Reduction of Raw Materials Inventory Costs: A Case Study of Auto Parts Company

Nichaphat Khamai
Master of Engineering Program in Logistics Engineering and Supply Chain Management
Department of Industrial Engineering, Faculty of Engineering
Chiang Mai University,Chiang Mai, Thailand
nichaphat_kh@cmu.ac.th

Apichat Sopadang
Excellence Center in Logistics and Supply Chain Management (E-LSCM)
Chiang Mai University, Chiang Mai, Thailand
apichat.s@cmu.ac.th

Abstract

Inventory management is essential for all businesses because raw materials in stock inventories are current assets that require significant investment. Having too few or too many raw materials also creates problems for the company, such as stock-outs, deterioration, or disappearance due to an excessively long storage period. Therefore, this study examines the order quantity of raw materials in group A derived from the ABC classification method of the case study company. The 112 items represent a group of raw materials requiring strict monitoring supervision and having the highest annual inventory turnover value. Then, the Coefficient of Variation (CV) of demand for raw materials used to determine the ordering volume of raw materials was analyzed. Economic Order Quantity (EOQ) method determines the stable demand for raw materials. An unstable demand is determined using two heuristic methods which are Silver-Meal (SM) and Part-Period Balancing (PPB) methods. In addition, safety stock levels were analyzed to avoid shortages. As a result, in comparison to the actual total inventory cost of the company in the case study, the total cost of raw materials in group A decreased by 44.58 percent in 2019, 44.52 percent in 2020, and 45.55 percent in 2021.

Keywords
Inventory Management, Economic Order Quantity, Heuristic Method, Silver Meal, Part-Period Balancing

1. Introduction
Thailand's automotive parts industry is one of the world's most important automotive parts production areas. In 2019, Thailand ranked first in ASEAN, fourteenth in the world, and sixteenth in automotive parts as an exporter of all types of automotive parts. The main export markets are America, Japan, and Indonesia (Thai Auto-Parts Manufacturers Association (TAPMA) 2022). However, Thailand's automotive parts industry has over 1,800 manufacturers (Yongpisanphob 2020), making it a highly competitive market.

The case study company is a factory that produces brakes and aluminum parts for vehicles, as well as the production and assembly of 2- and 4-wheeled parts that are sold to domestic and international customers. They have 2,564 raw materials used to manufacture products and orders from domestic and international suppliers. According to the logistics performance measurement of the case study company, it was found that the time management of raw material inventory is poor and has a lengthy inventory holding period. In other words, the company had an inventory stock of approximately 17,453,026 units in 2019, 14,737,539 units in 2020, and 13,210,881 units in 2021, which is an excessive amount of inventory and causes a low rotation of raw materials stored in a warehouse. As a result of having too many materials, there is a problem with unsuitable raw material inventory management, which is one of the reasons for the high cost of raw material inventory management. Inventory management is one of the primary activities of logistics, which is a crucial objective that every organization uses to gain a competitive advantage and focus on operational costs by finding a way to minimize costs and increase competitiveness.

Therefore, this study focuses on reducing inventory costs of raw materials at the case study company by determining the order quantity method according to the appropriateness of each raw material demand level in 2019 using ABC Classification Analysis, Coefficient of Variation (CV), Economic Order Quantity (EOQ), Silver Meal (SM), Part Period Balancing (PPB), and Safety Stock (SS) methods in order to minimize the total cost of inventory management, which consists of ordering cost and holding cost and rechecking methods in 2020 and 2021. This study employs an inventory model to minimize the total cost of normal inventories.

2. Literature Review

Logistic management "can reduce cost, cycle time, and improve activities and business performance, including smooth flows of materials and information at less cost." (Wichaisri and Sopadang 2017). Inventory management is one of the most important logistics activities. It is an important goal that every organization uses as a competitive advantage—focusing on the cost of operations by finding a way to minimize total inventory costs. Raw materials, work–in–process, maintenance, repair and operations (MRO), and Finished goods are included (Ballou 2004; Lancioni and Howard 1978). The proper way for determining the order quantity for each raw material is one of the primary methods that help minimize inventory management costs.

Inventory classification by importance using the ABC Classification method is widely and popular method used to classify inventory in practice, with demand value and demand volume as the most common ranking (Teunter et al. 2010). This classification method is based on the Pareto Rule principle and can classify items into three groups (Yu 2011; Magee and Boodman 1974); group A has 5 to 15% of items that account for 75 to 80% of the total value, while group B and C have 20 to 30% and 50 to 80 % of items that account for 15 to 20% and 5 to 10% of the total value of materials inventory, respectively. The Classification of this method is shown in figure 1 Then, based on the ABC classification, group A is extremely important materials because there is the highest annual usage value, while groups B and C have decreasing importance respectively.

