ComTech: Computer, Mathematics and Engineering Applications, 11(1), June 2020, 29-34 P-ISSN: 2087-1244
DOI: 10.21512/comtech.v11i1.5746 E-ISSN: 2476-907X

Analytical Hierarchy Process (AHP), Economic Order Quantity (EOQ), and Reorder Point (ROP) in Inventory Management System

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Received: 1st July 2019/ **Revised:** 8th October 2019/ **Accepted:** 29th October 2019

How to Cite: Lukiman, A. D., & Richard. (2020). Analytical Hierarchy Process (AHP), Economic Order Quantity (EOQ), and Reorder Point (ROP) in Inventory Management System. *ComTech: Computer, Mathematics and Engineering Applications, 11*(1), 29-34. https://doi.org/10.21512/comtech.v11i1.5746

Abstract **-** The research discussed the design of vendor selection features using the Analytical Hierarchy Process (AHP) method, inventory control using Economic Order Quantity (EOQ) method, and order notification using Reorder Point (ROP) method. The research aimed to find out the most appropriate time for procurement of goods, selection of vendors that fit the predetermined criteria and determine the number of items that had to be ordered within a period of time. Object-Oriented Analysis and Design (OOAD) method was used in building the system design. The sample of the research was a telecommunications service provider company. The result shows that by applying these three methods, the problems are overcome.

Keywords: Analytical Hierarchy Process (AHP), Economic Order Quantity (EOQ), Reorder Point (ROP), inventory management system

I. INTRODUCTION

Inventory is an important element for the company. The common problem that often occurs in managing inventory is the difficulties in determining the procurement time of goods, vendors, and the number of items that must be ordered.

Inventory can be stored and used by companies in a process carried out for specific purposes. Stevenson and Chuong (2014) said that inventory had several functions. The most important functions are to meet the customers' demand, facilitate production requirements, separate operations, prevent running out of inventory, take advantage of order cycles, prevent rising prices, allow operations, and take advantage of quantity discounts. Meanwhile, Handoko (2012) said that inventory was everything or organizational resources that were stored in anticipation of the fulfillment of requests.

Hasibuan (2015) mentioned that management was science and art regulating the process of utilizing human resources and other sources effectively and efficiently to achieve a certain goal. Moreover, Handoko (2012) agreed that management was the process of planning, organizing, directing, and supervising the efforts of members of the organization and the use of other organizational resources to achieve organizational goals that have been set.

According to Bateman and Snell (2014), management is a work process by using people and resources to achieve goals. Managers are capable of doing this effectively and efficiently. Effectiveness means achieving organizational goals. Meanwhile, efficiency means achieving organizational goals with minimal use of resources, namely using the possibility of time, material, money, and people. Based on Chen and Liu (2009), management is the intersection set of four disciplines, which are psychology, sociology, economics, and mathematics. Those majors are relevant disciplines of management.

According to Lancioni and Howard (1978), inventory management is very important in all fields of business. The lack of management can lead to serious problems in business processes. If it is not managed efficiently, there will be a possibility of delays in production, dissatisfied customers, or reduction of working capital. These problems can lead to potential pitfalls, from both cost and service perspective (Disney, Maltz, Wang, & Warburton,

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2016). In US, Morrice, Cronin, Tanrisever, and Butler (2016) built an inventory management model by combining the hurricane prediction and consumers' demand estimation. This example shows that inventory management is thoughtfully designed to ensure the sustainability of a company.

In the telecommunications industry, the inventory must be managed properly because it can affect the services provided to consumers. The common problem that often occurs in the telecommunications industry is the lack of inventory to be used. It occurs because there is no information about the procurement of goods at the right time. The problems in the procurement of goods are very important to deal with because it is one of the important parts of the company that can affect the company's business process. By knowing the right time to procure goods, the company will not experience shortages of goods, and the cost of storing goods is not high.

