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Early Warning System for Inventory Management using Prediction Model and EOQ Algorithm

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Abstract

An early warning system was developed to help identify stock status as early as possible. For performance to improve, there needs to be a feature to predict the amount of stock that must be provided and a feature to estimate when to buy goods. This research was conducted to improve the inventory early warning system and optimize the Reminder Block's performance in minimum stock settings. The models used in this study are the single exponential smoothing (SES) method for prediction and the economic order quantity (EOQ) model for determining the quantity. The research was conducted by analyzing the Reminder Block in the early warning system, identifying data needs, and implementing the SES and EOQ mathematical models into the Reminder Block. This research proposes a new Reminder Block that has been added to the SES and EOQ models. It is hoped that this study will help in obtaining accurate information about the time and quantity of repurchases for efficient inventory management.

Index Terms: Early warning system, Inventory management, Economic order quantity (EOQ), Prediction model, Single exponential smoothing (SES)

I. INTRODUCTION

Inventory management requires good and effective handling [1-3]. Problems that often occur are delays in procurement and the occurrence of over procurement. This makes inventory inefficient because it can depreciate cost management. In contrast, under-procurement possesses the risk of running out of stock when there is an increase in demand for goods [4].

Inventory control is thus important and must be supported by systems and technology to be effective and efficient. The concept of early warning is considered to be one of the important components in supply management [5]. This concept is used to design a system that can help identify or recognize the status and symptoms in inventory management. However, with the increasing complexity of supply chains and higher frequency of entry and exit of goods, developing an early warning system requires identifying the symptoms of non-ideal stock conditions.

Thus, this study used the concept of single exponential smoothing (SES) prediction to solve the aforementioned problem [6, 7]. In addition, to help optimize the number of items that must be ordered, the economic order quantity (EOQ) method [8, 9] was also used.

The proposed early warning system model adopts an early warning system framework for inventory management systems in vehicle repair shops [5]. The model is divided into four main blocks [5]: Monitoring Block, Condition Mapping

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block, Reminder Block, and Evaluation Block. The SES prediction method supports the Reminder Block to generate current inventory status information. In contrast, the EOQ method generates the proposed number of goods to be purchased [10]. This information gets stored in a database table and is used for generating warning information. With this research, it is hoped that the user finds the optimal solution while trying to determine the number of purchases and the gap before repurchase. It is expected that this is help reduce the cost of inventory.

The structure of this paper is as follows: Section II presents the system model and method. Section III describes the research methodology. Section IV describes the research results. Section V presents the discussion and conclusions.

II. SYSTEM MODEL AND METHODS

A. Inventory Concept

Inventories are material deposits that can include raw materials, work in progress goods, and finished goods. From a business point of view, inventory is the capital investment needed to store material under certain conditions [11].

Inventory includes goods stored by the company with the intent to sell during a normal business period, goods that are still in work or production process, or the basic raw materials to be used later in a production process [12].

B. EOQ Concept

EOQ is a method used to obtain several goods with minimum cost and reduction in ordering and carrying costs [13]. EOQ is the number of goods that can be purchased at a minimum inventory cost; it is often called the optimal order quantity [14].

C. Prediction/SES Concept

Prediction is a method to forecast the future requirement using past data with the help of a systematic model [15]. The prediction model commonly used in forecasting is Time Series, and SES is the most commonly used forecasting method.

According to Pakaja [16], Exponential Smoothing is a sophisticated weighted moving average forecasting method but is still easy to use. This method requires very little past data logging.

D. Early Warning System for Inventory Management

An early warning system has certain elements designed to provide immediate warning of a condition that is considered dangerous or may cause problems in the future. Early warning systems can also help identify beneficial community developments and manage organizational risks [17].

Based on previous studies, early warning system can be considered to be constituted of four main blocks, namely:[5] 1) Monitoring Block, 2) Condition Mapping Block, 3) Reminder Block, and 4) Evaluation Block. The adopted model is shown in Fig. 1.