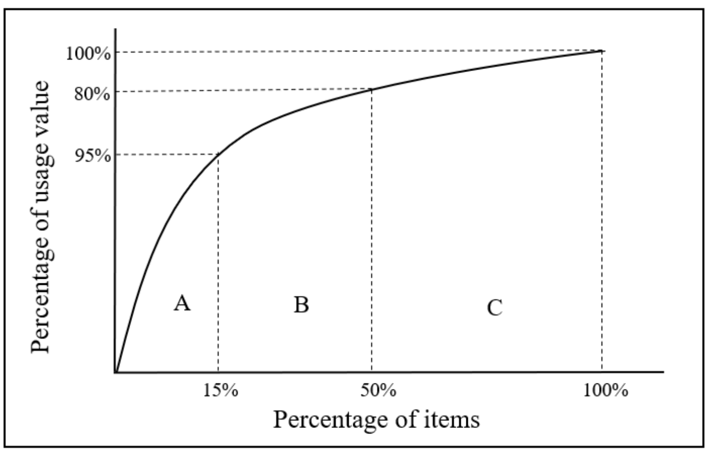

Figure 1. The Classification of ABC Classification method

The Coefficient of Variation (CV) method is used to figure out if there is a stable or unstable pattern in the nature of the demand for raw materials (Silver et al. 2006). There is a determination assuming that demand is a discrete random variable throughout the analysis periods and taking the standard deviation and the mean demand square into consideration (González-Garzón et al. 2021). Provided that the CV is less than 0.25, it represents stable raw material demand; nevertheless, if it is more than 0.25, it is greater than 0.25, it indicates that the raw material demand levels fluctuate or are unstable. The calculation using equation 1, where n represents the study period and D_t represents the amount of raw material demand in each period, as the same as a formulation in the Peterson Silver method.

$$VC = \frac{n\sum_{t=1}^{n} D_t^2}{\left(\sum_{t=1}^{n} D_t\right)^2} - 1 \qquad [1]$$

The primary objective of order quantity determination is to minimize the total raw material inventory management costs. According to Nasution et al. (2022), Economic Order Quantity (EOQ) method is one of the methods that always provides better control and is advantageous for maintaining the optimal level of materials in stock, which is the level that minimizes the total cost of inventory management (Khyati and Saxena 2021). This method identifies the point at which holding cost equals order cost (Russell and Taylor 2011) in order to calculate the order quantity that makes the total cost as low as possible. Vania and Yolina (2019) have solved the issue of excessive inventories of energy drinks in India and found that the EOQ method is suitable for stable raw materials, which is equivalent to the research of Zaedi et al. (2020) discovered that the EOQ method works best when demand is uniform. In this study, a stable demand for raw materials was analyzed to determine Economic Order Quantity (EOQ) using the equation of Shenoy and Rosas (2018) in equation 2 for unstable or variable requirements, which is suitable for the heuristic method and will result in low total inventory management costs.

$$Q_{opt} = \sqrt{\frac{2DC_o}{C_h}} \qquad [2]$$

In the study by Asmal et al. (2019) that applied the Silver-Meal method and Wagner-Whitin algorithm to control animal feed ingredients, there was a problem with excess ingredient inventory in stock that got high total inventory costs. Consequently, the SM method can reduce costs in a manner comparable to the Wagner-Whitin algorithm and those of Nazuk et al. (2021), who compared eight heuristic methods for inventory management in the surgical instruments manufacturing industry in Sialkot, Pakistan. There found best heuristic method is Silver-Meal (SM), Part-Period Balancing (PPB), and Least Unit Cost (LUC) methods that three techniques have similar analyses, which correspond to Uansamer and Kittithreerapronchai's (2014) research managed the inventory of the tire cord fabric factory to determine the order quantity for raw materials with unstable demand by comparing five heuristic methods. According to studies, no heuristic method minimizes the lowest cost for every product because each technique is appropriate for its respective raw material. Therefore, order quantity should be determined with two or more heuristic methods by comparing them to find which method is most appropriate for each situation. Furthermore, the Silver Meal (SM) and Part-Period Balancing (PPB) methods are used to determine the order quantity of unsuitable demand of raw materials. In numerous studies, both heuristic methods frequently provide the optimal solution. There are also easy-calculation steps that are simple to understand.