Related to the ordering process in inventory management, the number of items that must be ordered in one order becomes an important thing. If the company order too much, the cost of storing goods will increase. Meanwhile, the companies will experience shortages of goods that will disrupt the company's business process if the order number is not adequate. The problem of the determination process of the number of orders can be solved by using Economic Order Quantity (EOQ). According to Appadoo, Bector, and Bhatt (2012), EOQ is the most fundamental concept in making procurement policies that cover uncertainty risks in various estimated costs, such as transportation and ordering costs.

EOQ is used to determine the most economical number of orders within a certain time period. It is a method to minimize the sum of conflicting inventory costs (ordering cost and holding cost). With this method, the company tends to reduce its cost in managing inventory efficiently (Jawad, Jaber, & Bonney, 2015). According to Stevenson and Chuong (2014), EOQ is an order size that minimizes total annual costs. The basic model of EOQ involves several assumptions. First, only one product is involved. Second, annual demand is known. By utilizing EOQ, the company can minimize the cost related to the process of ordering and holding an inventory. This benefit can be a valuable tool for small business owners that need to decide with limited data. There are two most important categories of inventory cost. Those are ordering costs and carrying costs (Kumar, 2016).

In addition to the right time to procure goods, vendor selection is also one of the important aspects that must be considered in the procurement process. It is because the company can have many vendors for one type of goods. Inappropriate vendor selection can burden the company in terms of price, quality, and delivery time (Nagle, Fisher, Frazier, & McComb, 2018).

The selection of the right vendor can be done using Analytical Hierarchy Process (AHP). According to Al Qubaisi *et al*. (2016), AHP is a method of breaking down a complex and unstructured situation into its parts and arranging those parts, or variables into hierarchical order. Sivakumar, Kannan, and Murugesan (2015) used AHP to determine the evaluation of production outsourcing selection in the mining industry.

Analytic Hierarchy Process (AHP) is a general theory of measurement. Four types of measurement scales that are usually used are nominal, ordinal, interval, and ratio. Higher scale can be categorized into a lower scale, but not vice versa. Income scale per month can be categorized as an ordinal scale level or category (high, medium, and low) that is nominal in scale (Dweiri, Kumar, Khan, & Jain, 2016). Conversely, if at the time of measurement, the data obtained are categorical or ordinal, the higher scale data cannot be obtained. AHP overcomes some of these problems. AHP is a general theory of measurement used to find the best scale of ratio from discrete and continuous paired comparisons.

AHP is very suitable and flexible to determine decisions that help a decision-maker to make efficient and effective decisions based on all aspects. According to Setiawan (2009), there are two AHP types. First, the single criterion chooses one alternative with one criterion. Second, multi-criteria are decision making that involves several alternatives with more than one criterion and selects one alternative with many criteria. The basic concept of AHP is the use of pairwise comparison matrices to produce relative weights between criteria and alternatives. A criterion will be compared with another criterion in terms of how important it is to achieve the objectives.

Next, Reorder Point (ROP) determines the right time to make an order by paying attention to the needs of the company. It is the part of inventory control policy that can give the benefit for the organization to determine exact order amount from supplier. The main reason to apply ROP is to maintain the delivery lead times and uncertainties at the supply chain side (Sevgen & Sargut, 2019).

Moreover, Object-Oriented Analysis and Design (OOAD) is a method that checks the requirements of a class and object found in the scope of a problem. It leads to a software architecture based on the manipulation of system objects or subsystems. According to Satzinger, Jackson, and Burd (2011), OOAD defines all types of objects that do work in the system and displays what user interactions are needed to complete the entire task. OOAD defines all types of objects needed to communicate with people and various tools in the system. It shows how objects interact in completing tasks and perfecting definitions of each type of object. So, it can be implemented with a more specific language or environment.

OOAD is a powerful method for capturing and analyzing user requirements and designing the blueprint of an application. The analysis and design process is going through visual artifacts to define the software life cycle. Using OOAD, the software design will have better maintenance, reusability,

and modifiability (Pane & Sarno, 2015). It is commonly used in the analysis and design phase of software development. Therefore, some approach for verification and validation of OOAD results is applied to ensure that OOAD results are already compliant with users' needs. There are several techniques for verification and validation of UML diagrams (OOAD Results) that are used to perform a detailed examination of the design or requirement analysis developed by an analyst. The most popular technique is the use of a checklist that presents some list of verification derived from software quality standard, which is already given.