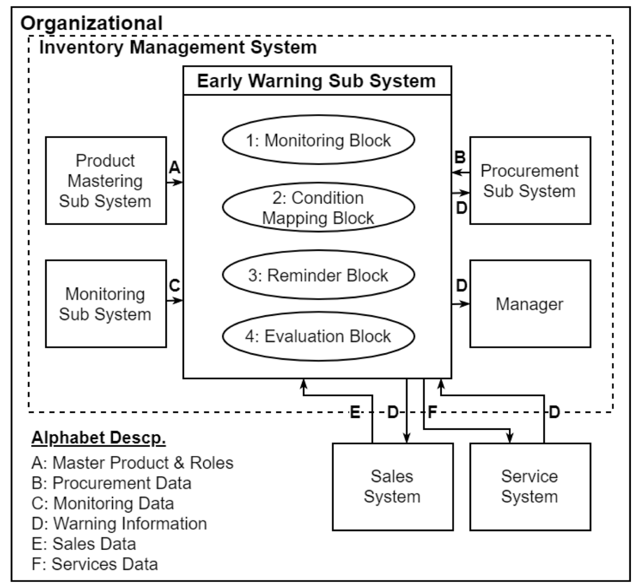

Fig. 1. Early Warning System Models for Inventory Management [5].

These blocks are described below: [5]

1) Monitoring Block

Monitoring is carried out to obtain existing facts using technology, where technology acts as a detector. Existing facts are then combined and processed, and any discrepancies or unfulfilled conditions become symptoms.

2) Condition Monitoring Block

The previously obtained symptoms are then processed to avoid the dangers and consequences caused according to the existing classification. This classification is carried out based on the conditions that will determine the warning type.

3) Block Reminder

Through Block Reminders, this system generates warnings that are given to recipients according to the conditions and types of warnings. Then the condition and type of warning are stored as reference data that will be used in the next warning.

4) Evaluation Block

This system evaluates past warnings and historical data to understand the effectiveness of warning results and to reduce the risk of recurring problems in the activities carried out.

III. RESEARCH METHODOLOGY

The methodology of this research is as follows:

A. Problem Identification

Identified problem statements:

- How to optimize the role of the early warning system for inventory management?
- How SES and EOQ can contribute to optimizing the role of early warning systems for inventory management
- What kind of prediction model is built and what are its components?

The objective is to generate a predictive model that can be used to optimize the role of the early warning system for inventory management in determining inventory status as well as effective purchase quantities. The model shows the need for input data, calculation processes, and outputs, and the knowledge base stored in the model in question.

B. Data Collection

1) Field Study

To support the analysis and system design phase, data were collected from the research organization and its environment. The data collection stage consisted of interviews with the authorities at the research site or direct observation of the system employed in the organization.

2) Study of literature

A search and comparison of references obtained from books, scientific journals, and e-books are carried out on the internet to obtain theories relevant to the problems that have been identified and align with the objectives of the project.

C. Analysis

An analysis is carried out to determine system requirements, identify running systems and identify data needed by the system and information generated by the system in the data collection stage. The analysis stage consists of the following:

1) Early Warning System Analysis

This stage is carried out to analyze the need for a prediction model applied to an early warning system for inventory management. The analysis is carried out on an existing model [5].

2) Analysis of Prediction Model from Inventory Management

This stage is carried out to analyze the relevant factors used in the SES and EOQ models to be applied to the early warning system. The factors in question include input data, formulas, and constants used.

D. Prediction Model Design

At this stage, a prediction model is designed for an early warning system that uses the concepts of SES and EOQ, by including some components such as input, process, output, storage, and the mechanism used.

E. Conclusions & Suggestions

At this final stage, conclusions are made, and suggestions for further research are discussed.

IV. RESULTS

The design of the proposed prediction model for the early warning system is presented in Fig. 2.

The EOQ Sub-block (3.1) plays a role in providing accurate calculation data regarding the number of goods to be purchased and when procurement activities must be carried out. A procurement system supports the EOQ Sub-block in obtaining purchase history and supplier performance. The EOQ Sub-block also obtains historical data of entry and exit of goods from the monitoring system. Purchase history and supplier performance are stored in a knowledge database.

The SES Sub-block (3.2) acts as a component that provides data about the estimated time an item will run out. This sub-block is supported by data from the monitoring and product mastering systems, which provide roles and KPIs.

