

DEVELOPMENT OF RAW MATERIAL INVENTORY MANAGEMENT SYSTEM FOR CARTON BOX MANUFACTURING FACTORY

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ABSTRACT

Purpose: This research focuses on improving the raw material process to enhance the inventory management system of a carton box manufacturing factory located in Wang Noi Subdistrict, Wang Noi District, Ayutthaya Province. The study analyzed 109 Stock Keeping Units (SKUs) from 2011 to 2022, aiming to prevent both material shortages and excess stock, which were primarily caused by inefficient order management and consequently increased overall costs.

Design/methodology/approach: Inventory management principles were applied to analyze ordering and holding costs. The raw materials were classified using ABC analysis and further evaluated with the Peterson-Silver rule by examining the coefficient of variation (VC) for each SKU. Raw materials with stable demand were managed using the Economic Order Quantity (EOQ) model, while those with fluctuating demand were handled using the Silver-Meal and Lot-for-Lot (LFL) methods. Additionally, safety stock levels and reorder points were determined for critical A and B category items. Microsoft Excel's VBA (Visual Basic for Applications) was also employed to develop a system that manages procurement schedules and records raw material inflows and outflows, thereby improving both data accuracy and efficiency.

Findings: The results showed a significant reduction in total inventory management costs. In 2021, total costs decreased from 210,093.63 Thai Baht to 96,419.75 Thai Baht, a reduction of 54.11%. In 2022, costs were reduced from 217,371.01 Thai Baht to 77,025.72 Thai Baht, reflecting a 64.56% decrease.

Keywords: Inventory Management, Economic Order Quantity, Silver-Meal, Least Unit Cost, Lot-for-Lot, Visual Basic

INTRODUCTION

A factory's warehouse and inventory management system are a critical component that directly affects overall operational costs. Without effective planning and management, raw material shortages or oversupply may arise, leading to unnecessary storage costs and missed business opportunities. This research focuses on improving the inventory management system of a corrugated box factory.

The factory has experienced recurring monthly shortages of raw materials. The primary cause of this issue was purchased orders that did not align with actual demand. In some periods, excessive ordering resulted in surplus stock, which further increased total inventory management costs.

To address this issue, the researcher studied and analyzed data from 109 raw material SKUs. The ABC classification method was used to prioritize inventory control, and demand variability was assessed using the coefficient of variation (VC), in accordance with the Peterson-Silver Rule, to determine suitable inventory management policies for each SKU type.

For Group A raw materials with stable demand, the Economic Order Quantity (EOQ) policy was applied. Additionally, safety stock levels and reorder points were calculated to prevent future shortages. For Group A and B materials with uncertain demand, the Silver-Meal (SM) was employed. For Group C materials, the Lot-for-Lot (LFL) policy was used.

EOQ (Economic Order Quantity) and Silver-Meal are inventory management methods used to optimize ordering decisions and minimize total inventory costs. EOQ determines the optimal order quantity by balancing ordering and holding costs (Oktiarso & Mandasari, 2024; Ruekkasaem, 2014). The Silver-Meal heuristic is a dynamic lot-sizing technique that calculates optimal order quantities for varying demand periods (Melnik & Piper, 1985). Comparative studies show mixed results regarding which method is superior. Oktiarso & Mandasari (2024) found that Silver-Meal produced lower inventory costs

than EOQ for raw material planning. However, Ruekkasaem (2014) demonstrated that EOQ achieved the least inventory cost when shortage was allowed. Melnyk & Piper (1985) identified that Silver-Meal performed well in MRP systems with tight lead time error distributions. A significant limitation of traditional Silver-Meal formulations is their inefficiency during periods with zero demand, leading to unnecessarily frequent replenishments and higher costs. Segerstedt et al. (2023) addressed this by proposing a reformulated Silver-Meal approach that eliminates these difficulties with zero-demand periods.

The results of this research are expected to help the factory reduce overall inventory management costs, improve order quantity accuracy, and minimize the risks of both dead stock and raw material shortages.

