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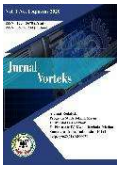

INTEGRATION OF FORECASTING AND MRP MODELS FOR OPTIMIZATION OF CPO RAW MATERIAL INVENTORY IN THE PALM OIL INDUSTRY

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Abstract

Inventory management of raw materials is a crucial aspect in ensuring the smooth production process of the palm oil industry. This study examines the effectiveness of integrating forecasting models and Material Requirement Planning (MRP) to optimize the inventory of Crude Palm Oil (CPO) raw materials at PT Salapian Indo Sawit. The palm oil industry in Indonesia represents about 3.5% of the national Gross Domestic Product (GDP) and provides employment for more than 17 million people. Inaccuracies in raw material inventory management lead to disruptions in the production process and inefficiencies in operational costs. The literature review shows that MRP methods with lot-for-lot techniques have been effectively implemented in various industries, but their application in the palm oil sector is still limited. The objective of this research is to analyze optimal forecasting methods for CPO raw material requirements and evaluate the efficiency of MRP implementation compared to conventional methods. The novelty of this research lies in the integration of forecasting methods (Moving Average and Single Exponential Smoothing) with MRP specifically for the palm oil industry, considering the unique characteristics of the palm oil supply chain. The study uses a descriptive quantitative approach with demand and historical production data from June 2020 to May 2021. The results indicate that the Single Exponential Smoothing method with α=0.5 provides the best forecasting accuracy (MAPE=0.120; MSE=436.17). Implementing MRP with lot-for-lot techniques results in significant efficiencies, including a reduction in order frequency (26.67%), a reduction in order quantity (7.63%), and a reduction in initial inventory (8.10%). This study concludes that integrating an accurate forecasting model with the MRP system is effective for optimizing CPO raw material inventory and enhancing the operational efficiency of the company.

Abstrak

Manajemen persediaan bahan baku merupakan aspek krusial dalam menjamin kelancaran proses produksi industri minyak kelapa sawit.

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Kata Kunci: *Manajemen Persediaan, Material Requirement Planning, Crude Palm Oil, Single Exponential Smoothing, Lot-for-Lot*

Penelitian ini mengkaji efektivitas integrasi model peramalan dan Material Requirement Planning (MRP) untuk mengoptimalkan persediaan bahan baku Crude Palm Oil (CPO) di PT Salapian Indo Sawit. Industri kelapa sawit di Indonesia merepresentasikan sekitar 3,5% dari Produk Domestik Bruto (PDB) nasional dan menyediakan lapangan kerja bagi lebih dari 17 juta orang. Ketidakakuratan dalam manajemen persediaan bahan baku menyebabkan gangguan proses produksi dan inefisiensi biaya operasional. Tinjauan literatur menunjukkan bahwa metode MRP dengan teknik lot-for-lot telah diimplementasikan secara efektif di berbagai industri, namun aplikasinya di sektor kelapa sawit masih terbatas. Tujuan penelitian ini adalah menganalisis metode peramalan optimal untuk kebutuhan bahan baku CPO dan mengevaluasi efisiensi penerapan MRP dibandingkan metode konvensional. Keterbaruan penelitian terletak pada integrasi metode peramalan (Moving Average dan Single Exponential Smoothing) dengan MRP khusus untuk industri kelapa sawit, dengan mempertimbangkan karakteristik unik dari rantai pasok minyak sawit. Penelitian menggunakan pendekatan kuantitatif deskriptif dengan data permintaan dan produksi historis Juni 2020 hingga Mei 2021. Hasil penelitian menunjukkan bahwa metode Single Exponential Smoothing dengan α=0,5 memberikan akurasi peramalan terbaik (MAPE=0,120; MSE=436,17). Implementasi MRP dengan teknik lot-for-lot menghasilkan efisiensi signifikan, meliputi pengurangan frekuensi pemesanan (26,67%), pengurangan kuantitas pemesanan (7,63%), dan pengurangan persediaan awal (8,10%). Penelitian ini menyimpulkan bahwa integrasi model peramalan yang akurat dengan sistem MRP efektif untuk mengoptimalkan persediaan bahan baku CPO dan meningkatkan efisiensi operasional perusahaan..

