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Original Research

Implementation of Single Moving Average Algorithm for Maintenance Material Prediction in Warehouse Supply Chain System

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ABSTRACT

Material inventory management at a telecommunication industry warehouse frequently experiences imbalances due to unpredictable monthly demand fluctuations, triggering the risk of material shortages or excessive stockpiling. This study aims to implement predictive computation into the supply chain information system to forecast the volume of material requirements for maintenance work. The quantitative forecasting method used is the Single Moving Average (SMA) algorithm, which extracts actual historical expenditure data. The accuracy level of the system's projection results is evaluated mathematically using the Mean Absolute Deviation (MAD) instrument. Furthermore, the system was developed using the Software Development Life Cycle (SDLC) Waterfall model and the CodeIgniter framework. Testing was conducted by comparing the moving average parameters for a three-month ($n = 3$) and a six-month ($n = 6$) period. The system's computation results on operational data show that the algorithm can dynamically calculate projections with MAD error values that vary depending on the fluctuation of the material type, such as ODP forecasting ($n = 3$) recording a MAD deviation of 1.06, and Iron Poles ($n = 6$) with a MAD of 0.83. This study proves that integrating the SMA algorithm into the warehouse database can serve as a reliable reference parameter for management in determining measurable material procurement volumes.

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1. INTRODUCTION

The application of information technology in the industrial sector transforms data governance mechanisms from conventional recording formats into digital databases. In complex industrial operations such as the telecommunications industry, supply chain management and warehouse governance are sectors that absolutely require the integration of a structured recording system [1]. Warehouse governance encompasses a series of operational stages ranging from planning, organizing, receiving, moving, to material picking and shipping [2]. To ensure synchronization between physical availability and material data records, a structured recording system that connects the entire series of stages within a centralized database is required.

In a case study at the telecommunication company warehouse, material recording to support network maintenance work is still conducted using physical documents in the form of official reports, and the current supply chain system frequently experiences server disruptions (bugs or downtime). Based on previous research, this decentralized recording method causes additional duration in the inventory search and validation flow, and restricts data exchange between the area warehouse and branch warehouses [3]. In the long term, conventional recording carries a high risk of discrepancies in physical data quantities, calculation errors, and even material loss [4–6]. Digital governance system improvement evaluations have proven able to assist warehouse management in sustainably minimizing stock discrepancies [7]. Furthermore, the absence of calculation parameters to determine future stock triggers inventory imbalances, which can lead to material excess (overstock) or material shortages (stockout) during ongoing maintenance work in the field [8, 9].

As a solution in the information systems domain, a number of previous studies have designed web-based supply chain systems with Create, Read, Update, Delete (CRUD) functions to facilitate stock recording [10–12]. However, basic recording systems do not resolve the issue of material demand fluctuations in the telecommunications industry; thus, the application of predictive calculation instruments within the system is necessary [10]. The Single Moving Average (SMA) algorithm is a forecasting method that calculates the moving average of historical data over a specific period range to generate projected figures for the future. The application of the SMA algorithm has been researched and proven useful in calculating food product sales volumes [13], tool sales [14], and spare part oil stock calculations [15]. Nevertheless, the application of the SMA algorithm directly integrated into the web system architecture to calculate maintenance material requirement predictions in the telecommunications supply chain has not been widely explored.

Based on this research gap, this study unites the recording of warehouse material flows with forecasting calculations. The SMA algorithm in this system is tasked with processing input variables in the form of historical material expenditure data, which is then calculated using the current average equation to generate an output in the form of predicted maintenance material requirement data for the subsequent period. The development of this software applies the Software Development Life Cycle (SDLC) Waterfall model and implements the CodeIgniter framework based on the Model-View-Controller (MVC) architecture [11]. System evaluation is conducted using the Black Box Testing method to test the suitability of functionality parameters [16], as well as the Mean Absolute Deviation (MAD) metric to calculate the absolute error from the developed algorithm's prediction results [15].