Prediction/forecasting is done using the SES method, which follows mathematical and statistical rules for showing the relationship between demand and one or more variables that affect it in a certain historical data period. Quantitative forecasting assumes that the degree of closeness, type of relationship between the independent variable, and demand that occurred in the past will be repeated in the future. Forecasting results are stored in a knowledge database so that they can be retrieved and updated.

Information Submission (3.3) sends and delivers information to parties in need, such as warehouse managers, sales, procurement, or service systems. Information is received from the Knowledge Repository previously formed by sub-blocks 3.1 and 3.2.

The Knowledge Repository is a database that stores processed data from the SES (3.1) and EOQ (3.2) processes. The stored data is used by Information Submission to be dis-

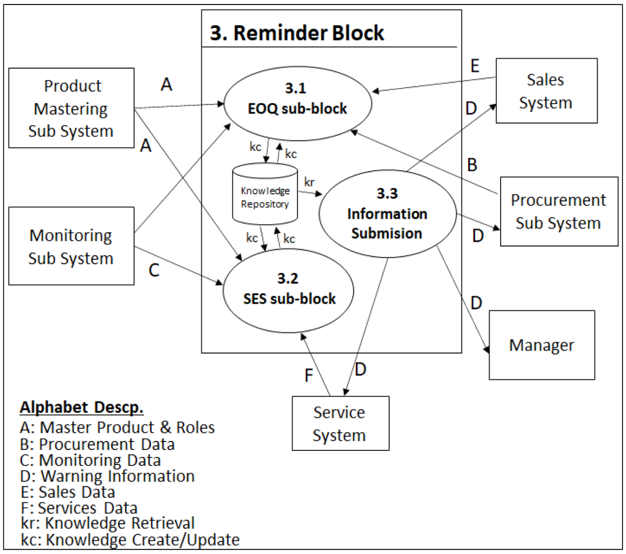

Fig. 2. Reminder Block.

tributed to those in need. The database is built with a relational model adapted to existing technological developments.

A. EOQ Sub-block

EOQ is a method used for the amount of inventory obtained at minimal cost or the optimal number of orders.

EOQ can be applied, assuming the following:

- Know with certainty the level of demand for each item.
- Know with certainty the cost of storage, price per unit.
- Know with certainty the cost of ordering.

1) EOQ Approach

The mathematical formula for EOQ is represented as follows:

$$EOQ = \sqrt{\frac{2 \times D \times S}{H}}. \quad (1)$$

Where:

EOQ = quantity of goods ordered
D = number of goods needed per year
S = cost of ordering/purchasing goods per unit
H = storage cost per unit

2) EOQ Algorithm

This section provides the algorithm of the EOQ method, as shown in Fig. 3.

3) Simulation Example

Given Information:

EOQ will be calculated for Item X1

- Number of sales in 1 year (D) = 27.756 unit
- Booking fee (S) = Rp 185.285

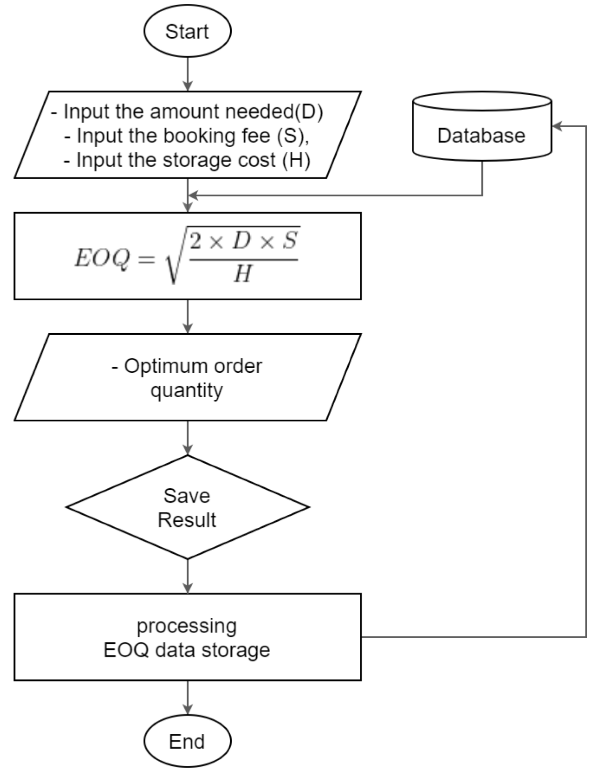

Fig. 3. EOQ Algorithm.