Silver Meal (SM) method developed by Edward Silver and Harlan Meal is one of the heuristic methods used to determine the order quantity that can minimize the total cost for each period. It will determine the total inventory costs by calculating the volume covered during that order cycle according to equation 3 (Shenoy and Rosas 2018). The criterion for choosing the period for determining the order quantity is referred to as the per period cost (PPC) for the order; if the PPC in j period is over $j-1$ period, we will stop calculating and set the sum of the analyzed order volume until $j-1$ period is the most optimal order period and quantity.

$$\frac{C_o + C_h \sum_{i=1}^{j} \frac{(2i-1)d_i}{2}}{\sum_{i=1}^{j} i} \qquad [3]$$

Part-Period Balancing (PPB) is the order quantity method, which is one of the heuristics that causes the balance between order cost and holding cost in the order cycle. The order calculation will cease when the storage cost of the order exceeds the order cost (Shenoy and Rosas 2018) and determined that the closeness factor (C_r) is equal to equation 4. The condition of choosing the time limit for determining the order quantity is that if the C_r of determining the order quantity in the $j-1$ period is less than determining the order quantity during the period j, we will stop calculating and set the order during the $j-1$ period as the optimal order quantity determination period.

$$C_r = \left| C_o - C_h \sum_{i=1}^{j} \frac{(2i-1)d_i}{2} \right| \qquad [4]$$

The total inventory cost is the sum of costs used to manage inventory, which an organization needs to adopt (Shenoy and Rosas 2018) to see if the method used is effective. This study's costs, including ordering cost and holding cost, were compared with the actual costs of the case study. The Economic Order Quantity (EOQ) method is given by equation 5, in which m is the total number of orders, which Silver Meal (SM) and Part-Period Balancing (PPB) are used to calculate in equation 6.

$$TIC = \frac{D}{Q_{opt}} C_o + \frac{Q_{opt}}{2} C_h \qquad [5]$$

$$TIC = C_o + C_h \sum_{i=1}^{j} \frac{(2i-1)d_i}{2} \qquad [6]$$

The purpose of safety stock is to prevent or avoid the risk of shortages of goods caused by the unpredictability of supply and demand (Thieuleux 2022), which can result in damages caused by the variability of demand for goods and lead times. The equation used for demand and lead time uncertainty is independent (Kloosterman 2022; King 2011). There can be used to calculate the reserve stock in equation 7.

$$SS = z\sqrt{\overline{LT}\sigma_d^2 + \overline{d^2}\sigma_{LT}^2} \qquad [7]$$

3. Methods

This study was conducted on a total of 2,564 items of raw material used by an auto-parts manufacturer in 2019 to determine the order quantity method, and will be rechecked in 2020 and 2021. Therefore, we classified them into three classes using the ABC classification methodology and analyzed only group A materials, which are the most important since they have the highest annual usage value. Subsequently, we analyze the raw material demand coefficient of variation (CV) to validate and determine the inventory method appropriate for each raw material of the case study company if there is less than 0.25 using the Economic Order Quantity (EOQ) technique by using the equation 2. In contrast, for values greater than 0.25, we compare the total inventory cost of Silver Meal (SM) and Part-Period Balancing (PPB) using equation 6, after analyzing the equation of each method by equations 3 and 4, respectively, to choose which technique is appropriate for each variable raw material. In addition, we calculate the Safety Stock (SS) to prevent or avoid the risk of shortages and to ensure that the number of raw materials determined by new techniques does not cause a production line shortage. Lastly, we compared the total cost of raw materials in group A to the actual total inventory cost of the case study, which is all analyzed in section 5, and then we discuss and conclude the result of this study. The process flow of this study is shown in figure 2.