2. RESEARCH METHODS

2.1. Data Collection Method

The field case study was conducted at the telecommunication company warehouse in East Jakarta. Requirement specifications were gathered through direct observations of physical material flow documents, including receiving (INWAREHOUSE), quality control (INSTOK and SCRAP), and distribution (INUSE) logs. The data collection also involved structured interviews with area and branch warehouse staff to identify constraints within the conventional data recording system.

2.2. Research Stages

The software engineering procedure in this study applies the Software Development Life Cycle (SDLC) Waterfall model. This approach ensures that every requirement parameter is designed sequentially. The research phases consist of the initial phase (proposal and requirement analysis), the development phase (system architecture design and coding), and the final phase (testing and evaluation). The systematic stages are visualized in Figure 1.

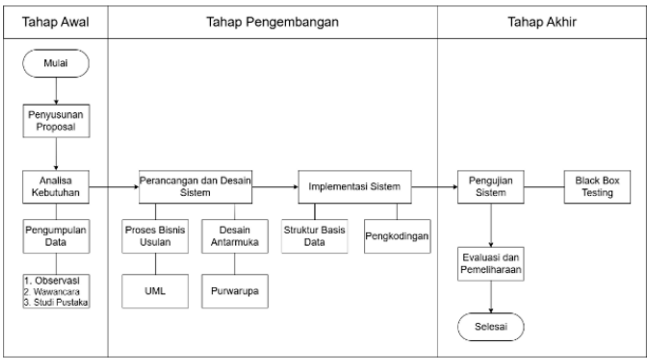

Figure 1. Research methodology and development stages

2.3. System Architecture and Database Design

The web-based supply chain information system was developed using the CodeIgniter framework based on the Model-View-Controller (MVC) architecture [11]. This structure independently separates the presentation layer, computational logic, and database interactions, utilizing a MySQL relational database to record centralized material transactions. To support the data governance and ensure a structured flow of information, the system's metadata is centralized within a MySQL relational database. The core metadata specifications are detailed in Table 1.

Table 1. Metadata Configuration of the Core System Entities

Entity (Table)	**Primary Metadata Attributes**	**Data Type**	**Description**
Materials	`id_material`, `qr_code`, `material_type`, `unit`	INT, VARCHAR, ENUM	Stores specific physical characteristics, categories, and identities of the warehouse logistics.
Distribution	`id_distribution`, `id_material`, `ticket_number`, `created_at`	INT, VARCHAR, TIMESTAMP	Records the chronological material expenditure logs (INUSE) utilized as the primary input.
Predictions	`id_prediction`, `periode_n`, `prediction_result`, `mad_error`	INT, VARCHAR	Stores computational variables, projected outputs, and absolute error metrics.

2.4. Algorithm Computational Logic

Instead of relying on manual assumptions, the mathematical instructions of the Single Moving Average (SMA) forecasting algorithm [13–15] are embedded dynamically into the system's controller. The computational logic flow of the algorithm executed by the system is illustrated in Figure 2.