- Storage fee (H) = Rp 56.585

Explanation:

a) Number of sales of Item X1 per year
This can be calculated from sales transactions obtained from the sales system.

b) Booking fee
It is obtained from the system of purchasing goods. Items that can be included in the ordering fee include shipping costs, telephone costs, loading and unloading costs, taxes, etc.

c) Storage fee
Storage costs are usually obtained by calculating the percentage of inventory value in a year multiplied by the constant of the investment value.
Storage cost data can be obtained from the inventory management system.

Then the EOQ value obtained for item X1 is:

$$EOQ = \sqrt{\frac{2 \times 27756 \times 185285}{56585}}. \quad (2)$$

EOQ = 426 units, i.e., 426 units of goods X1 must be ordered in the next period.

If there are many items, this process is carried out for only some items to determine how many orders are in the next period.

Table 1. Example of Calculation Results for n items

No	Product Item	Unit	EOQ	Order Frequency
1	Item X1	Box	426	65
2	Item X2	Box	147	85
3	Item X3	Pcs	258	19
4	Item X4	Pcs	111	21
5	Item X5	Pcs	16	23

B. Prediction/SES Sub-block

The SES method is included in the Time Series approach, which uses past data to predict future events. SES is a forecasting method that exponentially weighs past data in a way that the most recent data has a greater weight or scale. This SES method can be incorporated and implemented into an information system.

1) SES Approach

Generally, the forecast value is calculated as follows:

$$S_{t+1} = \alpha X_t + (1 - \alpha)S_t. \quad (3)$$

Where:

S_{t+1} = forecast value for the next period
α = smoothing constant ($0 < \alpha < 1$)
X_t = new data or actual value of X in period t
S_t = long smoothing value or smoothing average up to period t-1

2) Mean Absolute Deviation (MAD)

Results of the forecasting method can be evaluated using the number of absolute errors. Mean absolute deviation (MAD) measures the accuracy of the forecast by averaging the prediction error (absolute value of each error). MAD is useful when measuring forecast error in the same units as the original series.

The MAD value can be calculated as follows:

$$MAD = \frac{\Sigma_t^n = 1|X_t - F_t|}{n}. \quad (4)$$

Where:

X_t = actual data in period t
F_t = forecast value in period t
n = amount of data
α = Value Assignment

The SES method requires an alpha (α) value as a smoothing parameter value. A higher α value is assigned to newer data to provide an optimal forecast with the smallest error value. The right value is generally obtained by trial and error to determine the lowest error value. The value of α is obtained by comparing values within a smoothing interval between $0 < \alpha < 1$, namely (0.1 to 0.9).

4) SES Algorithm

This section provides the algorithm of the SES method, as shown in Fig. 4.

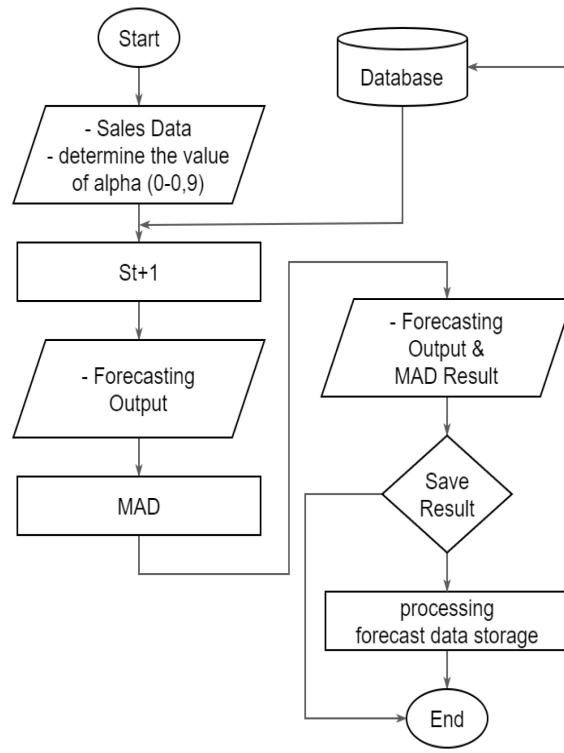

Fig. 4. SES Algorithm.