RESEARCH METHODOLOGY

This study focused on developing an efficient raw material inventory management system for a corrugated paper factory located in Ayutthaya Province. The methodology, illustrated in Figure 1, began with a review of relevant inventory management theories, including ABC classification, the Peterson-Silver Rule, Economic Order Quantity (EOQ), Silver-Meal, and Least Unit Cost (LUC) methods.

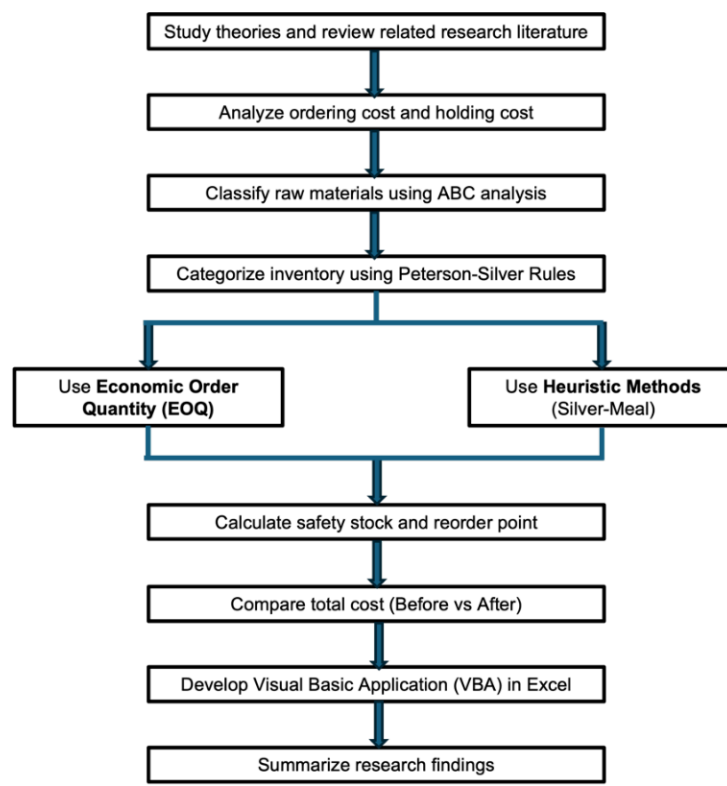


Figure 1 Methodology Flowchart

A total of 109 Stock Keeping Units (SKUs) were analyzed based on ordering and holding costs. The ABC analysis was used to classify items by value contribution, and the coefficient of variation (VC) was calculated to assess demand variability by using equation 1. SKUs with $VC \leq 0.25$ were managed using the EOQ model, while those with $VC > 0.25$ were optimized using heuristic methods such as Silver-Meal

$$VC = \frac{n \sum_{t=1}^n D_t^2}{(\sum_{t=1}^n D_t)^2} - 1 \quad (1)$$

The Economic Order Quantity (EOQ) analysis identifies the optimal order quantity for raw materials with stable demand, which is then used to calculate the total cost. This calculation considers various cost

components, including ordering cost, holding cost, order quantity per cycle, and the annual demand for raw materials. The EOQ and total cost can be determined using Equations (2) and (3).

$$EOQ = \sqrt{\frac{2 \times D \times c}{c_c}} \quad (2)$$

$$T_c = \left[\frac{C_o D}{Q} \right] + \left[\frac{Q C_c}{2} \right] \quad (3)$$

Where:

EOQ = Economic Order Quantity

D = Annual Demand

Co = Ordering Cost

Cc = Holding Cost

Q = Order Quantity

Safety stock levels and reorder points were determined to minimize stockout risks. To calculate the safety stock, the following parameters were used:

- Confidence level (z)
- Average lead time (\overline{LT})
- Standard deviation of demand (σ_n)
- Standard deviation of lead time (σ_{LT})
- Average daily demand (\overline{d})

The formula for safety stock is:

$$SS = z \times \sqrt{(\sigma_d^2 \times \overline{LT}) + (\overline{d}^2 \times \sigma_{LT}^2)} \quad (4)$$

