scenarios, including declining and varying demand. The paper also compares the reformulated Silver-Meal technique with other lot-sizing methods like Least Unit Cost and Part-Period Balancing, highlighting their characteristics and potential problems. The study emphasizes the importance of these techniques in practical operations and their relevance for students and future managers.

2. Methodology

Step 1: Process Analysis

From the study of the case company in the production of air compressors in the QS line, the researcher has gathered various data regarding the entire production process. Each air compressor consists of a total of 127 components, with 90% of the parts being common and the remaining 10% being unique parts. For the main raw materials, there have been issues with the unique parts being insufficient to meet the production process's frequent demands, leading to stoppages in the production line. According to the KPI records for the year 2022, from April 2022 to March 2023, the following information is noted:



Details			Apr'22	May'22	Jun'22	Jul'22	Aug'22	Sep'22	Oct'22	Nov'22	Dec'22	Jan'23	Feb'23	Mar'23	ACC.
QS	Production line stop	Hr.	0	1	0	0	2	1	0	0	1	0	0	3	8
EV	Production line stop	Hr.	0	0	0	1	0	0	2	0	1	0	1	0	5
Total Production line stop		Hr.	0	1	0	1	2	1	2	0	2	0	1	3	13
Target Production line stop		Hr.	3	3	3	3	3	3	3	3	3	3	3	3	3

Figure 2. KPI Raw material shortage -Production line stop

Step 2: Analyze the problem.

From the researcher's study of the current situation, it was found that there are urgent problems that need to be addressed, namely, the raw materials are insufficient to meet the demands of the production process, causing production lines to halt and delays in the manufacturing process. This results in the inability to deliver products to customers on time. Sometimes, there are excessive orders for raw materials into the warehouse, leading to insufficient storage space. The researcher has utilized the Why Why Diagram tool to analyze the causes as follows (Table 1):

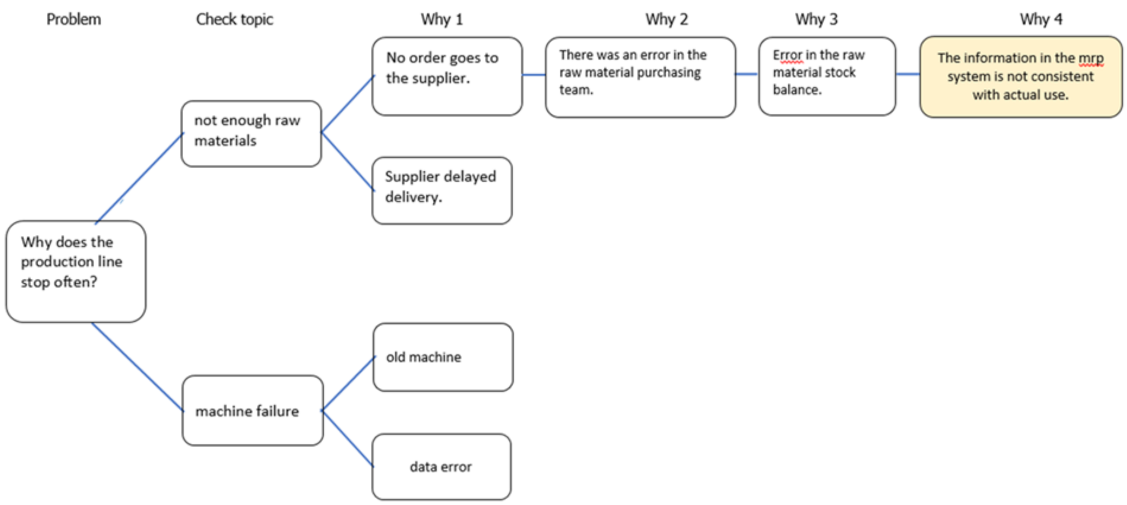


Figure 3. Show an analysis to find the causes of the problem using the Why Why Diagram tool

Step 3: Finding the coefficient of variation. (VC)

Finding the variance coefficient (variability coefficient, VC)

The equation for finding the coefficient of variation is as follows:

$$VC = \frac{Est.var\ D}{\bar{D}^2}$$

$$Est.var\ D = \frac{1}{n}\sum_{i=1}^{n}(d\frac{2}{i} - \bar{d}^2)$$

$$(\bar{d}) = \frac{1}{n}\sum_{i=1}^{n} d_i$$

Where d_i = The estimated demand for the product in each time period.

