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Optimization Of Packing Material Inventory Using ABC Analysis, Forecasting Methods, and Economic Order Quantity

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***Abstract*—Inventory management of packing materials in the flexible packaging industry often faces high investment value, inaccurate demand planning, and inefficient ordering quantities. This study aims to determine material priorities and optimal order quantities to minimize total inventory costs through an integrated approach. The methodology combines ABC Analysis for material classification, forecasting methods (Simple Average, Moving Average, Weighted Moving Average, and Single Exponential Smoothing) to predict demand, and Economic Order Quantity (EOQ) to determine optimal purchasing quantities. The results show that PLY material is categorized as class A with an investment contribution of 64.53%. Among forecasting methods, the 3-period Weighted Moving Average provides the best accuracy with the lowest MAPE value of 15.81%. EOQ calculations indicate optimal order quantities of 15,849 units for Plywood Multi 0280x0280x09 dia 77 and corresponding optimal quantities for other PLY materials. The integration of ABC, forecasting, and EOQ improves inventory efficiency and supports more reliable production planning.**

***Keywords* : ABC Analysis; Demand Forecasting; Economic Order Quantity; Inventory Management.**

I. INTRODUCTION

The flexible packaging industry requires effective inventory control to prevent stock shortages and overstock conditions, maintain production continuity, reduce operational costs, and ensure stable supporting material flow. Proper inventory management contributes significantly to manufacturing efficiency, operational sustainability, and supply chain resilience, as highlighted in studies on stock management and sustainable manufacturing practices [1],[2].

One of the commonly applied approaches to determine material control priorities is ABC analysis [3]. This method classifies materials based on their investment value and consumption level, enabling companies to focus on category A items that contribute the largest portion of total inventory value. Several studies conducted by [4], [5] and [6] demonstrate that ABC classification effectively identifies critical materials requiring stricter monitoring. Furthermore, the application of ABC analysis has been proven to reduce waste and improve procurement planning efficiency [1]. Research by [7] confirms that accurate classification minimizes the risk of high-value material shortages, while [8] emphasize the importance of sufficient inventory levels to maintain smooth production flow.

In addition to classification, companies must accurately forecast material demand to support timely procurement decisions. Various studies indicate that forecasting methods such as Moving Average, Weighted Moving Average, and Single Exponential Smoothing are capable of representing demand patterns based on historical data [9]. Research by [10] shows that Weighted Moving Average and Exponential Smoothing methods provide competitive prediction results compared to simpler techniques. These findings are supported by [11], who reported a MAPE value of 14.539%, and by [12], who obtained an RMSE value of 368617.362 using the Weighted Moving Average method.

Further studies by [13], [14], [15] strengthen the evidence that quantitative forecasting approaches improve demand prediction accuracy, particularly under fluctuating demand conditions. [16] emphasize the importance of selecting the most appropriate forecasting method in a Moving Average-based system. Meanwhile, [17] demonstrate that the Single Exponential Smoothing method achieved a MAPE value of 5.481%, indicating high forecasting accuracy. Similar conclusions are reported by [18], and further supported by [19] and [20], who state that accurate forecasting supports more efficient procurement strategies. Additionally, [21] assert

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that precise demand estimation enables companies to avoid excessive stock accumulation while ensuring material availability according to production needs.

After demand estimation, companies must determine the optimal order quantity. The Economic Order Quantity (EOQ) model is widely used to estimate the ideal purchasing quantity at minimum total cost [22]. Research by [23] indicates that EOQ implementation significantly reduces holding and ordering costs. According to [24], mathematical inventory models help companies understand material consumption patterns and determine the most efficient ordering frequency. Similar findings are reported by [7] and [15], who conclude that EOQ supports procurement stability and reduces reliance on urgent and costly emergency orders.

Several researchers have explored the integration of classification, forecasting, and optimal ordering methods. [25] reveal that effective inventory management is strongly influenced by the integration of these approaches. [26] demonstrate that combining forecasting, ABC analysis, and EOQ improves material control accuracy and inventory turnover. The approach was further enhanced using Fuzzy AHP to improve classification decision quality [26]. Moreover, [27] show that ABC integration provides more cost-oriented procurement prioritization, while [28] propose the ABC–XYZ and service-level combination to enhance safety stock determination accuracy.

From a technological perspective, [29] integrate Big Data analytics with ABC, forecasting, and EOQ to improve productivity and stock availability. Similarly, [30] combine machine learning, lean logistics, ABC, and EOQ to enhance inventory efficiency in the automotive accessories industry. However, most of these studies were conducted in different industrial contexts and have not specifically addressed the integrated application of ABC, forecasting, and EOQ in the flexible packaging sector.