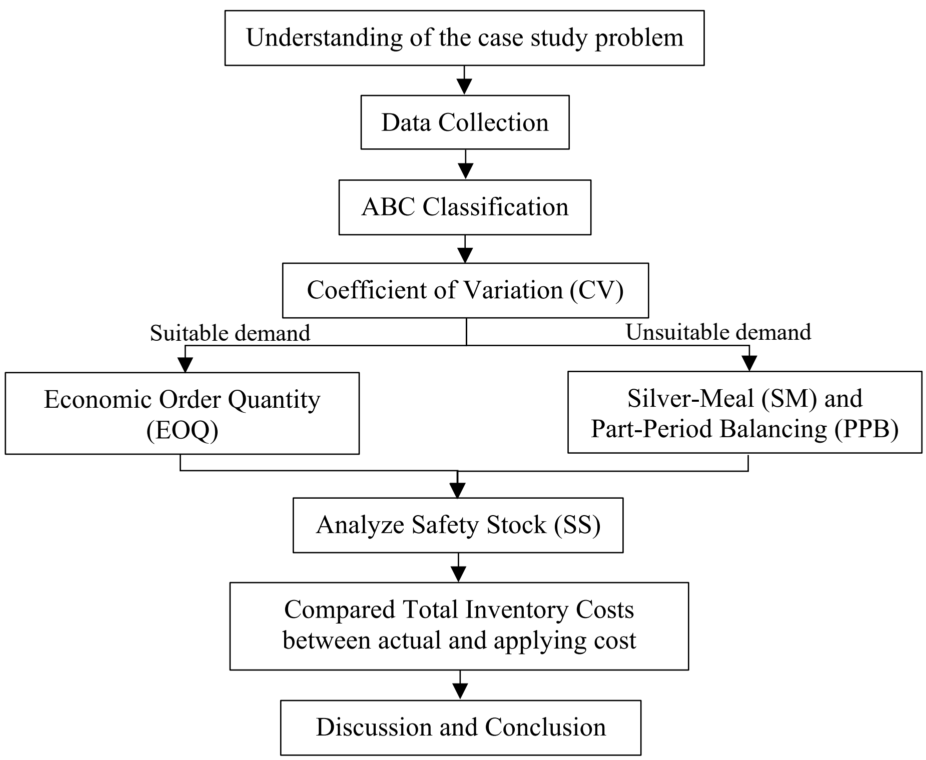

Figure 2. The study processes flow

4. Data Collection

This study conducted the purchase and storage inventory of all 2,564 raw materials used in the company's product production. As shown in figure 3, we collected data on the number of orders and usage of raw materials from January to December 2019 to 2021, and rechecking techniques are workable from 2020 to 2021. The cost of managing raw material inventory consists of ordering and holding cost. The objective of this study is to analyze the order quantity in order to minimize the total cost of raw material inventory management. Figure 2 shows the number of orders and usage of raw materials, which reveals that the case study company ordered more than used, which is one of the reasons for the high total inventory cost and inventory turnover. In order to reduce inventory costs of raw materials, this study determines order quantity methods based on the suitability of each raw material demand.

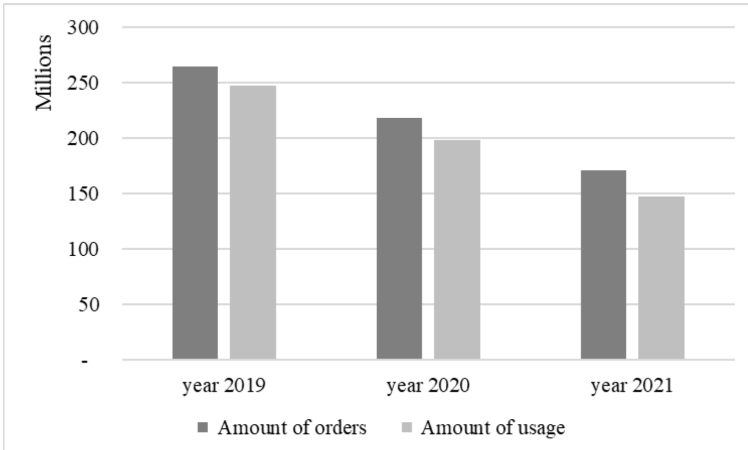

Figure 3. the amount of usage and orders of raw materials from January to December 2019 to 2021

5. Results and Discussion

The raw material inventory of the automotive parts manufacturer from 2019 to 2021 included 2,564 items for producing all of its products. This study analyzed only 112 items from groups A which derived from ABC classification method. In 2019, 2020, and 2021, the total inventory cost, composite ordering cost, and holding cost were determined to be $134,869, $93,662, and $71,775, respectively.

5.1 ABC Classification Method

The classification of raw materials according to the ABC classification method of the case study company can be summarized as shown in Table 1, classifying raw materials into three groups: group A consists of 112 raw materials, or 4.37% of the total raw material list, with a value equal to 78.53% of the annual usage value. Group B's raw materials inventory includes 507 items, accounting for 16.30% of raw materials and 19.77% of annual usage value; group C's raw materials inventory contains 1,945 items, accounting for 75.86% of raw materials but only 5.17% of annual usage value. In this study, the raw materials of only 112 items in group A will be examined as they are the most influential and must be strictly supervised.