INTRODUCTION

In the palm oil industry, accuracy in forecasting raw materials not only affects product availability but also comprehensive operational costs. Research conducted by [1]. Shows that the application of the Continuous Review System (CRS) methodology can reduce storage expenditure while increasing operational efficacy. The use of the MRP method as a tool in material planning is crucial to ensure that the required raw materials are available promptly, reduce the risk of overstocking or understocking, and minimize total costs [2]. The palm oil sector in Indonesia is an important component of its economic architecture, serving as a major agricultural export. The sector, representing approximately 3.5% of Indonesia's Gross Domestic Product (GDP) [3], facilitates the generation of more than 17 million employment opportunities and plays an important role in boosting the country's GDP. The proliferation of oil palm plantations has seen a substantial increase, with an annual average growth in cultivated area of 5% over the past two decades, particularly in regions such as Sumatra and Kalimantan, driven by large industrial plantations alongside smallholders cultivating around 40% of the total oil palm area [4][5].

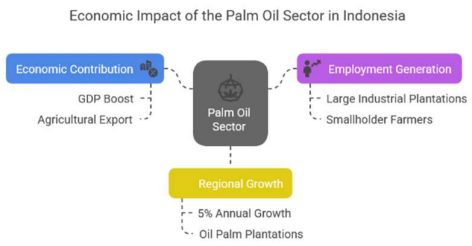

Figure 1 Economic Impact of the Palm Oil Sector in Indonesia

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Inventory management relating to raw materials is an essential element in facilitating a seamless production process in the manufacturing sector, particularly concerning palm oil processing [6]. Discrepancies in inventory management can trigger disruptions in production activities and contribute to inefficiencies in operational expenditures [7]. PT Salapian Indo Sawit has encountered deficiencies in the inventory control of primary raw materials (i.e. Fresh Fruit Bunches [FFB]). This has resulted in a disruption to the Crude Palm Oil (CPO) production process [8]. In instances where there is a shortage of raw materials, corporations are compelled to source supplies from third-party plantations. This phenomenon has a dual impact: it engenders cost escalation and volatility in production schedules [9]. The application of the appropriate methodology in the control of raw material inventories constitutes a tactical resolution to overcome the associated challenges [10][11]. Material Requirements Planning (MRP) utilizing lot-by-lot techniques is a strategy that can enhance inventory management by ensuring the requisite raw materials are available to meet demand within the stipulated timeframe [12]. The integration of forecasting methodologies with MRP empowers organizations to achieve greater precision in estimating raw material requirements and in establishing procurement intervals that are optimized [13].

State Of The Art

Table 1 State Of Teh Art

No	Researchers (Year)	Research Title	Research Object	Forecasting Method	Lot Sizing Technique	Key Findings
1	Siti Zahrotul Uyun, Adi Indrayanto, Retno Kurniasih (2020) [14]	Analysis of Raw Material Inventory Control Using the Material Requirement Planning (MRP) Method	PT Tiara Ready Mix Ciamis (Concrete Industry)	Single Exponential Smoothing	Lot for Lot and Economic Order Quantity	Lot for Lot method is more efficient with lower total inventory costs compared to EOQ method.
2	Trio Yonathan Teja Kusuma (2017) [15]	Analysis of Material Requirement Planning (MRP) at C-Maxi Alloy cast	PT C-Maxi Alloycast (Metal-Based Manufacturing)	Moving Average and Exponential Smoothing	Lot for Lot and Period Order Quantity	MRP implementation minimizes inventory and reduces production delay risks. The POQ method results in the lowest inventory costs.
3	Mochammad Dadang Firmansyah (2019) [16]	Implementation of Material Requirements Planning (MRP) in Raw Material Inventory Planni	PT Karet Ngagel Surabaya Wira Jatim (Rubber Industry)	Single Exponential Smoothing	Lot for Lot and Silver Meal Algorithm	Forecasting using SES produces high accuracy. MRP implementation increases production

