Comparative analysis of the least squares method and double moving average technique for forecasting product inventory

Surfa Yondri[1], Dwiny Meidelfi[2*], Tri Lestari[2], Fanny Sukma[2] and I.S. Mutia[2]

[1] Department of Electronic Engineering, Politeknik Negeri Padang, **INDONESIA**
[2] Department of Information Technology, Politeknik Negeri Padang, **INDONESIA**

* Corresponding Author: dwinymeidelfi@pnp.ac.id
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Abstract: The cosmetics industry necessitates efficient inventory management to balance customer demand with stock control. This case study explores how Liza Cosmetics Shop optimized inventory for Lip Cream Implora 01, a popular product, using data-driven forecasting techniques. Traditional trend-based methods often resulted in inaccurate forecasts. This study proposed implementing the SDLC Waterfall Model to apply two forecasting techniques: Least Squares and Double Moving Average. Historical sales data (April 2021 - June 2022) was analyzed to identify demand patterns, seasonality, and trends. The Least Squares method was chosen for its suitability in capturing stable, linear relationships between sales and time, while the Double Moving Average method catered to data exhibiting both long-term trends and short-term fluctuations. Rigorous testing using white-box and black-box methods ensured the accurate functionality and system behavior of the implemented models. The Mean Absolute Percentage Error (MAPE) determined the method best suited for predicting July 2022 demand. This case study contributes insights into data-driven inventory management in cosmetics, highlighting benefits such as optimized stock levels, reduced costs, and enhanced customer satisfaction through improved demand fulfillment. This studys' limitations including unforeseen marketing campaigns and economic fluctuations impacting forecasts were acknowledged. Despite these challenges, the study emphasizes the potential of data-driven techniques to optimize inventory management and meet customer demands effectively.

Keywords: Industry, innovation and infrastructure; Cosmetics industry; Management production; Demand prediction

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1. Introduction

The cosmetics industry appeals to people of all ages and backgrounds, driven by a universal desire for beauty enhancement. This global market, particularly booming in the Asia-Pacific region, shows exceptional growth within the fast-moving consumer goods (FMCG) sector [1], [2]. In Indonesia, the cosmetics industry stands out with an estimated 7% growth rate in 2021 [3], [4], [5], [6], [7], [8]. However, despite this growth and increasing demand for beauty products, many cosmetic stores struggle with inefficient inventory management practices. Inventory control usual relies heavily on trends, which can change rapidly and lead to significant financial losses. Depending solely on current trends to predict future demand is risky, akin to navigating a minefield blindfolded. Due to trends in cosmetics can shift quickly, leaving stores with an excess stock of products that are no longer popular.

Moreover, the trend-based approach overlooks the unique characteristics of a store's customer base and local market dynamics. It fails to consider targeted marketing efforts, seasonal fluctuations, or local events that strongly influence consumer buying behaviors. For example, a store near a university campus may experience spikes in demand for specific products during exam periods,

while a suburban store serving families might see different buying patterns on weekends. The consequences of inaccurate forecasting using trends are significant. Stockouts can lead to customer dissatisfaction and missed sales opportunities, damaging customer loyalty. Conversely, overstocked inventory ties up capital, occupies valuable storage space, and risks products becoming obsolete or expiring, impacting profitability.

To address these challenges, a shift to data-driven inventory forecasting is crucial. By analyzing historical sales data, market trends, and employing advanced forecasting techniques [9], [10], [11], [12], [13], [14], cosmetic stores can predict future demand more accurate. This approach enables them to optimize stock levels, minimize losses from stockouts and overstocking, and ultimately improve operational efficiency and customer satisfaction. Thus, adopting a data-driven approach to inventory management is essential for navigating the complexities of the cosmetics industry. By embracing sophisticated forecasting methods, cosmetic stores can better anticipate market trends, meet consumer demands more effectively, and position themselves for sustainable growth in a competitive market.