Table 1. ABC Classification Analysis of raw materials

Group of raw materials	Percentage of value	Percentage of items
Group A	78.53%	4.37%
Group B	16.30%	19.77%
Group C	5.17%	75.86%

5.2 Coefficient of Variation

By measuring the Coefficient of Variation (CV) of raw material items in group A, it is possible to determine the optimal ordering method for each raw material. The CV value is used to determine the stability demand of raw materials. If the CV is less than 0.25, the Economic Order Quantity (EOQ) method is used. If the CV is greater than 0.25, Silver Meal (SM) and Part-Period Balancing (PPB) are used. The CV calculation for raw materials of 112 items yielded a CV of less than 0.25 for 86 items and greater than 0.25 for 26 items, as shown in Table 2, which compares three methods to determine the best result in each item with the lowest total inventory cost.

Table 2. The Coefficient of Variation of raw materials group A

Coefficient of Variation (VC)	Amount of raw materials	Method
VC < 0.25	86	EOQ
VC > 0.25	26	SM & PPB

5.3 The order quantity

From the CV method of raw materials, we analyzed the suitable method for each item to minimize the total inventory costs. The 86 items are stable demand of raw materials using the Economic Order Quantity (EOQ) method. The calculation of raw material inventory involves ordering and holding costs of each raw material. The analysis based on formula 2, the estimation of the Economic Order Quantity (EOQ) method for raw material code 001 based on the following data:

- Demand (D) is 791,526 units per year
- Order cost (C_o) is \$8 per order
- Holding cost $(C_h)$is \$0.0019 per unit per period

$$Q_{opt} = \sqrt{\frac{2DC_o}{C_h}}$$

$$Q_{opt} = \sqrt{\frac{2(8)(791{,}526)}{0.0019}}$$

$$Q_{opt} = \text{81,642 units}$$

According to the EOQ analysis, the optimal amount was 81,642 units, but in reality, we must define it based on the condition of suppliers' terms. Therefore, the material code 001 should order 81,645 units. Silver Meal (SM) and Part-Period Balancing (PPB) are the heuristic methods used to determine the appropriate order technique for each unsteady raw material for 26 items and they use the logic as the EOQ method. The analysis of the Silver Meal (SM) method, demand (units), and costs for the unstable raw material code 002 yielded the following data:

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Demand	8,760	7,770	7,745	6,330	8,865	6,300	6,971	6,436	5,580	698	576	992

- Order cost (C_o) is \$5 per order
- Holding cost $(C_h)$is \$0.002 per unit per period

PPC of period 1; $$\frac{C_o + C_h \sum_{i=1}^{j} \frac{(2i-1)d_i}{2}}{\sum_{i=1}^{j} i} = \frac{5 + 0.002\left(\frac{(2(1)-1)(8{,}760)}{2}\right)}{1}$$

$$PPC = 13.76$$

PPC of period 2; $$\frac{C_o + C_h \sum_{i=1}^{j} \frac{(2i-1)d_i}{2}}{\sum_{i=1}^{j} i} = \frac{5 + \left[0.002\left(\frac{(2(1)-1)(8{,}760)}{2}\right) + \left(\frac{(2(2)-1)(7{,}770)}{2}\right)\right]}{1+1}$$

$$PPC = 18.49$$

The condition of the SM method is that if the per period cost (PPC) in period j is over period $j-1$, we will stop calculating and set the sum of the analyzed order volume until $j-1$ period. Due to analysis, the PPC of period 2 is greater than that of period 1. Hence, we should place an order for 8,760 units in period 1. However, we will order 8,800 units based on the suppliers' requirements. For the analysis of the Part-Period Balancing (PPB) method, if the closeness factor (C_r) of $j-1$ periods is less than that of j periods, we will stop calculating and use the order during the $j-1$ period as the optimal order quantity determination period. We will use the same cost parameters for raw material code 002 that we used in the Silver Meal (SM) method.

C_r in period 1; $\left|C_o - C_h \sum_{i=1}^{j} \frac{(2i-1)d_i}{2}\right| = \left|5 - 0.002\left(\frac{(2(1)-1)(8,760)}{2}\right)\right|$

$C_r = 13.76$

C_r in period 2; $\left|C_o - C_h \sum_{i=1}^{j} \frac{(2i-1)d_i}{2}\right| = \left|5 - 0.002\left(\frac{(2(1)-1)(8,760)}{2}\right) + \left(\frac{(2(2)-1)(7,770)}{2}\right)\right|$

$C_r = 26.98$

Based on the PPB method and suppliers' terms, we placed an order for 8,800 units. After knowing the number of orders, we can calculate the total inventory cost of each raw material for the Economic Order Quantity (EOQ) using equation 5, whereas equation 6 is used by the Silver Meal (SM) and Part-Period Balancing (PPB) methods. Then, we will calculate the total inventory cost of the previously calculated variable raw materials in order to compare and choose the suitable methods using equation 6. The Silver Meal (SM) method costs $105 compared to $109 for Part-Period Balancing (PPB) method. Therefore, SM has a lower total cost of inventory than PPB. We suggest that Silver Meal (SM) is suitable for this material. Table 3 shows the total inventory costs using the order quantity method for 104 raw materials items in the years 2019 to 2021.