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		ng for Multi-PLY Conveyor Belt Products				efficiency.
4	Nyimas Desy Rizkiyah and Rifqi Fadhlurrahman (2019) [17]	Analysis of Inventory Control Using the Material Requirement Planning (MRP) Method for Paper Products	PT Indah Kiat Pulp & Paper Tbk (Paper Industry)	Winter Multiplicative, Trend Analysis, Moving Average	Lot for Lot, Part Period Balancing	Holt Winter Multiplicative forecasting method was chosen with the lowest error rate. Lot for Lot technique is more efficient for fluctuating demand products.
5	Bagus Maulana Wisnu Atmoko (2016) [16]	Analysis of Raw Material Inventory Control Using Lot Sizing Approach to Support MRP System	CV Hery Jaya (Automotive Industry)	Moving Average and Single Exponential Smoothing	EOQ, POQ, PPB, LFL	EOQ method results in the lowest total inventory cost of Rp 329,091,881 for the next 6 periods.
6	Kukuh Anggara Martha, Putu Yudi Setiawan (2018) [18]	Analysis of Material Requirement Planning for Coconut Sugar Products at Kul-Kul Farm	Kul-Kul Farm (Coconut Sugar Industry)	Trend Analysis and Single Exponential Smoothing	Lot for Lot	MRP implementation with Lot for Lot reduces inventory costs by 15% and minimizes stockouts.
7	Asvin Wahyuni, Achmad Syaichu (2015) [19]	Raw Material Inventory Planning Using the MRP Method for Shanghai Peanut Products	Gangsar Ngunut - Tulungagung Company (Food Industry)	Weighted Moving Average and Exponential Smoothing	Lot for Lot	MRP implementation with Lot for Lot increases raw material planning efficiency by 22%.
8	Imaya Indriani, Acmad Slamet (2017) [20]	Production Planning and Raw Material Requirements Using MRP Method	CV Fawas Jaya (Bakery Industry)	Single Exponential Smoothing	Lot for Lot	Demand forecasting of 35,538 bread units with MRP results in an optimal flour order schedule.

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9	Oky Febryanta Sitepu (2022)	Analysis of Palm Oil Raw Material Inventory Control Using Material Requirement Planning (MRP) Method	PT Salapian Indo Sawit (Palm Oil Industry)	Moving Average and Single Exponential Smoothing	Lot for Lot	SES method with a=0.5 was selected for forecasting. MRP implementation reduces order quantity and optimizes raw material levels.

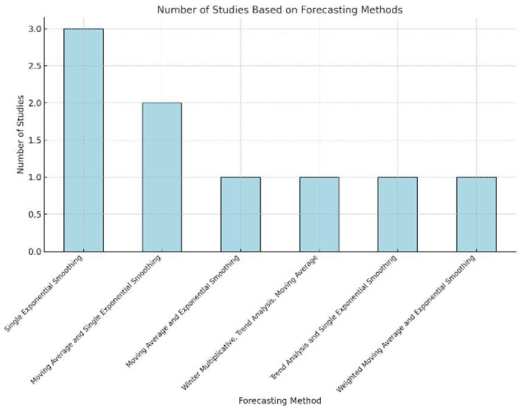

Figure 2 Number Of Base on Forecasting Methods

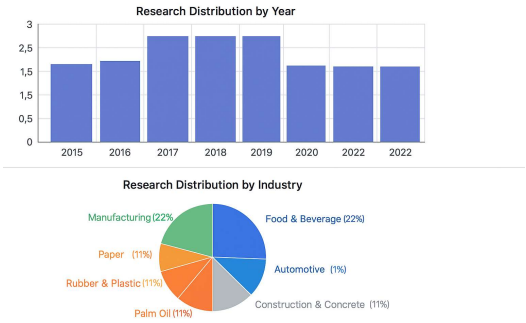

Figure 3 Research Distribution by Year

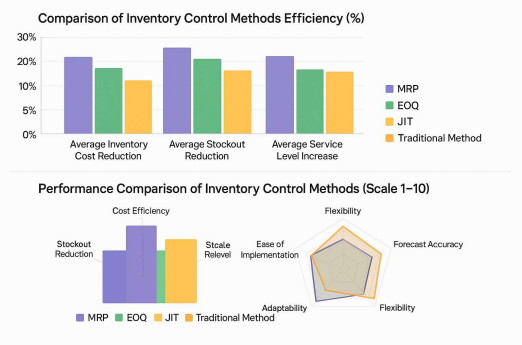

Figure 4 Comparison of Inventory Control Methods Efficiency (%)

RESEARCH METHODS

This study employs a descriptive quantitative approach [21][22], focusing on the analysis of palm oil raw material inventory control using the Material Requirements Planning (MRP) method at PT. Salapian Indo Sawit. The research was conducted during the March-April 2022 period, utilizing historical demand and production data from June 2020 to May 2021.