N = The period during which the study is conducted.

Table 1. Example Calculation of the Coefficient of Variation of Raw Material Part Number AKV214B432

Month	Usage	d_i^2
Apr-22	19,957.00	398,281,849.00
May-22	9,188.00	84,419,344.00
Jun-22	12,052.00	145,250,704.00
Jul-22	9,224.00	85,082,176.00
Aug-22	30,427.00	925,802,329.00
Sep-22	12,759.00	162,792,081.00
Oct-22	11,017.00	121,374,289.00
Nov-22	21,801.00	475,283,601.00
Dec-22	22,016.00	484,704,256.00
Jan-23	36,548.00	1,335,756,304.00
Feb-23	31,706.00	1,005,270,436.00
Mar-23	50,258.00	2,525,866,564.00
Sum	266,953.00	7,749,883,933.00
$\bar{D}$	22,246.08	
$\overline{d^2}$	494,888,223.67	
$(\bar{d})$ $\frac{1}{n}\sum_{i=1}^{n} d_i$		645,823,661.08
Est.var D		150,935,437.41
VC		0.30

From the calculation of the coefficient of variation, it can be concluded that there are 45 items with fluctuating demand levels and another 82 items with stable demand levels out of a total of 127 items.

Step 4: Calculate the safety stock (SS)
Spare inventory is another crucial aspect of running a business because, in addition to affecting costs and storage space, having too much spare inventory can lead to product shortages due to insufficient spare inventory, which in turn reduces customer satisfaction. This can impact future sales. Therefore, managing spare inventory to an appropriate level is extremely important. The calculation of inventory quantity can be done using the formula (Table 2).

Table 2. Example of calculating the quantity of safety stock for raw materials.

Part number AKV214B432							
Time	d	$\bar{d}$	$\frac{(d-\bar{d})^2}{N}$	$\overline{LT}$	Z	$\overline{LT}\sigma_a^2$	SS
Unit	Piece	Piece		Day			Piece
Apr-22	19,957	22,246.08	436,658.54	8	1.64	40,249,449.98	10,405
May-22	9,188	22,246.08	14,209,461.70	8	1.64		
Jun-22	12,052	22,246.08	8,659,944.58	8	1.64		
Jul-22	9,224	22,246.08	14,131,221.20	8	1.64		
Aug-22	30,427	22,246.08	5,577,283.13	8	1.64		
Sep-22	12,759	22,246.08	7,500,395.85	8	1.64		
Oct-22	11,017	22,246.08	10,507,692.71	8	1.64		
Nov-22	21,801	22,246.08	16,508.26	8	1.64		
Dec-22	22,016	22,246.08	4,411.53	8	1.64		
Jan-23	36,548	22,246.08	17,045,401.70	8	1.64		
Feb-23	31,706	22,246.08	7,457,501.95	8	1.64		
Mar-23	50,258	22,246.08	65,388,956.28	8	1.64		
σ_a^2			150,935,437.41				

Step 5: Reorder Point (ROP)

Determining the inventory level at which to issue a purchase order. Therefore, the level of new orders depends on two variables: usage rate and lead time. To calculate the new order level, we multiply the usage rate by the lead time. However, to prevent stockouts, we should not risk tight schedules. The lead time for ordering raw materials in the case study company is 8 days. Therefore, a certain amount of safety stock should be maintained. The formula for calculating the reorder point is as follows:

$$\text{ROP} = \text{SS} + (\bar{d})(\overline{LT})$$

An example of calculating the reorder point for part number AKV214B432

SS = 10405 piece

$\bar{d}$ = 22246 piece

LT = 8 day

Therefore, the new reorder point is equal to ROP = 10405+(22246x8)

= 188373 piece

Step 6: Economic Order Quantity(EOQ)