Table 3. Result of total inventory costs using each order quantity method in 2019 to 2021

Years	Total costs of EOQ for 86 items ($)	Total costs of SM for 26 items ($)	Total costs of PPB for 26 items ($)
Year 2019	62,341	9,660	7,286
Year 2020	42,040	6,146	6,062
Year 2021	33,177	3,145	3,131

After developing each technique, we calculated the safety stock (SS) to prevent the risk of shortages. The confidence service used in this study is 95%, and the safety stock of raw material code 002 is 7,436 units, which is solved by equation 7;

$$SS = 1.64\sqrt{(1.479)(3{,}076^2) + (5{,}585^2)(1216^2)}$$

$$SS = 7{,}436 \text{ units}$$

Then, we compared the total inventory cost of the case study company's actual total inventory cost from 2019 to 2021, indicating that this study could minimize total inventory costs, as shown in table 4. In addition, the comparison of order quantity from 2019 to 2021 is shown in figure 4.

Table 4. Comparison of total inventory costs with safety stock in 2019 to 2021

Years	Actual total costs of the case study ($)	Total cost by applying methods ($)	Percentage of saving (%)
Year 2019	$130,290	$72,211	44.58%
Year 2020	$86,851	$48,184	44.52%
Year 2021	$66,704	$36,322	45.55%