Based on the mentioned problem, the researchers want to design the vendor selection features using the AHP, inventory control using the EOQ, and order notification using ROP. The research aims to find out the most appropriate time for procurement of goods and selection of vendors that fit the predetermined criteria and determine the number of items that has to be ordered within a period of time.

II. METHODS

The methods applied in the research are library research and observation. Library research is conducted to collect data from books and journals as a theoretical basis. Moreover, observation is another method of data collection used to determine the company's business process and the use of inventory management applications in managing inventory. The method used can be seen in Figure 1.

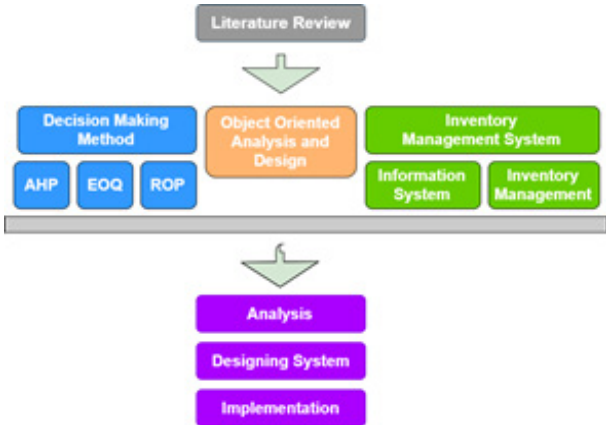

Figure 1 The Method used in this Research

The sample of the research is a telecommunication service provider company which is a client of a startup company engaged in information technology. Currently, the information technology startup is developing a web-based inventory management application that will be used by telecommunication service provieder company to manage all inventories. It starts from the procurement of goods, storage of goods to the use of goods owned. However, in the inventory management application of procurement module, it is still done manually so the users have trouble in ordering goods.

III. RESULTS AND DISCUSSIONS

The research simulates the calculation of AHP, EOQ, and ROP. The purpose of this simulation is to demonstrate AHP, EOQ, and ROP that will be applied to inventory management applications.

For AHP, this scenario will represents the calculation procedure used in the inventory management system. Telecommunication service provider company purchases fiber optic cables which are provided by three vendors. It wants to know the best vendors to order fiber optic cables based on the criteria of delivery time, price, and quality. It determines that quality is very important compared to price. Then, quality is more important compared to the delivery time. Last, delivery time is more important compared to price.

Furthermore, the inventory management application compares the data in the database to determine the best vendor. Delivery time comparison data is obtained from the difference in date of a purchase order with goods received. There are three results obtained. First, vendor A is slightly better than vendor B. Second, vendor C is better than vendor A. Third, vendor C is much better than vendor B.

For the price comparison data, there are several results of price of items in the database. First, vendor B is slightly cheaper than vendor A. Second, vendor B is much cheaper than vendor C. Third, vendor A is slightly cheaper than vendor C. moreover, the quality comparison data is obtained from item quality data in the received goods. The vendor B is better than vendor A. Then, vendor A is slightly better than vendor C, and vendor B is much better than vendor C.

The next step in the AHP calculation is a calculation table. In creating the matrices, it should be considered if it is compared with the same value, it is given a value of 1 or equally important. For example, delivery time is compared. The value is 1. In giving weights, the researchers must compare the rows and columns. For example, the price is 5. If the weight of the delivery time to the price is 5, the weight of the price of the delivery time is 1/5 or 0,200. After filling in all the data in the table, the data from each column must be added together. Table 1 shows the comparison criteria.

Table 1 Comparison Criteria

	DT	P	Q
DT	1,000	5,000	0,200
P	0,200	1,000	0,143
Q	5,000	7,000	1,000
Total	6,200	13,000	1,343

Note: Delivery Time (DT), Price (P), and Quality (Q)

Then, the researchers will create a normalization table. In Table 2, the researchers also calculate eigenvector from each line of criteria. The eigenvector is the result of calculating the average of the ratings. It can be calculated by summing all rows and dividing by the number of rows. For example, to calculate eigenvector from delivery time, it is (0,161 + 0,385 + 0,149) / 3.