An example of calculating the economic order quantity for raw material part number AKV214B432, with the following information on the demand for the raw material:

P/N	Month												Total
	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23	
AKV200A432	36,548	19,957	9,188	12,052	9,224	30,427	12,759	11,017	21,801	22,016	31,706	50,258	266,953

Calculate the economical order quantity (EOQ) as follows:

$$Q = \sqrt{\frac{2DS}{H}}$$

$$Q = \sqrt{\frac{2(266953)(5419.55)}{3.28}}$$

Q = 29701 Piece/Time

Step 7: Period Order Quantity: POQ

Determine the order size to cover the net demand for k consecutive periods, where k is found by dividing the Economic Order Quantity (EOQ) by the average net demand per week.

Example calculation for finding the value of k for the order quantity of raw material Part number AKV214B432 in the following sequence.

$$K = \frac{EOQ}{D}$$

Where $\overline{D}$ represents the average weekly demand for raw materials, substituting the values will yield the following:.

$$K = \frac{29701}{5561.52} = 5.34 \approx 6 \text{ weeks}$$

Each order cycle of the periodic order quantity method covers the net demand for 6 consecutive weeks. For example, the order size for cycle 1 covers the net demand for weeks 1 to 6, totaling 52,401 pieces.

Step 8 : (Silver-Meal: SM)

Method for determining order quantity for variable demand, considering demand for each periods in the future (m) to find the order quantity with the lowest cost when the demand for goods in each future period is equal to D1, D2, etc.Dn and Km) equal the average variable cost in the period, the total lead time for placing orders in advance. By assumption, the holding cost occurs at the end of each period, and the quantity of goods required in each period will start to be used from the beginning of the period, with the following calculation formula.

$$K(1) = A \quad (1)$$

$$K(2) = 1/2\,(A + hD2) \quad (2)$$

$$K(3) = 1/3\,(A + hDz + 2hD3) \quad (3)$$

$$K(m) = 1/m\,(A + hDz + 2hD3 + \ldots + (m-1)\,hDm) \quad (4)$$

Where A is the cost per order. (THB)
H is the cost of storage per unit per month. (THB)

3. Results and Conclusions

This research demonstrates the application of MRP in determining the order quantity of raw materials for use in the production process of an automotive air compressor manufacturing plant. In this independent study, the researcher compared inventory order models using three heuristic methods: Economic Order Quantity (EOQ), Periodic Order Quantity (POQ), and Silver-Meal. The selection was based on the type of raw material demand: for constant demand, the EOQ method was used, while for variable demand, the POQ and Silver-Meal methods were employed. Subsequently, the total cost was calculated to compare the results and determine which method was most suitable for each type of raw material in the case study company, by calculating the VC to classify the demand types.

By comparing the costs between the three heuristic methods, namely the (EOQ), (POQ), and Silver-Meal, with the actual ordering used in the current factory.