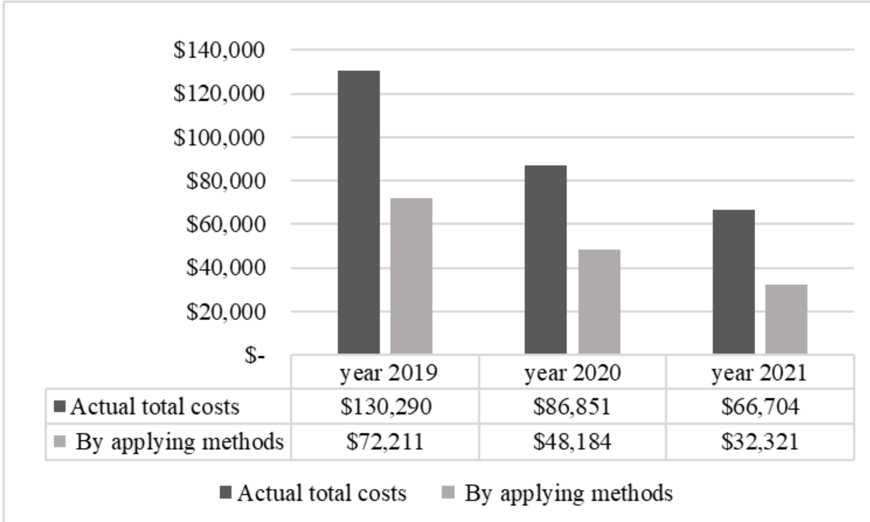

Figure 4. Comparison of total costs in 2019 to 2021

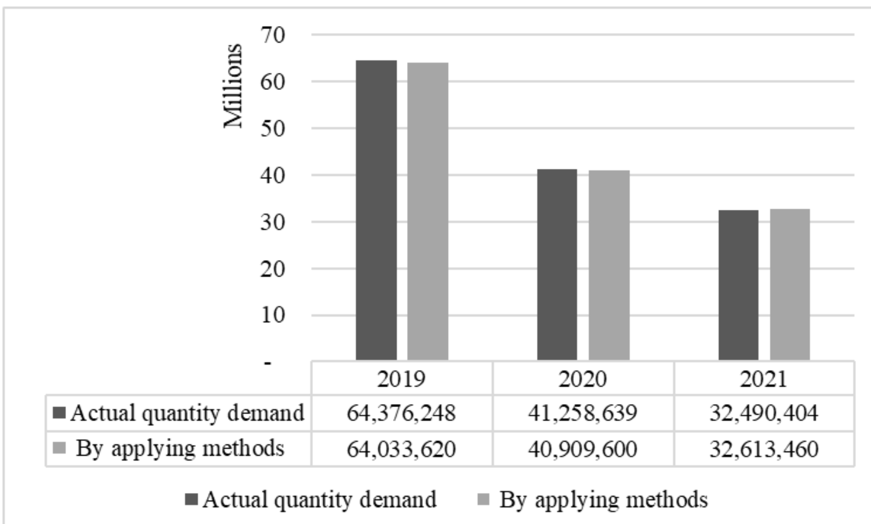

Figure 5. Comparison of annual material quantity in 2019 to 2021

The inventory methods can reduce the total inventory costs of the case study company from $130,290 to $72,211 by 44.58% in 2019, in distinction to $86,851 to $48.184 by 44.52% in 2020, and $66,704 to $36,321 by 45.55% in 2021, as shown in Table 3 and figure 4. Due to figure 5, we annual ordered a similar number of raw materials as materials demand of the case study company; however, by using these inventory management methods, we can reduce our total inventory costs below what the case study company actually incurred. It should be noted that once we have the amount for determining inventory quantity by methods, we will define it based on the condition of suppliers' terms being subsequent to the fact that the company placed an order, and the inventory methods are used to minimize inventory costs. However, not every method is suitable for every raw material, and each material has its appropriate technique.

6. Conclusion

This study aims to minimize the total inventory cost of raw materials group A in the case study of an automotive parts manufacturer by determining the order quantity method for each item and rechecking the technique that can be used from 2020 to 2021 using ABC classification, Coefficient of Variation (CV) of demand, Economic Order Quantity (EOQ), Silver-Meal (SM) and Part-Period Balancing (PPB) methods. It can be summarized as follows:

We classified raw materials into three groups using the ABC classification method to establish the annual usage value due to their widespread practical application (Teunter et al. 2010) and we analyzed only group A with 112 items of raw material lists since it was the most important of the materials due to its highest annual usage value. Then, using the Coefficient of Variation (CV), the optimal ordering method and stability demand for 112 items in group A were determined. Employing the Economic Order Quantity (EOQ) method, we discovered a stable demand for 86 raw materials. For 26 items that are unstable in demand, we compared the total costs for the appropriate items with two heuristic methods, the Silver Meal (SM) and Part-Period Balancing (PPB) methods, and examined the method that resulted in the lowest total inventory costs.

Finally, based on the application methods of raw materials in group A, and calculated Safety Stock (SS) to avoid the risk of product shortages, we can reduce total inventory costs by 44.58% in 2019, and by 44.52% and 45.55%, respectively, from 2020 to 2021. This study determines the order quantity based on the method analyzed according to the specified supplier raw material order conditions. According to studies, not all methods are suitable for all raw materials, so the appropriate technique for each raw material should be assigned to minimize total inventory costs as much as possible. According to the research of Uansamer and Kittithreerapronchai (2014) and Thavornwat and Kanchana (2013), each method has its strengths for determining order volume, as described previously. For further study, more than three methods should be analyzed in this study because each material has its own appropriate technique. Consequently, multiple techniques that minimize total inventory costs should be compared.

References

Asmal, S., Setiawan, I., Ikasari N. and Adriani Y., Inventories Analysis of Animal Feed Raw Materials by Using the Silver Meal Method and Wagner within Algorithm (Case Study of PT. XYZ Makassar), *The 3rd EPI International Conference on Science and Engineering 2019 (EICSE2019)*, pp. 1-10, Makassar, Indonesia, September 24-25, 2019.

Ballou, R. H., *Business Logistics/Supply Chain Management: Planning, Organizing, and Controlling the Supply Chain*, 5th Edition, Pearsons-Prentice Hall, 2004.

González-Garzón, C., Montero-Santos, Y. and Saraguro Piarpuezan, R. V., Inventory Model for Raw Material: A Case Study of a Chemical Company, *the International Conference on Industrial Engineering and Operations Management*, pp. 102-110, Rome, Italy, August 2-5, 2021.

Khyati and Saxena A. K., Review on EOQ Models for Review on EOQ Models for Instantaneous and Non-Deteriorating Items, *10th International Conference on System Modeling & Advancement in Research Trends (SMART)*, pp. 312-315, Moradabad, India, December 10-11, 2021.

King, P. L., *Crack the code Understanding safety stock and mastering its equations, Association for Supply Chain Management (APICS) magazine*, pp. 33-36, 2011.