Table 2 Normalization Criteria

	DT	P	Q	EV
DT	0,161	0,385	0,149	0,232
P	0,032	0,077	0,10	0,072
Q	0,806	0,538	0,745	0,697
Total	1,000	1,000	1,000	1,000

Note: Delivery Time (DT), Price (P), Quality (Q), and Eigenvector (EV).

In Table 3, a comparison is made with the delivery time by vendors to the company. The data shown is based on vendors' weight data on predetermined criteria. The research is able to know the fastest delivery time. In this case, vendor C is the best choice in delivery time.

Table 3 Delivery Time Criteria

	A	B	C
A	1,000	3,000	0,200
B	0,333	1,000	0,143
C	5,000	7,000	1,000
Total	6,333	11,000	1,343

Table 4 is a normalization table from the delivery time. Based on Table 4, the researchers can get eigenvectors from the weighting criteria of delivery time from each vendor. It shows that the vendor C is the best option related to delivery time with the weight of 0,724 or 72,4%. Meanwhile, vendor A has the weight of 0,193 or 19,3%. Then, the weight of vendor B is slightly worse than vendor A with 0,083 or 8,3%.

Table 4 Normalization of Delivery Time

	A	B	C	EV
A	0,185	0,273	0,149	0,193
B	0,053	0,091	0,106	0,083
C	0,789	0,636	0,745	0,724
Total	1,000	1,000	1,000	1,000

Note: Eigenvector (EV)

In Table 5, the price comparison of goods is provided by the vendor. The data are based on vendors' data that has been predetermined. Table 5 shows the best price from the vendor. In this case, vendor B is the best choice in the product price.

Table 5 Price Criteria

	A	B	C
A	1,000	0,333	3,000
B	3,000	1,000	7,000
C	0,333	0,143	1,000
Total	4,333	1,476	11,00

Table 6 is the normalization table of price criteria by vendors. The researchers get eigenvector of goods price goods from each vendor. Table 6 shows that the vendor B is the best option related to the product quality with the weight of 0,669 or 66,9%. Moreover, vendor C has the weight of 0,088 or 8,8%. Then, the weight of vendor A is slightly better than vendor C with 0,243 or 24,3%.

Table 6 Normalization of Price

	A	B	C	EV
A	0,231	0,226	0,273	0,243
B	0,692	0,677	0,636	0,669
C	0,077	0,097	0,091	0,088
Total	1,000	1,000	1,000	1,000

Note: Eigenvector (EV)

Table 7 shows a comparison of the quality of goods from vendors. It is based on vendors' data on the predetermined criteria. Based on Table 7, the researchers know the best quality goods. In this case, vendor B is the best in terms of goods quality.

Table 7 Quality Criteria

	A	B	C
A	1,000	0,200	3,000
B	5,000	1,000	7,000
C	0,333	0,143	1,000
Total	6,333	1,343	11,000

Table 8 is a normalization table of the price criteria of goods by vendors. It shows that the vendor B is the best option related to the product quality with the weight of 0,724 or 72,4%. Then, vendor C has the weight of 0,083 or 8,3%. However, the weight of

vendor A is slightly better than vendor C with 0,193 or 19,3%.

Table 8 Normalization of Quality

	A	B	C	EV
A	0,185	0,149	0,273	0,193
B	0,789	0,745	0,636	0,724
C	0,053	0,106	0,091	0,083
Total	1,000	1,000	1,000	1,000

Note: Eigenvector (EV)

After the calculation of eigenvector from delivery time, price, and quality for the vendors A, B, and C, the next step is the calculation between the EV to determine. It is to see the best option in vendor selection. The calculation is shown as follow:

$$\begin{bmatrix} 0,193 & 0,243 & 0,193 \\ 0,083 & 0,669 & 0,724 \\ 0,724 & 0,088 & 0,083 \end{bmatrix} \times \begin{bmatrix} 0,232 \\ 0,072 \\ 0,697 \end{bmatrix} = \begin{bmatrix} 0,197 \\ 0,571 \\ 0,232 \end{bmatrix} \quad (1)$$

The rows in matrices shows vendors A, B and C in sequence from the top to bottom. The result from the matrix multiplication shows that vendor B has the highest weight with 0,571 or 57,1%. Meanwhile, vendor A has the value of 0,197 or 19,7%. Then, vendor C is with 0,232 or 23,2% value. Therefore, vendor B is the best option for the company.