2. Literatur review

Accurate inventory forecasting is crucial for businesses to maintain optimal stock levels, minimize costs, and enhance customer satisfaction. This review explores various forecasting methods commonly used for predicting goods demand:

Moving Average (MA) methods:

1. Single Moving Average (SMA): This is a widely used and straightforward method that calculates the average of historical sales data over a chosen period (e.g., weekly, monthly). The SMA is effective for capturing general trends but may not be sensitive to recent fluctuations [15], [16].
2. Double Moving Average (DMA): This method utilizes two SMAs with different time horizons. One SMA captures the long-term trend, while the other captures shorter-term fluctuations. The DMA calculates a forecast by averaging these two SMAs, offering a balance between trend and responsiveness to recent changes [17].
3. Weighted Moving Average (WMA): This method assigns weights to historical data points, with more recent data points receiving higher weights. This approach gives more importance to recent trends, making it suitable for data with frequent fluctuations [12], [18], [19].

Exponential Smoothing methods:

1. Least Squares (LS): This statistical technique establishes a linear relationship between historical sales data and time. It essentially fits a trend line to the data and uses that line to forecast future demand. The Least Squares method is effective for data exhibiting a clear linear trend [20], [21], [22].
2. Single Exponential Smoothing (SES): This method assigns an exponential weight to past data points, with the weight decreasing exponentially as we go further back in time. This approach emphasizes recent data, making it suitable for situations with changing trends or seasonality [23], [24].

The choice of forecasting method depends on several factors, including data characteristics, forecasting horizon and accuracy needs. Several studies have compared the effectiveness of these methods. According to [25], [26] which compared the performance of SMA, WMA, and SES for inventory forecasting in a retail setting, WMA often outperforms SMA due to its ability to adapt to recent trends. However, the study emphasizes the importance of selecting the method based on specific data characteristics and forecasting needs.

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3. Material and methods

3.1 Case study

This study focuses on forecasting the sales of Lip Cream Implora 01 at Liza Cosmetics Shop from April 2021 to June 2022 using the Least Squares and Double Moving Average methods. Figure 1 presents the sales data for this period.

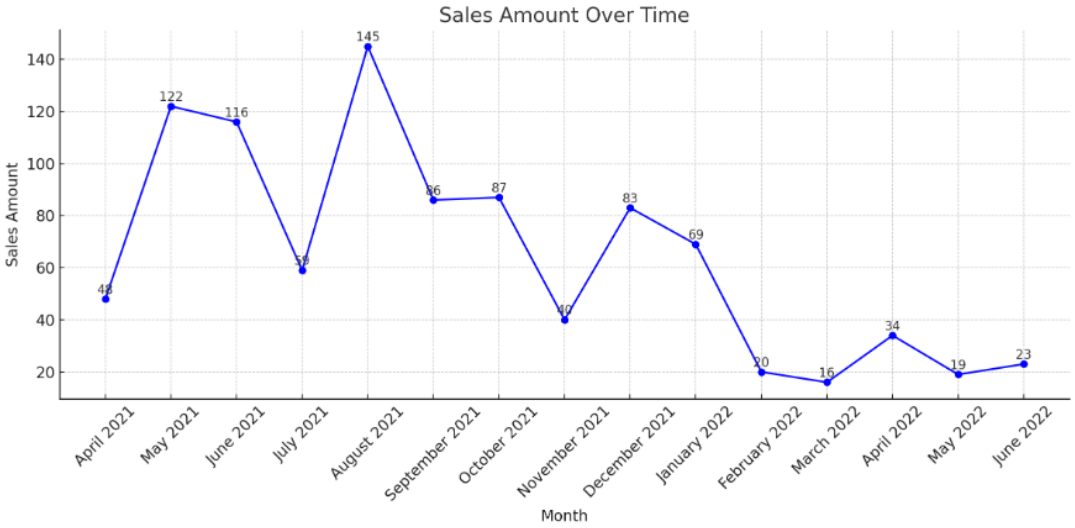

Figure 1. Industrial GDP value and growth analysis for lip cream sales by implora 01 from April 2021 to June 2022

3.2 Methodology

We employ the Software Development Life Cycle (SDLC) method [27], [28], specifically using the Waterfall model, which involves a sequential approach where each phase must be completed before the next phase begins. This ensures that the work at each stage is thoroughly focused and optimized [29].