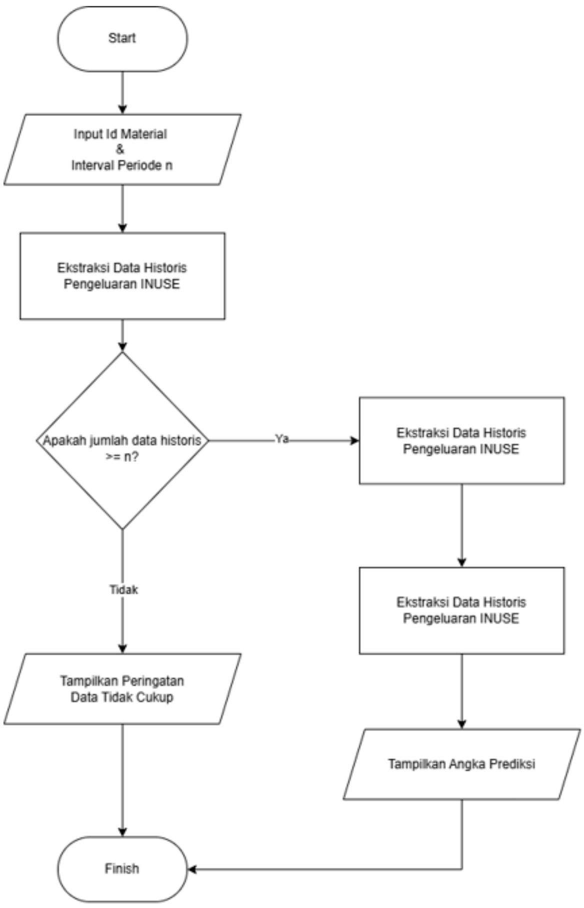

Figure 2. Single Moving Average algorithm computational logic

Based on Figure 2, the system is initiated by user input specifying the material identity and the forecasting period interval (n). The system then executes a validation query to ensure the sufficiency of historical data within the database. If the historical data volume meets the interval prerequisites, the system calculates the projection utilizing equation (1).

$$F_{t+1} = \frac{\sum_{i=1}^{n} A_{t-i+1}}{n} \tag{1}$$

Where F_{t+1} is the projected material forecasting value for the next period, A_{t-i+1} is the actual material usage amount in the previous period, and n is the moving average time interval.

To emphasize the computational logic, the mathematical instructions of the Single Moving Average algorithm were translated into a structured pseudocode integrated within the system's controller. The algorithm autonomously validates the adequacy of historical data before executing the forecasting loop, as demonstrated in the following pseudocode:

```
START
data_inuse[] = SELECT volume FROM distribution WHERE id = id_material
               ORDER BY date DESC LIMIT periode_n
IF LENGTH(data_inuse) < periode_n THEN
    PRINT "Error: Insufficient historical data"
    RETURN ERROR
ELSE
    sum_inuse = 0
    FOR i = 0 TO periode_n - 1 DO
        sum_inuse = sum_inuse + data_inuse[i]
    END FOR
    prediction_result = sum_inuse / periode_n
    INSERT INTO predictions (prediction_result)
    PRINT prediction_result
END IF
END
```

2.5. System Evaluation

To validate the system's reliability, the evaluation phase was divided into two main instruments. First, the application's functional reliability was evaluated using the Black Box Testing method with the Equivalence Partitions technique to verify input and output responses on the user interface [16]. Second, the predictive algorithm's accuracy was mathematically measured using the Mean Absolute Deviation (MAD) metric [15] through a backtesting approach. This instrument calculates the average absolute error between the actual operational data in the field and the system's prediction, as shown in equation (2).

$$\text{MAD} = \frac{\sum_{t=1}^{m} |A_t - F_t|}{m} \tag{2}$$

Where MAD is the average absolute error deviation, A_t is the actual material usage value in month t, F_t is the forecasting value for month t, t is the total historical data periods, and m is the backtesting evaluation interval.

3. RESULTS AND DISCUSSION

3.1. System Interface Implementation

The supply chain management information system was successfully developed and implemented using the CodeIgniter framework. The system interface is dynamically designed to facilitate warehouse staff in recording material movement circulation and to provide a specialized module for managerial users to execute predictive computations [17–20]. The interface implementation for the material requirement prediction feature is shown in Figure 3.