5) Simulation Example

The SES formula is tested on actual sales data to see how it works and obtain the appropriate α value. Examples of sample data are presented in Table 2.

Table 2. Sample Data for Simulation

Period	Data Actual	α = 0,1		α = 0,9	
		S_{t+1}	MAD	S_{t+1}	MAD
Jan-20	15861	15861	0	15681	0
Feb-20	20582	16333,1	4249	20110	472
Mar-20	13584	16058,19	2474	14237	653
Apr-20	16748	16127,17	621	16497	251
May-20	17285	16242,95	1042	17206	79

The data has been simulated for α = 0.1 and α = 0.9; the smallest deviation value was sought using the MAD formula. As seen in Table 2, the smallest MAD value was obtained for May 2020 at α = 0.9. Forecast value used for the next period is at α = 0.9.

From these results, it is predicted that there will be sale of 17206 units in May 2020.

C. Reminder Block Environment

There are six external entities included in the scope of Reminder Sub-block. Each external entity contributes to the provision of data for the Reminder Block or obtains information from the Reminder Sub-block.

From the relationships in the Reminder Block, it can be seen that the Product Mastering Sub-system contributes to two blocks, 3.1 and 3.2, similar to the Monitoring Sub-system.

In case of the Manager, only the concerned person receives information from block 3.3. In contrast, the Service System, Sales System, and Procurement Sub-system play a role in supporting data for Block Reminders and benefiting from Block Reminders.

Service System relates to sub-blocks 3.2 and 3.3, namely SES Sub-block and Information Submission. Sales System is related to sub-blocks 3.1 and 3.3, i.e., EOQ Sub-block and Information Submission. The same is true for the Procurement Sub-system, which is related to sub-blocks 3.1 and 3.3.

A detailed description of the role and contribution of each external entity can be seen in Table 3 below. Table 3 is divided into two main explanation columns, namely "external related entities" and "role and contribution". The role and contribution column explains the role of each external entity, both in providing data and in obtaining information.

Table 3. Role of External Entity

No	External Entity	Role and Contribution
1	Product Mastering Sub System	A system that provides performance indicators as financial or non-financial metrics is used to help organizations determine and measure progress against inventory management goals.
2	Procurement Sub System	A *procurement information system* has the authority to procure goods that are directly related to suppliers. The order provides purchase history data and supplier performance data.
3	Monitoring Sub System	An inventory monitoring information system exercises authority in monitoring the conditions of inventory and the conditions required for storage of goods.
4	Service System	Service system includes goods repair systems or other systems that get information about the optimization of inventory conditions.
5	Sales System	Sales systems include systems that get information about the optimization of inventory conditions.
6	Manager	The manager is the company owner who receives a warning report that the early warning system has created. Its main task is to control the management and procurement of goods.

V. CONCLUSIONS & SUGGESTIONS

A. Conclusions

An early warning system model is designed to assist companies in carrying out inventory management activities. The model is made with a pilot approach using existing models. The EOQ & SES models provide a more accurate solution regarding the number and time of current purchases of goods. This model was created to improve the ability of Reminder Sub-block. The addition of the prediction feature is expected to help reduce the time interval between generating warning information and running high inventory usage operations. With the prediction method, the time and quantity of goods to be procured can be identified. This research consists of a thought model or framework that can be developed into a detailed technical information system.

According to theory, the EOQ and SES models can provide forecasts for the next period and are only suitable for data containing stationary elements, which is appropriate to deliver the objectives of the current research. The method used is suitable because, in the case raised [5], it has stable characteristics, and does not contain data in the form of trends. Additionally, this exponential method also provides a relatively higher weight to the latest observation values than the previous period's values [10].

B. Suggestions

Future research prospects should include building more detailed information systems, including requirements analysis, specifications, logical design, physical design, and implementation activities. A more complex inventory with a large variety of items and a high frequency of item issuance transactions can be proposed to build EOQ using genetic algorithms. The EOQ algorithm should also be developed by including the formula for safety stock and maximum stock.

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