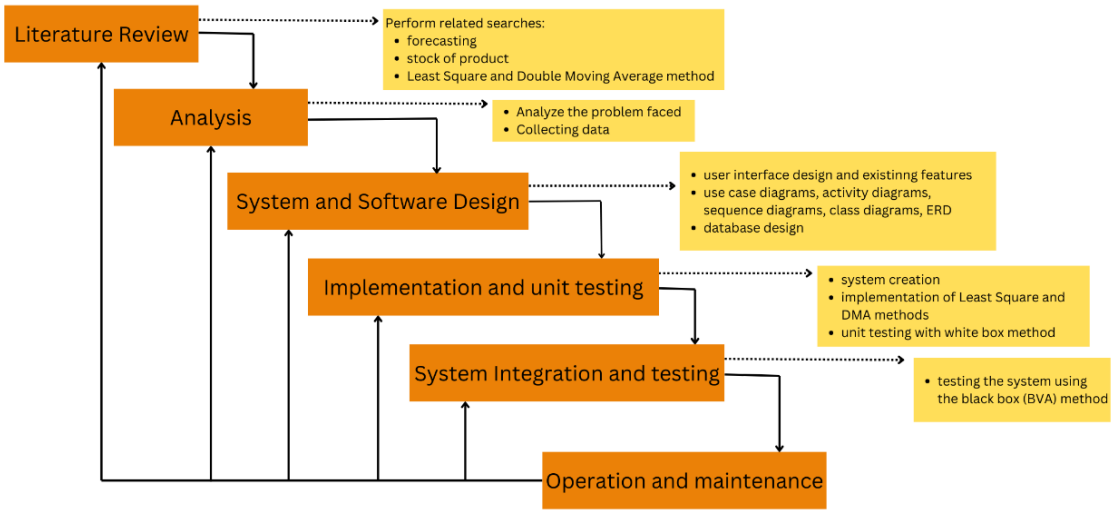

Figure 2. Phases of the SDLC waterfall model

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According to the waterfall model depicted in Figure 2, the stages of system development in this study include:

1) Literature Review: This phase involves reviewing existing research to understand previous findings related to the study and identifying gaps that this research aims to fill.
2) Analysis: In this stage, we analyze all requirements necessary for the system development process, including determining product availability.
3) System and Software Design: Here, we design the system based on analyzed requirements, detailing the design using UML diagrams, user interface design, database design, and system features.
4) Implementation and Unit Testing: This involves coding the system and implementing the Least Squares and Double Moving Average methods. Unit testing is done using the white box testing method to verify the functionality by examining the code structure.

a) Least square method

The Least Squares method is used to determine the best-fit line for forecasting future data based on historical data. The general equation for the trend line is: [30], [31]:

$$Y = a + bx \tag{1}$$

Where:

$$a = \frac{\sum y}{n} \quad \text{represents the intercept} \tag{2}$$

$$b = \frac{\sum xy}{\sum x^2} \quad \text{represents the slope.} \tag{3}$$

The time variable (x) is coded to simplify calculations, with different coding schemes for even and odd data sets.

b) Double moving average method

The Double Moving Average method involves calculating two consecutive moving averages to smooth out the data trend. As for steps for getting results namely [32]:

1. Single moving average

$$S' = \frac{X_t + X_{t-1} + X_{t-2} + \cdots + X_{t-k-1}}{k} \tag{4}$$

2. Double moving average

$$S'' = \frac{S_t + S_{t-1} + S_{t-2} + \cdots + S_{t-k-1}}{k} \tag{5}$$

Using these averages, we compute:

1. The constant value:

$$a_t = 2S'_t - S''_t \tag{6}$$

2. The trend coefficient:

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$$b_t = \frac{2}{k-1}(S'_t - S''_t) \quad (7)$$

3. The forecast:

$$f_{t+p} = a_t + b_t p \quad (8)$$

At this stage, unit testing is performed using the white box testing method. White box testing involves examining the internal structure of the software to ensure it is functioning correctly. This method focuses on controlling the flow of the software by identifying bugs directly from the source code [33]. To evaluate the forecasting methods, the Mean Absolute Percentage Error (MAPE) is calculated. MAPE is used to measure the accuracy of the predictions by comparing the actual scores with the predicted scores. This calculation highlights the differences between actual and forecasted values, providing a clear metric for evaluation [34], [35].

$$\text{MAPE} = \frac{\sum(|A-F|/A)\times 100}{n} \quad (9)$$

The MAPE values help categorize the accuracy of the forecast as follows in Table 1.

Table 1. MAPE criteria

MAPE Value	Criteria
<10	Very Good
10-20	Good
20-50	Sufficient
>50	Poor

5) The system undergoes testing using the black box testing method, focusing on the input and output functions. This stage also includes boundary value analysis to test the limits of the system's fields, ensuring valid data input.

6) Operation and Maintenance: The final stage involves deploying the system and performing ongoing maintenance, addressing any errors discovered during the previous phase.

4. Results and discussion

The system trial phase was conducted to forecast sales and calculate the Mean Absolute Percentage Error (MAPE) using different methods. This trial utilized sales data for Lip Cream Implora 01 from April 2021 to June 2022.

4.1 Forecasting results using the least square method

Using the Least Squares method with sales data from April 2021 to June 2022, the forecasted sales for Lip Cream Implora 01 were 13 units. The average MAPE for this method was 48%, which falls into the "sufficient" category. The results are depicted in Figure 3.

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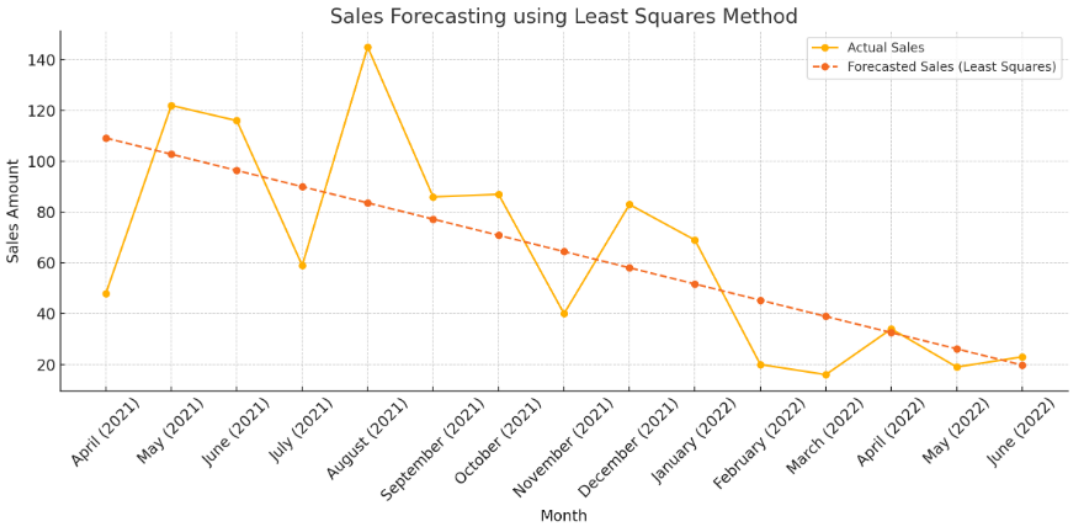

Figure 3. Forecasting results using the least square method

4.2 Forecasting results using the double moving average method (3-Period range)

Employing the Double Moving Average method with a 3-period range and the same sales data, the forecasted sales for Lip Cream Implora 01 were 27 units. This method resulted in an average MAPE of 94%, which is considered "poor." The outcomes are illustrated in Figure 4.