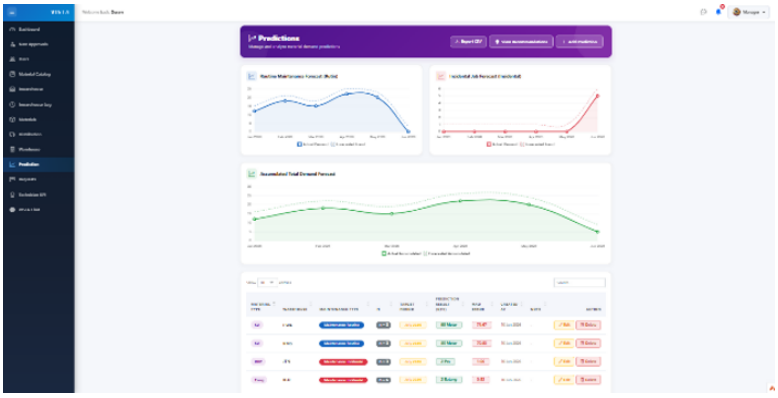

Figure 3. Single Moving Average prediction module interface

Based on Figure 3, users are presented with a comprehensive visual interface containing historical data movement graphs (forecast trend) and a form to set computational variables. The input parameters include the maintenance type, target branch warehouse, material category, and the moving average period interval (n). When the user executes the instruction, the system automatically extracts data from the distribution history log (INUSE) within the database. The visualization of the distribution history recording interface can be seen in Figure 4.

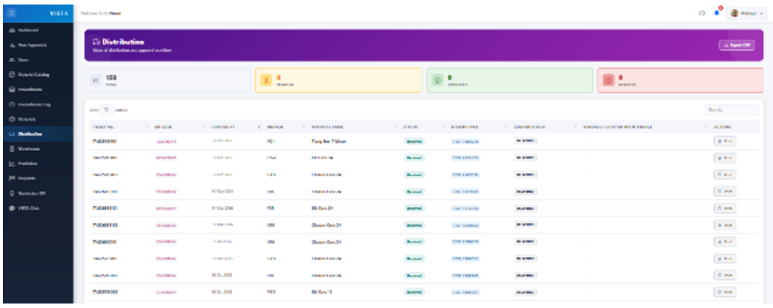

Figure 4. Distribution history recording module interface

3.2. System Functional Testing

Before evaluating the algorithm's architecture, the software passed a functional validation phase using the Black Box Testing method. This test focused on the Equivalence Partitions technique to verify the system's responsiveness to user inputs, particularly in error-handling scenarios. The summary of the test results on several crucial interface modules is detailed in Table 2.

Table 2. Black Box Testing Results on the System Interfaces

Test ID	Tested Module	Testing Scenario	Expected Output	Actual Output	Status
TC-01	Material Menu	Manage stock (search QR/SN & filter stock).	Real-time data, responsive search, filter by branch.	Displays data correctly according to branch, QR search dynamic.	Pass
TC-02	Material Request	Approve material request from technician.	Ticket status changes to Approved, creates delivery row.	Ticket status changes to Approved, distribution generated.	Pass
TC-03	Distribution Menu	Receive material by clicking Receive button.	English confirmation dialog, status changes to USED.	Dialog appears in English, material status updates to USED.	Pass
TC-04	Inbound Material	Move new materials using Shift All button.	English confirmation dialog, status changes to AVAILABLE.	Dialog appears in English, materials moved to main inventory.	Pass
TC-05	Prediction Menu	Generate and monitor forecast (SMA & MAD).	MAD error and timestamp filled, plotted on graph.	Prediction, MAD error, and timestamp displayed correctly.	Pass

Based on the comparison between the testing scenarios and the actual responses in Table 2, the evaluation validates that the fundamental modules of the software function dynamically. The 100% Pass status across all scenarios proves that the system's interface functionality can accommodate interactive instructions without triggering internal logic disruptions (bugs).

3.3. Predictive Computation and MAD Evaluation

The system automatically compared the projection figures with the actual field usage figures. The visual representation of these predictive computation results, which separates the forecast trends into routine maintenance, incidental jobs, and accumulated total demand, is dynamically plotted by the system as illustrated in Figure 5.

Figure 5. Forecasting trend graphs for routine, incidental, and accumulated material demand

The implementation of the system's computation based on operational data from the database is presented in Table 3.