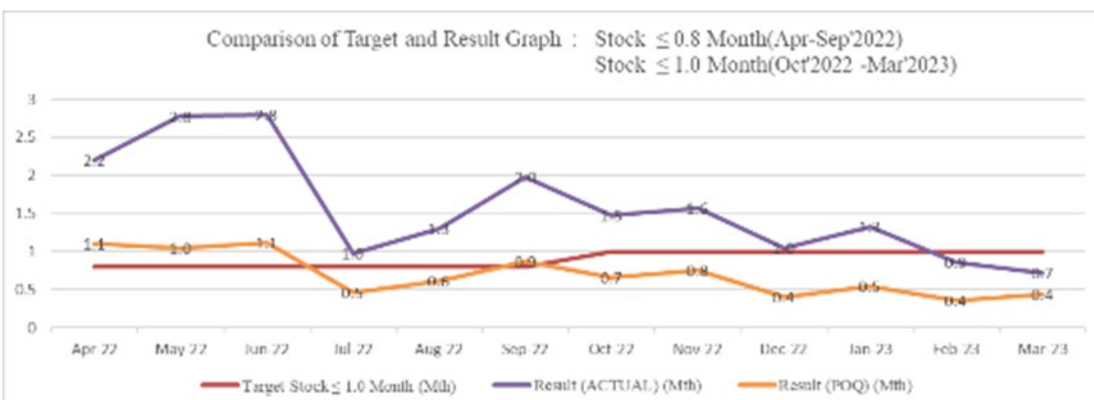
Table 3. Summary of Inventory Costs

Costs	Actual cost	Heuristic Methods		
		EOQ	POQ	Silver-Meal
Holding Cost	1,783,213.27	3,544,673.83	39,013.07	147,222.80
Ordering Cost	15,773,360.00	3,544,673.83	3,544,673.83	6,043,214.81
Total Cost	17,556,573.27	7,089,347.66	3,583,686.90	6,190,437.61
Percentage of Cost reduction	-	59.62%	79.59%	64.74%

From Table 3, it is found that the Periodic Order Quantity (POQ) heuristic method has the lowest inventory cost, with an inventory cost of 3,545,090.39 baht, which is 79.59% lower than the actual inventory cost. The next method is the Silver-Meal method, with an inventory cost of 6,043,214.81 baht, which is 64.74% and lower than the actual inventory cost. The Economic Order Quantity (EOQ) method has an inventory cost of 7,089,347.66 baht, which is 59.62% lower than the actual inventory cost.

All heuristic methods for determining order sizes have inventory costs lower than the actual inventory costs. The heuristic method that provides the lowest cost for this case study is the POQ method. Therefore, it is appropriate for the factory in this case study to use it for determining order sizes in the raw material demand planning system because this method reduces the factory's inventory costs by 79.59%. Additionally, the calculation mechanism of the POQ method is not complex and is easy to implement in practice. The main factors that make the POQ method suitable for the case study company, compared to the other two methods, EOQ and Silver Meal, are the variability of customer demand, lead time for ordering, and storage space due to the factory constantly adjusting its production plans to meet customer demands. Thus, it is essential to use the POQ method to cover customer demand.

When comparing the monthly inventory of the case study company with the inventory after using the POQ method to determine the optimal order size, it was found that the monthly inventory decreased by an average of 44.59%, as shown in Figure 4.



Details		Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22	Nov-22	Dec-22	Jan-23	Feb-23	Mar-23
Target Stock ≤ 1.0 Month	(Mth)	0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.0	1.0
Result (ACTUAL)	(Mth)	2.2	2.8	2.8	1.0	1.3	2.0	1.5	1.6	1.0	1.3	0.9	0.7
Result (POQ)	(Mth)	1.1	1.0	1.1	0.5	0.6	0.9	0.7	0.8	0.4	0.5	0.4	0.4
Q'ty of Component Stock (ACTUAL)	(PCS)	2626169	2929773	2721664	2592191	2437291	2829685	2604527	2463740	3077816	3247447	2916289	2177987
Value of Component Stock (ACTUAL)	(BAHT)	68237538	70719295	60731038	64104592	62975436	64419301	60469233	62707753	78657951	81808267	72901917	56592119
Q'ty of Component Stock (POQ)	(PCS)	1300956	1104075	1085641	1215599	1141889	1250483	1161364	1186465	1192286	1342991	1216983	1311036
Value of Component Stock (POQ)	(BAHT)	33803626	26650326	24224925	30061627	29504461	28467918	26963356	30198216	30470559	33832043	30422360	34065541
Percentage of cost component stock		49.5	37.7	39.9	46.9	46.9	44.2	44.6	48.2	38.7	41.4	41.7	60.2

Figure 4. The case study company's monthly inventory decreased after using the POQ method to determine the optimal order size.

Figure 4. shows that the case study company's monthly inventory decreased after using the POQ method to determine the optimal order size.

Recommendations

3.1 Due to the uncertainty in the demand for raw materials each year, it is advisable to regularly review the appropriate order quantities to avoid mistakes in purchasing raw materials.

3.2 The results obtained from calculating the Variability Coefficient (VC) should be consistently compared with the actual raw material demand behavior to conclude whether the method is truly appropriate.

3.3 Should also study the inventory used as raw materials for other production processes.

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