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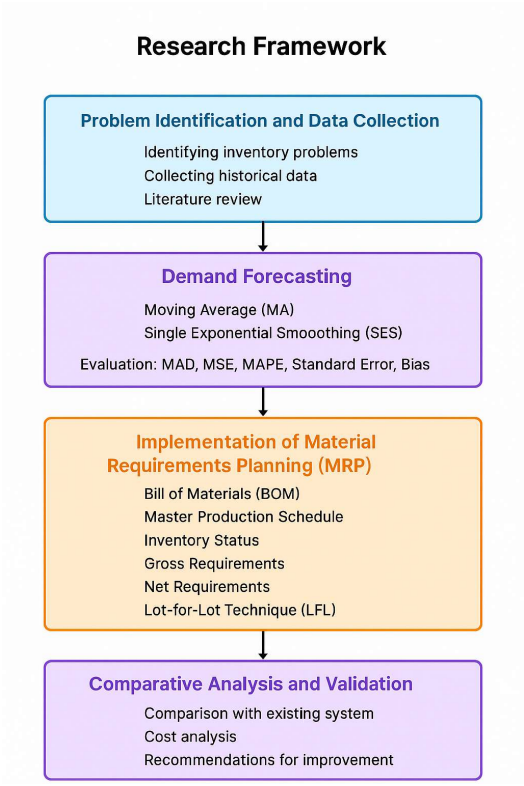

Figure 5 Research Framework

The research was conducted at PT. Salapian Indo Sawit, located at Jl. Besar Tanjung Langkat Tambunan, Ujung Teran, Salapian, Langkat Regency, North Sumatra. Data collection was carried out from March 25-28, 2022, by observing the production process and the raw material inventory control system for CPO (Crude Palm Oil).

Types and Sources of Data

Primary Data

Primary data was obtained through:

1. **Direct observation**: Observation of raw material inventory management process, production process, and TBS (Fresh Fruit Bunches) reception flow.
2. **Semi-structured interviews**: Conducted with production managers, inventory supervisors, and procurement staff to obtain information regarding:
   - Current inventory policy
   - Order lead time
   - Ordering and storage costs
   - Operational constraints faced

Secondary Data

Secondary data collected includes:

1. Historical demand data for TBS raw materials from June 2020 - May 2021
2. CPO production data from June 2020 - May 2021
3. Raw material specifications and BOM (Bill of Material) structure
4. Documentation of standard operational procedures for inventory management

Research Variables

Variables used in this research are:

1. **Raw material inventory (TBS)**: Measured in Metric Tons (MT)
2. **CPO production**: Measured in Metric Tons (MT)
3. **Lead time**: Measured in days
4. **Ordering costs**: Measured in Rupiah (Rp)
5. **CPO composition**: Percentage of TBS becoming CPO (25%)

Data Collection Techniques

Data collection was conducted through three techniques:

1. **Documentation**: Collection of historical data from company documents
2. **Observation**: Direct observation of production and inventory management processes
3. **Interviews**: Question and answer with company management

Research Instruments

Instruments used in this research include:

1. Production process observation sheet
2. Semi-structured interview guidelines
3. Historical data collection form
4. Data processing software (Microsoft Excel and POM for Windows)