Table 3. Prediction Computation Results and MAD Values

Material Type	**Warehouse**	**Period (n)**	**Prediction Result**	**MAD Value**
Kabel Udara (KU)/Aerial Cable	Cawang (CWA)	3	95 Meters	71.67
Kabel Udara (KU)/Aerial Cable	Rawamangun (RMG)	3	85 Meters	70.83
ODP	Jatinegara (JTN)	3	2 Pcs	1.06
Tiang/Iron Pole	Klender (KLD)	6	2 Poles	0.83

To prove the validity of the application's computation, a manual calculation validation was performed on one material sample, the Optical Distribution Panel (ODP) for the Jatinegara branch with a 3-period interval parameter ($n = 3$). Based on the database records, the actual usage history (INUSE) of the ODP material in the three previous periods (March, April, and May) were consecutively 1 Pcs, 3 Pcs, and 1 Pcs. The prediction calculation for the $(t + 1)$ period is executed using the SMA formula as follows:

$$F_{t+1} = \frac{1+3+1}{3} = \frac{5}{3} = 1.67 \text{ Pcs} \tag{3}$$

According to the computational logic of the warehouse system, the forecasting result is then rounded up (ceiling) to 2 Pcs to represent the whole physical form of the ODP material. This calculation result aligns perfectly with the output number displayed by the system in Table 3.

Furthermore, the forecasting error rate was comprehensively evaluated through the backtesting method. The system calculated the absolute deviation difference between the actual usage figures and the forecasting results over a 6-month testing interval (January to June 2026). The details of the error computation iterations executed by the system's controller are outlined in Table 4.

Table 4. Backtesting Iteration Details for ODP Material ($n = 3$)

Test Month	**Actual Usage**	**System Prediction**	**Absolute Error**
January 2026	1 Pcs	2.00	1.00
February 2026	2 Pcs	1.67	0.33
March 2026	1 Pcs	1.67	0.67
April 2026	3 Pcs	1.33	1.67
May 2026	1 Pcs	2.00	1.00
June 2026	0 Pcs	1.67	1.67

Based on the testing in Table 4, the system dynamically executed the moving average calculation from the three months prior to each test month. The calculation of the overall Mean Absolute Deviation (MAD) metric was obtained by accumulating all absolute error values in Table 4 and dividing it by the total testing periods (6 months), resulting in an average error of 1.06. This minimal absolute difference mathematically proves that the PHP source code instructions embedded in the software architecture have perfectly translated the Single Moving Average logic and the backtesting evaluation method.

3.4. Discussion

The results of this study demonstrate that the accuracy of the Single Moving Average (SMA) algorithm is highly contingent upon the demand characteristics of the material being forecasted. For unit-based materials with relatively stable consumption patterns, such as ODP ($n = 3$; MAD = 1.06) and iron poles ($n = 6$; MAD = 0.83), the system produced minimal absolute deviations, indicating that SMA is a reliable forecasting instrument when historical demand fluctuates within a narrow range. The lower MAD obtained for iron poles using a six-month window further illustrates the classic smoothing–responsiveness trade-off inherent in moving average models: a longer period ($n = 6$) dampens random noise more effectively for stable items, whereas a shorter period ($n = 3$) reacts more quickly to changes in demand. In contrast, the substantially higher MAD values recorded for meter-based aerial cable (71.67 and 70.83) reveal the algorithm's fundamental limitation, namely its assumption that future demand will approximate the average of recent periods; sudden, project-driven spikes in cable usage cannot be captured by an unweighted average, so the forecasts systematically lag behind actual field requirements. Importantly, because the manual validation of the ODP calculation ($(1 + 3 + 1)/3 = 1.67$, rounded up to 2 Pcs) matched the system output exactly and all Black Box test scenarios passed, these error deviations can be attributed to the nature of the demand data rather than to computational or functional defects in the software.