The reorder point for SKU001, with an average lead time of 0.1038 days, was then calculated as follows:

$$ROP = \overline{d} \times \overline{LT} + SS \quad (5)$$

The Silver-Meal (SM) method is a type of heuristic approach for determining order quantities that minimize the total cost per period (Silver et al., 1998). This method considers both the quantity and timing of orders to minimize the cumulative inventory management cost. Developed by Edward Silver and Harlan Meal, the method considers two primary cost components: ordering cost and holding cost. The objective is to identify the optimal order quantity by minimizing the average total cost per period.

The Silver-Meal method calculates an order quantity that covers demand for multiple future periods. The steps for calculating the order quantity using the SM method, as described by Shenoy and Rosas (2018), are as follows:

1. Calculate the Per Period Cost (PPC):

For each planning period j, compute the average cost per period using Equation 6.

$$PPC_j = \frac{C_o + C_h \sum_{i=1}^j \frac{(2i-1)d_i}{2}}{\sum_{i=1}^j i} \quad (6)$$

This is done by incrementally increasing the value of j (i.e., the number of periods the order will cover) and comparing the results.

- The calculation continues until the per period cost at period j exceeds that of period j-1.
- Once this condition is met, the algorithm stops, and the optimal order quantity is determined for period j-1, which yields the minimum average cost.
- The optimal order quantity can be calculated using Equation 7.

$$Q_j = \sum_{i=1}^{j-1} d_i \quad (7)$$

2. Repeat the Process:

The calculation then restarts using the next unplanned period as the new starting point j and continues the procedure until all periods in the planning horizon have been covered.

The total inventory cost per period resulting from the Silver-Meal method can be calculated using Equation 8, as referenced in Shenoy and Rosas (2018).

$$TIC = C_o + C_h \sum_{i=1}^j \frac{(2i-1)d_i}{2} \quad (8)$$

Finally, total costs were compared before and after implementation to evaluate the effectiveness of the proposed approach.

Additionally, a stock management system was developed using Microsoft Excel with Visual Basic for Applications (VBA). The system calculates optimal order quantities, tracks inventory levels, and generates alerts when stock reaches the safety threshold, supporting timely replenishment.

RESULTS AND DISCUSSION

Ordering cost refers to the expenses incurred in procuring raw materials or components required to produce finished goods. These costs arise each time an order is placed and are typically calculated on a per-order basis, making them directly proportional to the number of orders placed.

In the context of the case study factory, ordering costs include:

- Employee wages for procurement staff, and
- Communication expenses associated with placing orders.

All ordering activities are carried out online, primarily through communication platforms such as LINE applications and email.

To calculate the average cost per order, the employee's monthly salary of 18,000 baht was divided by the portion of their workload related to ordering, which accounted for one-third (33.33%) of their total responsibilities. This results in an ordering-related monthly cost of:

$$18,000 / 33.33 = 5,999.40 \text{ baht}$$

Using this, the salary cost per order was calculated as:

$$5,999.40 / 78.22 = 76.70 \text{ baht per order}$$

The detailed breakdown of the ordering cost is presented in Table 1.

Details	Bath per Order
Labor	76.7
Internet	7

Table 1 Ordering Cost Breakdown

Holding cost refers to the expenses incurred for storing and maintaining raw materials in the warehouse. These costs are variable costs that fluctuate depending on the quantity of inventory held in storage. In the case study factory, the holding cost consists of:

- Wages for warehouse staff, and
- Electricity expenses related to the operation of storage facilities.

The detailed breakdown of the holding cost for the case study factory is presented in Table 2.