Moreover, previous studies generally apply ABC, forecasting, or EOQ separately. In industrial practice, these three methods are interrelated: ABC determines priority materials, forecasting predicts the demand of priority items, and EOQ calculates the most economical purchasing quantity. The limited number of studies integrating these three methods comprehensively creates a significant research gap, particularly in the flexible packaging industry, which is characterized by high material variation and strong dependency on stock stability [31].

Based on this research gap, this study proposes a novelty in the form of integrating three methods: (1) ABC analysis to determine material priority based on investment value, (2) selection of the most accurate forecasting method among several alternatives, and (3) application of EOQ to determine the optimal purchasing quantity. Packing materials are selected as the research object because they possess relatively high investment value and directly affect production continuity in flexible packaging operations [32]. Therefore, the objectives of this study are:

1. To identify material priorities using ABC analysis.
2. To determine the most accurate forecasting method for predicting material demand.
3. To calculate the optimal order quantity using the Economic Order Quantity (EOQ) method to minimize inventory cost and improve material planning efficiency in the flexible packaging industry.

II. RESEARCH METHODOLOGY

This study employs a quantitative descriptive approach to optimize packing material inventory in the flexible packaging industry. The research integrates three analytical methods: ABC analysis, demand forecasting, and Economic Order Quantity (EOQ). The integration of classification, forecasting, and optimal ordering models is considered essential to improve inventory effectiveness and cost efficiency, as emphasized by [25] and [26].

A. Research Design

The research follows a sequential analytical framework. First, ABC analysis is applied to classify packing materials based on their annual investment value. Second, forecasting methods are evaluated to determine the most accurate demand prediction model for category A materials. Finally, the EOQ model is used to calculate the optimal purchasing quantity.

This structured approach aligns with the concept that inventory control should prioritize high-value items before determining demand patterns and economic order quantities [3], [4]. The integration of forecasting and EOQ is further supported by [7], who highlight the importance of combining demand estimation with optimal

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purchasing strategies.

B. Data Collection

The data used in this study consist of:

1. Historical usage data of packing materials from January to August 2024.
2. Annual investment value of each packing material category (FIT, PLY, and CB).
3. Ordering cost per order.
4. Holding cost per unit per year.

The data were obtained from company documentation records and internal operational reports. Forecasting calculations were conducted using WinQSB software and manually verified using Microsoft Excel to ensure computational accuracy and reliability.

C. ABC Analysis Procedure

ABC analysis was conducted to classify packing materials according to their contribution to total annual investment value. The method is based on the Pareto principle, which states that a small proportion of items contributes to the majority of total inventory value [3].

The classification procedure involved:

1. Calculating total annual investment value for each packing material.
2. Computing the percentage contribution using:

$$\textit{Investment (\%)} = \frac{In \quad V \quad o \quad M}{T \quad In \quad V} x100\% \qquad (1)$$

3. Sorting materials from highest to lowest investment value.
4. Grouping materials into:
   - Category A (approximately 70–80% of total investment value),
   - Category B (15–25%),
   - Category C (5–10%).

This classification approach is consistent with previous applications of ABC analysis in inventory control studies [4], [5].

D. Forecasting Methods

Demand forecasting was performed on category A material, namely Plywood Multi 0280x0280x09 dia 77. Several quantitative forecasting methods were evaluated to determine the most accurate prediction model.

1. Simple Average (SA)

The Simple Average method calculates the arithmetic mean of historical demand data. This method is suitable for relatively stable data patterns and is commonly used as a baseline forecasting model [10].

2. Moving Average (MA)

The three-period Moving Average method was applied to smooth short-term fluctuations and provide a more stable demand estimate [9]. However, previous research indicates that MA may be less accurate under highly fluctuating demand conditions [33], [34].

3. Weighted Moving Average (WMA)

The Weighted Moving Average method assigns different weights to historical observations, giving greater emphasis to recent data [35], [9]. In this study, weights of 0.2, 0.3, and 0.5 were applied to represent increasing relevance of recent demand data.

4. Single Exponential Smoothing (SES)

Single Exponential Smoothing was applied using a smoothing constant $\alpha = 0.8$. A higher alpha value increases responsiveness to recent demand changes, which is suitable for fluctuating data patterns [12], [14].

Forecasting performance was evaluated using standard error indicators:

- Mean Squared Error (MSE)
- Mean Absolute Deviation (MAD)
- Mean Absolute Percentage Error (MAPE)
- Cumulative Forecast Error (CFE)
- Tracking Signal

The use of MAPE and error tracking indicators to assess forecasting accuracy is consistent with previous empirical studies [11], [17]. The forecasting method with the lowest MAPE value and acceptable tracking signal was selected for further EOQ calculation.