Kloosterman, L.H.P.M., Multi-echelon Safety Stock Management Approach for Pharmaceutical Companies, (Master), Eindhoven University of Technology, 2022.

Lancioni, R. A. and Howard, K., Inventory Management Techniques, *International Journal of Physical Distribution & Materials Management*, vol. 8, no. 2, pp. 385-428, 1978.

Magee, J.F. and Boodman, D.M., *Production Planning and Inventory Control*, 2nd Edition, McGraw-Hill, New York, 1974.

Nasution, S. L. R., Asthariq, M. and Girsang, E., Analysis of the Implementation of Drug Inventory Control with the Always Better Control-Economic Order Quantity-Reorder Point Safety Stock Method, *Open Access Macedonian Journal of Medical Sciences*, vol. 10, no. A, pp.1397-1401, 2022.

Nazuk, A., Rashid, M. and Salman, V., Optimizing Inventory Management Cost: Case of Simap, *Journal of Statistics, Computing and Interdisciplinary Research*, vol. 3, no. 3, pp. 99-116, 2021.

Russell, R. S. and Taylor, B. W., *Operations Management: Creating Value Along the Supply Chain*, 7th Edition, John Wiley & Sons, 2011.

Shenoy, D. and Rosas, R., *Problems & Solutions in Inventory Management*, Springer Nature, 2018.

Silver, E. A., Pyke, D. F. and Peterson, R., *Inventory Management and Production Planning and Scheduling*, 3rd Edition, John Wiley & Sons, New York, 2006.

Teunter, R. H., Babai M. Z. and Syntetos, A. A., ABC Classification: Service Levels and Inventory Costs, *Production and Operation Management (POMS)*, vol. 19, no. 3, pp. 343–352, 2010.

Thai Auto-Parts Manufacturers Association (TAPMA), Thailand Auto -Parts Trade Performance as of Jan-Aug 2022, Available: https://www.thaiautoparts.or.th, 2022.

Thavornwat, C. and Kanchana, R., Improvement of the Inventory Management System: Case Study in Make-To-Order Production System, *Journal of Engineering, RMUTT*, vol. 2, pp. 1-13,2013.

Thieuleux, E., 6 Best Safety Stock Formulas: Calculation & Examples in Excel (Full Tutorial), Available: https://youtu.be/p40SxvWFQ_A, June, 2022.

Uansamer, J. and Kittithreerapronchai, O., Chemical Inventory Management in Tire, *Journal of KMUTNB*, vol. 24, no. 2, pp. 308-317, 2014.

Vania, A. and Yolina, H., Analysis Inventory Cost Jona Shop with EOQ Model, *Engineering, Mathematics and Computer Science (EMACS) Journal*, vol. 3, no. 1, pp. 21-25, 2021.

Wichaisri, S. and Sopadang, A., Integrating sustainable development, lean, and logistics concepts into a lean sustainable logistics model, *International Journal of Logistics Systems and Management*, vol. 26, no. 1, 2017.

Yongpisanphob, W., Industry Outlook 2020-2022: Auto Parts Industry, Available: https://www.krungsri.com/en/research/industry/industry-outlook/Hi-tech-Industries/Auto-Parts/IO/Industry-Outlook-Auto-Parts, September 10, 2020.

Yu, M. C., Multi-criteria ABC analysis using artificial-intelligence-based classification techniques, *Expert Systems with Applications*, vol. 38, pp. 3416-3421, 2011.

Zaedi, N. I. A. G., Majid, H. and Samah, A. A., Material Requirement Planning using LFL, EOQ and PPB Lot Sizing Technique, *Academia of Fundamental Computing Research*, vol. 1, no. 2, pp. 1-9, 2020.

Biographies

Nichaphat Khamai is currently a full-time student in the Master of Engineering Program in Logistics Engineering and Supply Chain Management – Chiang Mai University, Thailand. She earned a Bachelor of Economics (Bilingual Program) from Chiang Mai University, Chiang Mai, Thailand.

Apichat Sopadang is an Associate Professor at Industrial Engineering Department and a Head of Excellence Center in Logistics and Supply Chain Management (E-LSCM) Faculty of Engineering, Chiang Mai University. He received B.Eng. degree in Industrial Engineering, from Chiang Mai University, Thailand, an M.S. degree in Management of Technology School of Engineering, Vanderbilt University, USA, and a Ph.D. (Industrial Engineering) School of Engineering, from Clemson University, USA. His research interests include Supply Chain and Logistics Management, Multiple Criteria Decision Making, Performance Measurement, Risk Management, Lean System and Sustainable Supply Chain.