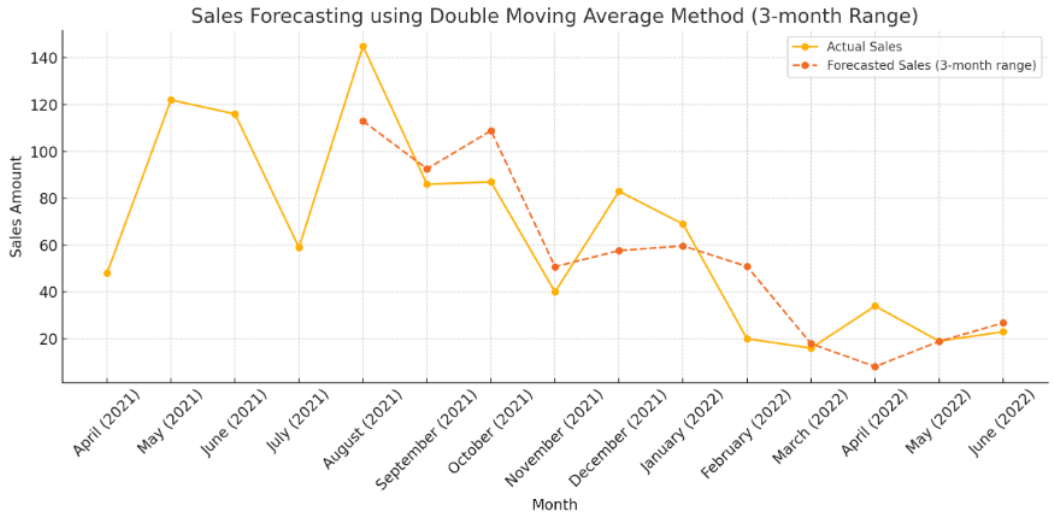

Figure 4. Forecasting results using the double moving average method (3-Period range)

4.3 Method results double moving average 5 range

Using the Double Moving Average method with a 5-period range, the forecast indicated that no additional units of Lip Cream Implora 01 would be needed for the next month. The average MAPE for this method was 65%, which is also categorized as "poor." These findings are shown in Figure 5.

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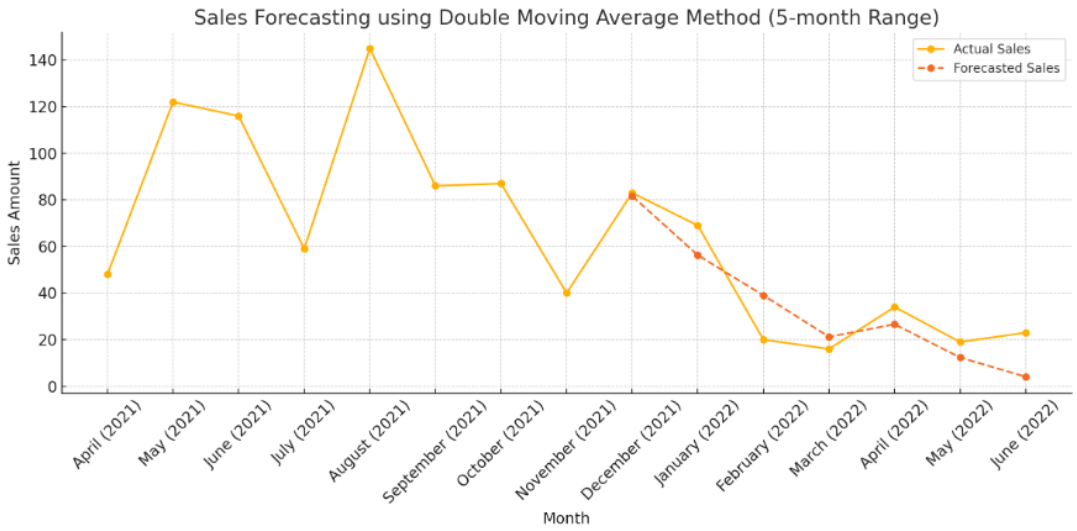