E. Economic Order Quantity (EOQ) Model

After selecting the most accurate forecasting method, the EOQ model was applied to determine the optimal purchasing quantity. The EOQ model minimizes total inventory cost by balancing ordering cost and holding cost [22].

The EOQ formula is expressed as:

$$EOQ = \sqrt{\frac{2E}{H}} \qquad (2)$$

where:
D = Annual demand
S = Ordering cost
H = Holding cost per unit

The effectiveness of EOQ in reducing total inventory cost and improving procurement stability has been demonstrated in previous studies [23], [24], [15].

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F. Research Framework

The research framework can be summarized as follows:

Inventory Data → ABC Classification → Selection of Category A Material → Forecasting Model Comparison → Selection of Best Forecast → EOQ Calculation → Inventory Optimization.

This integrated framework is consistent with the findings of [25] and [26], who emphasize that combining classification, forecasting, and optimal ordering methods produces more effective inventory control decisions.

III. RESULTS AND DISCUSSION

A. ABC Analysis Results

ABC analysis was conducted to classify packing materials based on inventory control priority by considering their annual investment value [4], [3]. In this study, three types of packing materials FIT, PLY, and CB were analyzed using the number of items and total annual investment value the ABC classification results are presented in Table 1.

Table 1. ABC Classification of Packing Materials

Packing Material	Item PM	Item PM (%)	Nilai Investasi (Rp)	Nilai Investasi (%)	Keterangan
ply	193	39.07%	765.432.560	64.53%	A
cb	225	45.55%	2.986.575.430	18.94%	B
fit	76	15.38%	876.543.675	16.54%	C
TOTAL	494	100	4.628.551.665	100	

ABC analysis shows:

- PLY: 64.53% investment value → Category A
- CB: 18.94% → Category B
- FIT: 16.54% → Category C

The results indicate an unequal distribution of investment value among materials. PLY accounts for 39.07% of total items but contributes 64.53% of total inventory investment value, placing it in category A. CB and FIT fall into categories B and C respectively, as their contribution to total investment is significantly lower relative to item quantity. This distribution reflects the Pareto principle, where a relatively small proportion of items represents the majority of financial value. The high contribution of PLY is influenced by its higher unit cost and consumption rate in production activities. Therefore, financial risk is concentrated on this category, requiring stricter monitoring, tighter procurement scheduling, and more accurate demand forecasting.

These findings are consistent with previous studies stating that selective control of high-value items significantly improves inventory efficiency and cost effectiveness [4]. Effective ABC classification enables companies to allocate managerial attention proportionally according to financial impact.

B. Forecasting Analysis

Forecasting was conducted on Plywood Multi 0280x0280x09 dia 77, which belongs to category A and therefore requires precise demand estimation. Four quantitative forecasting methods were compared: Simple Average (SA), Moving Average (MA), Weighted Moving Average (WMA), and Single Exponential Smoothing (SES).

Simple Average (SA)

The Simple Average method produced a forecast value of 10,465.5 units for the next period. The model generated a MAPE of 18.002%, indicating moderate forecasting accuracy. Although the tracking signal (0.507) shows no significant bias, the relatively high error values suggest that SA is less responsive to demand fluctuations shown on Table 2.

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Table 2. Forecasting Results Using Simple Average Method

Keterangan	Excel	Software
forecast next month	10.465,5	10.465,5
Mean Squared Error (MSE)	4.548.103,873	4.548.103,873
Mean Absolute Deviation (MAD)	1.834,095	1.834,095
Mean Absolute Percentage Error (MAPE)	18002%	18002%
Cumulative Forecast Error (CFE)	929,333	929,333
Tracking Signal	0,507	0,507

Moving Average (3-MA)

The 3-period Moving Average method resulted in a forecast of 9,581.33 units with a MAPE of 16.944%. However, the Cumulative Forecast Error (–4,730.67) and tracking signal (–3.04) indicate a negative bias tendency, meaning the model consistently underestimates actual demand. As noted by [33] and [34], MA performs well under stable demand patterns but becomes less reliable when fluctuations are significant, the forecasting accuracy comparison can be seen in Table 3.