In EOQ and ROP calculation, the company must manage its inventory so the company can operate properly. It will not burden the company with the cost of storing goods that are too large. Inventory in the company is a large quantity of fiber optic cable. The use of fiber optic cable from January to June 2018 is 31,8 km. From June to December 2018, it is 42,5 km. So, the total installation until the end of 2018 is 74,3 km. It can be estimated that the use of fiber optic cables in 2019 is 37,15 km. The price of 100 m of fiber optic cable is Rp1.500.000,00, and the cost of each order is Rp200.000,00. Then, the percentage of storage costs is 30% of the unit price of goods in each order. It requires a waiting time or lead time of two weeks. The company determines the safe stock of fiber optic cable is 700 m. Currently, the company requires a plan to procure inventory with economic value.

To calculate the EOQ, the storage costs are needed. To find storage costs, the researchers use the equation with Storing Cost (*H*), Transaction Cost (*S*), and Percentage of Storing Cost (*h*) as follows:

$$H = \frac{S}{12} \times h \quad (2)$$

It is known that S is Rp1.500.000,00, and h is 10%. Thus, referring to Equation (2), the result is:

$$H = \frac{1.500.000}{12} \times 10\% = 37500$$

Then, for EOQ, the researchers use the following equation. The D is demand.

$$EOQ = \sqrt{\frac{2 \times S \times D}{H}} \quad (3)$$

It is known that S is Rp200.000,00. Then, D is 37,15 km or 37150 m, and H is Rp37.500,00. The result is as follows:

$$EOQ = \sqrt{\frac{2 \times 200.000 \times 37150}{37.500}}$$

$$EOQ = \sqrt{\frac{14.860.000.000}{37.500}}$$

$$EOQ = \sqrt{396266,666}$$

$$EOQ = 629,49 \text{ m}$$

The most economical order is 629,49 m for every time the company makes an order. Because each unit of fiber optic cable is 100 m in length, the rounding will be done. So, the result is 600 m.

For ROP calculation, the researchers use the following equation:

ROP = average usage x lead time + safety stock (4)

From the data, the average usage is 3.096 m/ month. Then, the lead time is two weeks (0,461 month), and SS is 700 m. It can be calculated as follows:

$$ROP = 3096 \times 0,461 + 700 = 2.127,256\ m$$

Thus, it can be concluded that the goods must be ordered when the fiber optic cable reaches 2.127,256 m.

The AHP method has been implemented by some researchers to solve vendor selection problems. This method is to find the best vendor by including some important factors in the analysis process. The results show the best selection among the available vendors based on some important factors.

There are results from the running system analysis. First, ROP in inventory management can calculate the exact time to place an order. Second, the AHP in inventory management can provide the best vendor recommendations based on criteria determined by the users. Third, the EOQ in inventory management can perform calculations and provide

recommendations regarding the most economical number of orders by considering the company's needs.

IV. CONCLUSIONS

Based on the analysis of the current system, it is known that the user of inventory management application has difficulties in carrying out the work. It is difficult to determine the best order time because the user must check manually. Improper checking will lead to inaccurate data. It will affect the company's business processes that are running. Moreover, it is challenging to choose vendors because of the many types of goods and vendors that the company has. Then, it is also difficult to determine the most economical number of orders. If the company is wrong in placing an order, it will affect the business processes. With the use of AHP, ROP, and EOQ, the problems can be solved.

For future research, it is recommended to build an expert system that can be embedded in the current system used in Small Medium Enterprise (SME). The expert system will help the SME owners to determine the reorder value of each item in their inventory. With this system, the SME should cut the cost in managing inventory and increasing more efficiency in the inventory management process.

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