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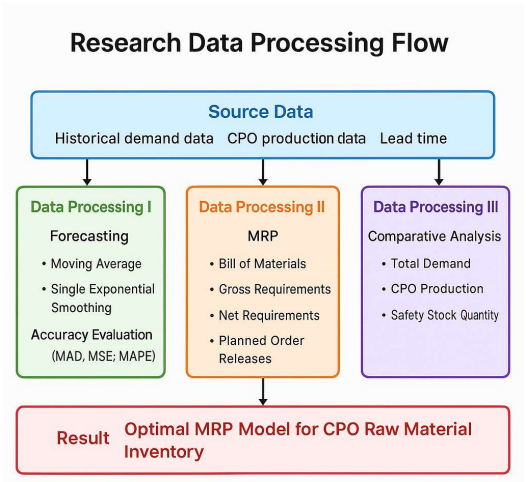

Figure 6 Research Data Processing Flow

Research Procedure

This research was conducted through four stages as follows:

1. **Problem Identification and Data Collection**
   - Conducting preliminary study through observation and interviews
   - Identifying inventory control problems
   - Collecting historical demand and production data
   - Determining research parameters (lead time, ordering cost, raw material specifications)

2. **Raw Material Demand Forecasting**

Forecasting is done using two different methods to select the best method:

a. 3-Month Moving Average (MA) Method

Calculation using the formula:

$$MA_3 = \frac{D_1 + D_2 + D_3}{3} \dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where:

MA_3 = 3-month Moving Average forecast result

D_1, D_2, D_3 = Actual demand data from the previous 3 months

b. Single Exponential Smoothing (SES) Method

Calculation using the formula:

$$F_{(t)} = F_{(t-1)} + \alpha(D_{(t-1)} - F_{(t-1)} \dots\dots\dots (2)$$

Where:

$F_{(t)}$ = Forecast for period t

$F_{(t-1)}$ = Forecast for previous period

$D_{(t-1)}$ = Actual demand for the previous period

α = Smoothing constant (in this study using α = 0.5)

c. Forecast Accuracy Evaluation

Using indicators:

- Mean Absolute Deviation (MAD)
- Mean Squared Error (MSE)
- Mean Absolute Percentage Error (MAPE)
- Bias (Mean Error)
- Standard Error

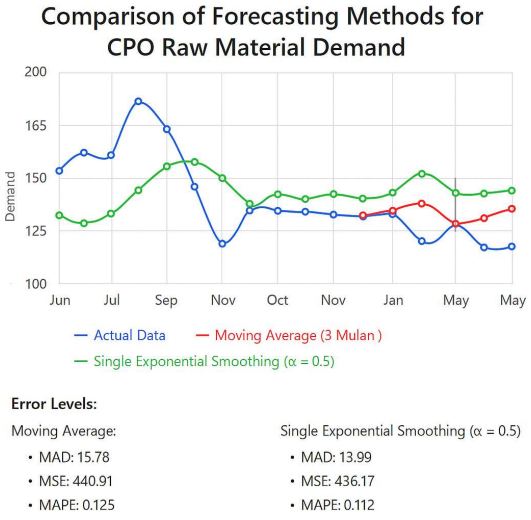

Figure 7 Comparison of forecasting Methods

RESULTS AND DISCUSSION

1. Descriptive Data Analysis

The data on CPO raw material demand and CPO production from June 2020 to May 2021 shows a fluctuating pattern, with an average raw material demand of 144.38 MT per month (standard deviation 19.43) and an average CPO production of 32.76 MT per month (standard deviation 4.81). The highest raw material demand occurred in August 2020 (179.92 MT), while the lowest was in November 2020 (113.99 MT). The average conversion ratio of raw material to CPO was 22.64%, ranging between 17.54% and 24.65%.

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2. Forecast Results

A comparison of the two forecasting methods yields:

Table 2 Forecasting Method Comparison

Metrik Error	Moving Average (3 months)	Single Exponential Smoothing (α=0,5)
Bias (ME)	-7,43	-2,14
MAD	15,78	17,03
MSE	440,91	436,17
MAPE	0,125	0,120
Forecast for next period	137,26 MT	133,36 MT

Based on the lower MSE and MAPE values, the Single Exponential Smoothing method with α=0.5 was selected as the best forecasting method, with a forecast result of 133.36 MT for the next period.