From a practical standpoint, the integration of SMA into a web-based supply chain system extends prior applications of the method in food product sales, tool trading, and spare-part oil inventory to the telecommunications maintenance domain, while simultaneously transforming forecasting from a manual, offline exercise into an automated decision-support capability. By embedding the mathematical logic directly into the system controller and linking it to the centralized distribution (INUSE) logs, the application eliminates the delays, calculation errors, and data discrepancies associated with the conventional paper-based recording described in earlier warehouse studies. The automatic extraction of historical data, validation of data sufficiency, and ceiling rounding of projection results into whole physical units ensure that the output is immediately actionable for procurement planning. Consequently, management is provided with a measurable and auditable reference parameter for determining purchase volumes, which directly addresses the risks of overstocking and stockouts identified as persistent problems in warehouse governance. The 100% pass rate in the functional testing further confirms that the Model-View-Controller architecture implemented in the CodeIgniter framework is robust enough to operationalize this predictive computation in a real working environment.

Nevertheless, several limitations must be acknowledged. The high error margins for meter-based materials confirm that SMA is less suitable for items whose demand is volatile and subject to sudden spikes, as the method assigns equal weight to all observations within the averaging window and cannot respond rapidly to structural changes in consumption. Moreover, the accuracy of the forecasts depends entirely on the quality and completeness of the historical input data, which in the current implementation is still entered manually and is therefore prone to human error. Future research should therefore explore comparative or hybrid forecasting techniques, such as Weighted Moving Average, Exponential Smoothing, or ARIMA, and consider adaptive period selection tailored to the demand pattern of each material type. On the system development side, integrating QR code scanners, a central API from the main server, and a mobile-responsive interface would further reduce input errors and accommodate the mobility of warehouse staff. From a managerial perspective, until more responsive algorithms are adopted, forecasts for highly fluctuating materials should be complemented with safety-stock policies to ensure that field maintenance operations are not disrupted by demand spikes.

4. CONCLUSION

Based on the research results, the web-based supply chain management application for the telecommunication company warehouse has been successfully developed using the CodeIgniter framework with a Model-View-Controller (MVC) architecture to centralize material data recording. The implementation of the Single Moving

Average (SMA) algorithm within the system's controller has proven capable of running dynamically to translate actual historical expenditure data into projected figures for future maintenance material requirements. The evaluation of the algorithm's computational capability using the Mean Absolute Deviation (MAD) instrument demonstrated that the system produces a minimal error percentage for whole physical unit materials, such as ODP ($n = 3$) with a MAD value of 1.06, and iron poles ($n = 6$) with a MAD of 0.83.

The integration of predictive computation into the warehouse information system provides a substantial practical contribution by replacing conventional procurement estimation methods that relied heavily on subjective assumptions. The implication of applying this algorithm is that it presents a precise and measurable logistical reference parameter for the management. Through this forecasting approach, stakeholders can accurately execute inventory procurement decisions, thereby effectively mitigating the potential risks of material overstocking or stockouts during ongoing field maintenance operations.

Despite these promising results, the algorithm's performance generated a relatively high error margin for meter-based materials due to extreme fluctuations in field requirements, indicating that the SMA algorithm is less suitable when sudden demand spikes occur. For future system development, it is recommended to integrate additional hardware, such as QR Code scanners, and a central Application Programming Interface (API) from the main server to prevent potential human errors during operational data input. Furthermore, development can be directed toward building a mobile-responsive interface to accommodate warehouse staff mobility, as well as applying other comparative predictive algorithms to perfect the prediction calculations for highly fluctuating material specifications.

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Steven Aditya Pratama: Conceptualization, Methodology, Software, Data curation, Writing – original draft.
Anita Ratnasari: Supervision, Methodology, Validation, Writing – review and editing.

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Data Availability:

The operational warehouse datasets that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy and corporate confidentiality restrictions of the telecommunication company.

AI Use Statement:

The authors declare that no generative AI or AI-assisted technologies were used during the preparation, writing, or analysis of this manuscript.

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