Details	Bath per Month
Warehouse Staff (per month)	12,800.00
Computers	802.56
Printer	60.19
Air Conditioning	1,508.56
Light bulb	541.73
Total Holding Cost	15,713.04

Table 2 Monthly Holding Cost Breakdown

The total monthly holding cost is allocated to each SKU based on its percentage share of the total inventory value. An example calculation for raw material SKU001 is as follows:

The average monthly quantity of SKU001 is 3,345 units, with an average unit price of 32.80 baht, resulting in an annual inventory value of:

$$3,345 \times 32.80 = 109,699.28 \text{ baht}$$

The total inventory value for all raw materials is 2,547,914.38 baht per year, and the total holding cost per month is 15,713.04 baht.

To determine SKU001's share of the total inventory value:

$$109,699.28 / 2,547,914.38 = 0.04306 \text{ (or 4.306\%)}$$

Using this percentage, the monthly holding cost for SKU001 is:

$$15,713.04 \times 0.04306 = 676.60 \text{ baht}$$

Finally, the average monthly holding cost per unit of SKU001 is:

$$676.60 / 3,345 = 0.2022 \text{ baht}$$

To classify the inventory, the ABC classification method was applied by sorting raw materials in descending order of annual usage value and calculating the cumulative percentage of each item. This follows the classification theory of Magee and Boodman (1974), which groups inventory into three categories: A, B, and C. The classification results for all 109 SKUs are presented in Table 3.

Group	Number of SKUs	Percentage of Total Value (%)	Percentage of Total Raw Materials (%)
A	18	66.18	16.51
B	30	29.74	27.52
C	61	4.08	55.96

Table 3 ABC Classification of 109 SKUs

The Peterson-Silver Rule was applied to analyze demand variability across all SKUs. The analysis revealed that only **one item—SKU001—**had stable demand, with a coefficient of variation (VC) less than 0.25. The remaining 108 items exhibited variable demand (VC > 0.25).

Based on this classification, the most appropriate ordering method was determined for each SKU. For SKU001, which has stable demand, the Economic Order Quantity (EOQ) model was used. The parameters for the EOQ calculation were as follows:

- Ordering cost (C_o): 83.70 baht per order
- Carrying cost per unit per year (C_c): 0.2022 baht per unit
- Annual demand (D): 40,140 units

The EOQ is calculated using the standard formula:

$$EOQ = \sqrt{\frac{2 \times D \times C_o}{C_c}} = \sqrt{\frac{2 \times 40,140 \times 83.7}{0.2022}}$$

$$EOQ = \sqrt{\frac{6,714,738}{0.2022}} \approx 5,765 \text{ units}$$

Therefore, the optimal order quantity for SKU001 is approximately 5,765 units per order.

The total cost for the order quantity (Q) of 5,765 units can be calculated as follows:

$$\text{Ordering Cost} = \frac{D}{Q} C_o$$

$$= (40,140 \times 83.7) / 5,765 = 582.77 \text{ Baht}$$

$$\text{Holding Cost} = \frac{Q}{2} C_c$$

$$= 5,765 \times 0.2022 = 1,165.68 \text{ Baht}$$

Total Cost = Ordering Cost + Holding Cost

$$= 582.77 + 1,165.68 = 1,748.453 \text{ Baht}$$

In addition, Safety stock (SS) and reorder point (ROP) were calculated for 48 raw materials in Groups A and B to prevent shortages, which are a significant contributor to increased inventory management costs.

Safety stock (SS) calculation example for SKU001

To calculate the safety stock for SKU001, the following parameters were used:

- Confidence level (z): 95% $\rightarrow z = 1.645$
- Average lead time (\overline{LT}): 0.1038 days
- Standard deviation of demand (σ_n): 1,727.427 units
- Standard deviation of lead time (σ_{LT}): 0.2561 days
- Average daily demand (\bar{d}): 3,345 units

Substituting the values into the safety stock formula:

$$SS = 1.645 \times \sqrt{(1,727.427^2 \times 0.1038) + (3,345^2 \times 0.2561^2)} \approx 1,679.92$$

Thus, the Safety Stock for SKU001 is approximately 1,680 units.