Figure 5. Forecasting results using the double moving average method (5-Period range)

The study evaluated three forecasting methods for predicting demand of Lipcream Implora 01 at Liza Cosmetics Shop: Least Squares, Double Moving Average with range 5, and Double Moving Average with range 3. Each method was assessed based on their Mean Absolute Percentage Error (MAPE) averages. The Least Squares Method yielded the most accurate forecasts with an average MAPE of 48%. The Least Squares method is known for its effectiveness in capturing linear trends over time. This result aligns with previous studies that have shown Least Squares to be suitable for stable and predictable sales patterns [36]. On the other hand, the Double Moving Average (Range 5) method with a range of 5 exhibited an average MAPE of 94%. This higher error rate suggests that while this method captures short-term fluctuations, it may struggle with capturing overall trends effectively, as noted in similar studies [37]. The Double Moving Average method with a range of 3 produced an average MAPE of 65%. This method strikes a balance between capturing short-term fluctuations and broader trends compared to the range 5 method. Previous literature has indicated varying performance of Double Moving Average methods depending on the dataset and the nature of demand patterns [37], [38].

Comparing these findings with previous research highlights consistent themes regarding the performance of forecasting methods in inventory management. Studies by [39], [40], underscore the importance of selecting the appropriate forecasting technique based on the nature of sales data and the desired level of accuracy. Our study corroborates these findings by demonstrating that the Least Squares method, which assumes a linear relationship between time and sales, outperformed the Double Moving Average methods in predicting demand for Lip Cream Implora 01. Implementing the findings of this study can lead to significant improvements in inventory management practices at Liza Cosmetics Shop. By adopting the Least Squares method for forecasting, the shop can minimize stockouts and overstocking, thereby reducing storage costs and improving customer satisfaction. These findings also suggest avenues for future research into more sophisticated forecasting techniques that could further enhance accuracy in volatile market conditions or during promotional periods.

5. Conclusion

In conclusion, this study underscores the pivotal role of data-driven inventory forecasting methods in enhancing operational efficiency for cosmetic stores. Our findings clearly demonstrate that adopting sophisticated techniques such as the Least Squares method can significantly improve demand predictions, as evidenced by its low Mean Absolute Percentage Error (MAPE) of 48% for

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Lip Cream Implora 01. In contrast, the Double Moving Average methods with ranges of 5 units and 3 units yielded moderate and high MAPE values of 65% and 94%, respectively, highlighting their varying effectiveness in capturing demand fluctuations. These results emphasize the critical importance of method selection in achieving accurate inventory forecasts. By leveraging historical sales data and selecting appropriate forecasting models, cosmetic stores can optimize stock levels, reduce costs associated with overstocking and stockouts, and ultimately enhance profitability and customer satisfaction. Future research avenues could explore the application of advanced forecasting techniques across a broader array of cosmetic products and consider additional factors such as seasonal variations and marketing influences to further refine inventory management practices.

Author contribution

Surfa Yondri: Research conceptualization, writing review – original draft, supervision. Dwiny Meidelfi: Conceptualization, writing-result analysis. Tri Lestari: Data analysis, visualization. Fanni Sukma: Gathering data. I.S.Mutia: Gathering data, visualization.

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Competing interest

No potential conflict of interest was reported by the authors.

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