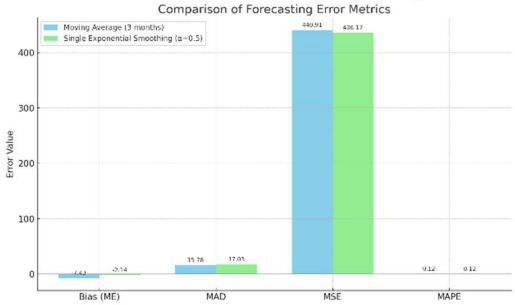

Figure 8 Forecasting Method Comparison

3. Implementation of MRP with Lot-for-Lot Technique

The implementation of MRP with the lot-for-lot technique results in inventory planning with the following characteristics:

- Initial inventory: 145.11 MT
- Number of orders in one period: 11 times
- Order size per instance: 133.36 MT

The MRP implementation results show more structured order planning with clearly defined quantities and order timing. This approach enables the company to better anticipate raw material needs and reduce reliance on emergency orders from external plantations.

4. Comparison of Company Method and MRP

Table 3 Comparison of Company Method and MRP

Comparison Variable	Company Method	MRP Method	Efficiency Percentage
Order Quantity	15	11	26,67%
Order Cost	Rp. 6.800.000	Rp. 6.800.000	0%
Initial Requirement	145,11 MT	133,36 MT	8,10%
Order Quantity per Batch	144,37 MT	133,36 MT	7,63%

The comparison shows that the MRP method achieves an efficiency of 26.67% in order quantity and 7.63% in single-order quantity. Thus, implementing MRP has the potential to reduce overall inventory costs and enhance operational efficiency.

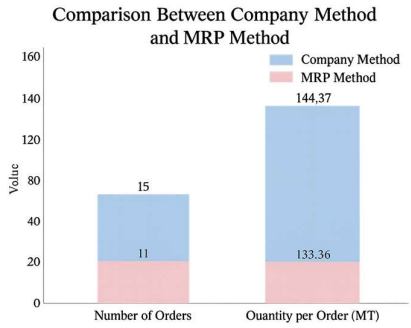

Figure 9 Comparison of Company Method and MRP

Table 4 Comparison of Error Matrics Forecasting

Comparison of Error Metrics of Forecasting Methods

Error Metrie	Moving Avarage (3 months)	Single Exp. Smoothing (α=0.5)
Bias (ME)	−7.43	−2.14
MAD	15.78	17.03
MSE	440.91	436.17
Standard Error	23.81	21.03
MAPE	0.125	0.120
Next Period	137.26	133.36

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CONCLUSION

This research examines the effectiveness of integrating forecasting models and Material Requirement Planning (MRP) in optimizing the inventory of Crude Palm Oil (CPO) raw materials in the palm oil industry at PT Salapian Indo Sawit. Based on the analysis of historical data on CPO demand and production from June 2020 to May 2021, several important conclusions can be drawn:

1. **Optimal Forecasting Method**: A comparison of the 3-month Moving Average (MA) and Single Exponential Smoothing (SES) methods with α=0.5 shows that the SES method is superior with an MSE value of 436.17 and a MAPE of 0.120. The forecast result for the next period is 133.36 MT of CPO raw material.
2. **MRP Implementation Efficiency**: The implementation of the MRP method with the Lot-for-Lot technique results in significant efficiencies compared to the company's conventional methods, including:
   - 26.67% reduction in order frequency (from 15 to 11 times)
   - 7.63% reduction in order quantity per batch (from 144.37 MT to 133.36 MT)
   - 8.10% reduction in initial inventory (from 145.11 MT to 133.36 MT)
3. **Operational Stability**: The application of MRP facilitates more structured order planning with clear timing and quantities, thus reducing dependence on emergency orders from external plantations.
4. **Financial Implications**: Although the fixed ordering cost (Rp. 6,800,000), the reduction in frequency and quantity of orders has the potential to decrease overall inventory costs and increase the operational efficiency of the company.

The results of this study provide significant contributions to inventory management in the palm oil industry, particularly in facing fluctuations in raw material demand. The integration of accurate forecasting methods with the MRP system has proven effective in optimizing CPO raw material inventory, which in turn can enhance profitability and operational sustainability for the company. This methodology can be adopted by similar industries to improve their inventory management efficiency.

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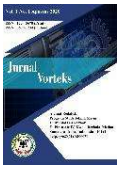

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