The reorder point for SKU001, with an average lead time of 0.1038 days, was then calculated as follows:

$$ROP = (3,345 \times 0.1038) + 3,107 \approx 3,455 \text{ units}$$

Therefore, raw material SKU001 should maintain a safety stock of 3,107 units and a reorder point of 3,455 units.

For raw materials in Groups A and B with uncertain demand, the Silver-Meal (SM) method was employed to determine the optimal order quantity. According to previous studies, the Silver-Meal method has been shown to produce the lowest total inventory cost, is easy to implement, and consistently yields effective results (Nazuk et al., 2021; Thuannadee et al., 2019).

The Silver-Meal heuristic method was applied to determine the optimal order quantity for raw material SKU004, based on monthly demand. This method aims to minimize the average total inventory cost per period by considering both ordering and holding costs.

Given Parameters:

- Ordering cost per order (Co): 83.70 THB
- Holding cost per unit per month (Ch): 0.1185 THB
- Beginning inventory at the end of the previous month: 1,632 units
- Monthly demand: As shown in Table 4

Period	Demand	Period	Demand
Month 1	2,010	Month 7	-
Month 2	4,015	Month 8	-
Month 3	4,030	Month 9	6,020
Month 4	3,010	Month 10	-
Month 5	10,030	Month 11	6,030
Month 6	4,020	Month 12	-

Table 4 Demand quantity of raw material SKU004

The results obtained from the Silver-Meal heuristic are presented in Table 5, while Table 6 provides an example comparing the total cost from the existing ordering method with that derived from the proposed policy, including the cost difference between the two approaches.

Period	Demand	Period	Demand
Month 1	400	Month 7	-
Month 2	4,000	Month 8	-
Month 3	4,025	Month 9	6,025
Month 4	3,025	Month 10	-
Month 5	10,025	Month 11	6,025
Month 6	4,025	Month 12	-

Table 5 Silver-Meal Order Quantity Calculation for Raw Material SKU004

Raw Material Item	Appropriate Policy	Actual Cost	Analyzed Cost	Difference
SKU001	EOQ	9,348.12	1,558.23	7,789.89
SKU002	SM	9,167.83	4,695.27	4,472.56
SKU003	SM	6,049.35	3,103.37	2,945.98
SKU004	SM	5,840.07	2,999.37	2,840.70
SKU005	SM	5,547.27	3,139.34	2,407.93
SKU006	SM	5,523.77	2,764.12	2,759.65
SKU007	SM	5,007.46	3,324.94	1,682.52
SKU008	SM	4,930.77	3,556.55	1,374.21
SKU009	SM	4,594.68	2,575.72	2,018.96
SKU0010	SM	3,997.97	1,934.54	2,063.43

Table 6 An example of the total cost obtained from the existing ordering method and the total cost derived from the proposed policy, including the cost difference between the two approaches.

For Group C materials, the Lot-for-Lot (LFL) method was applied, where the ordering quantity exactly matches the monthly demand.

CONCLUSIONS

Based on the analysis, the optimal ordering quantities for all 109 raw materials were determined using the Peterson-Silver Rule in combination with ABC classification, aligning the ordering strategy with the specific demand characteristics of each item. In 2021, prior to implementing the optimized ordering approach, the total inventory management cost amounted to 210,093.63 THB. Following the adoption of demand-specific ordering methods, this cost was reduced to 96,419.75 THB, representing a reduction of 113,673.89 THB or 54.11%. Likewise, in 2022, the initial cost of 217,371.01 THB was decreased to 77,025.72 THB, yielding a cost savings of 140,345.29 THB or 64.56%.

These findings highlight the effectiveness of applying demand-based inventory strategies to significantly reduce overall inventory management expenses. Furthermore, the integration of a Visual Basic for Applications (VBA)-based inventory control system within Microsoft Excel improved the operational efficiency of stock management. The system not only enabled accurate purchasing based on predetermined reorder points but also provided real-time alerts via the LINE application when inventory levels approached safety stock thresholds. Furthermore, it facilitated systematic tracking of raw material inflows and outflows, supporting more accurate and timely procurement decisions.

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