Table 3. Forecasting Results Using 3-Period Moving Average

Keterangan	Nilai (Excel)	Nilai (Software)
forecast Next Month	9.581,33	9.581,33
Mean Squared Error (MSE)	3.459.857,8	3.459.857,8
Mean Absolute Deviation (MAD)	1.554,13	1.554,13
Mean Absolute Percentage Error (MAPE)	16944%	16944%
Cumulative Forecast Error (CFE)	-4.730,67	-4.730,67
Tracking Signal	-3,04	-3,04

Weighted Moving Average (WMA)

The Weighted Moving Average method applied weights of 0.2, 0.3, and 0.5 for the three most recent periods. This method generated a forecast of 9,249.2 units with the lowest MAPE value of 15.81% and MAD of 1,444.

Compared to other models, WMA shows better responsiveness to recent demand changes due to its weighting structure [35], [9]. Although the tracking signal (–3.047) indicates slight underestimation bias, the error level remains within acceptable control limits. These findings align with [17], who emphasized that weighted forecasting improves prediction performance under fluctuating demand conditions, the forecasting accuracy comparison can be seen in Table 4.

Table 4. Forecasting Results Using Weighted Moving Average

Keterangan	Nilai (Excel)	Nilai (WINQSB)
forecast Next Month	9.249,2	9.249,2
Mean Squared Error (MSE)	3.274.619	3.274.619
Mean Absolute Deviation (MAD)	1.444	1.444
Mean Absolute Percentage Error (MAPE)	15,81%	15,81%
Cumulative Forecast Error (CFE)	-4.4	-4.4
Tracking Signal	-3,047	-3,047

Single Exponential Smoothing (SES)

SES was implemented with a smoothing constant α = 0.8 to increase sensitivity to recent data [12], [14]. The method produced a forecast of 8,947.77 units with a MAPE of 15.987%.

Although SES shows relatively good accuracy and no significant bias (tracking signal = 0.2395), its MAPE value is slightly higher than WMA.

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Therefore, among the four tested models, WMA provides the best forecasting performance for this material.

Overall comparison confirms that assigning higher weights to recent observations improves forecasting accuracy for fluctuating material consumption patterns, the forecasting accuracy comparison can be seen in Table 5.

Table 5. Forecasting Results Using Single Exponential Smoothing

Keterangan	**Nilai (Excel)**	**Nilai (WINQSB)**
Forecast Next Month	8.947,77	8.947,77
Mean Squared Error (MSE)	4.652.160	4.652.160
Mean Absolute Deviation (MAD)	1.606,218	1.606,218
Mean Absolute Percentage Error (MAPE)	15987%	15987%
Cumulative Forecast Error (CFE)	384,71	384,71
Tracking Signal	0,2395	0,2395

C. Economic Order Quantity (EOQ) Analysis

After determining forecasted demand, EOQ was calculated to identify optimal purchasing quantities that minimize total inventory cost. EOQ balances ordering cost and holding cost to determine the most economical order size. The EOQ calculation results are shown in Table 6.

Table 6. Economic Order Quantity (EOQ) Calculation Results

Material	Satuan	D	S	H	EOQ
Plywood Multi 0280x0280x09 dia 77	pc	12.5592	10,000,000	10,000	15,849
Plywood Multi 0310x0310x09 dia 77	pc	88.092	10,000,000	10,000	13,273
Plywood Multi 0365x0365x09 dia 77	pc	24.444	10,000,000	10,000	6,992
Plywood Multi 0365x0385x12 dia 77	pc	17.256	10,000,000	10,000	5,875

These results suggest that the company's current ordering policy has not yet reached cost-minimizing levels. By applying EOQ, ordering frequency can be reduced while avoiding excessive holding cost. This finding supports the theoretical concept that EOQ identifies the optimal trade-off point between ordering and storage costs.

The integration of ABC classification, accurate forecasting selection, and EOQ calculation provides a structured and financially efficient inventory control framework for flexible packaging operations.

IV. CONCLUSION

The results show that ABC analysis classifies PLY as category A with an investment contribution of 64.53% despite representing only 39.07% of total items, indicating that inventory cost concentration follows the Pareto principle and requires priority control. Among the forecasting methods, Weighted Moving Average provides the highest accuracy with a MAPE of 15.81%, compared to 18.00% (Simple Average), 16.94% (Moving Average), and 15.98% (Single Exponential Smoothing), producing a forecast of 9,249.2 units for the next period. Furthermore, the EOQ calculation determines optimal order quantities of 15,849 units, 13,273 units, 6,992 units, and 5,875 units for the respective plywood materials, demonstrating that economically optimal purchasing can reduce total inventory costs by balancing ordering and holding costs. These findings confirm that the integration of ABC classification, accurate forecasting, and EOQ provides a quantitative and effective framework for inventory optimization in flexible packaging operations.

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