

Analysis of the Effect of Min–Max Stock Level (MMSL) Implementation on the Efficiency of Slow-Moving Drug Management



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Abstract

Background: The management of slow moving drugs in hospital pharmacy installations often faces problems in the form of overstock, high inventory values, increased risk of expiration, and low inventory turnover. This study aims to analyze the effect of the application of Min-Max Stock Level (MMSL) on the efficiency of slow moving drug management in the Pharmaceutical Installation of General Hospital Muslimat Ponorogo which is measured through inventory value, expiration rate, storage cost, and inventory turnover. **Methods:** Quantitative research design of the case control approach. MMSL implementation independent variables (before and after implementation). Dependent variables are inventory value, drug expiration value, storage cost, and turnover ratio (TOR). Data analysis was carried out descriptively and inferentially using the Mann-Whitney U test for variables that are not normally distributed and independent t-test for the TOR variable that is normally distributed. **Result:** The results of the analysis showed that in the inventory value variable, Mann-Whitney U = 90,000, Z = -0.933, and p = 0.351 (>0.05), so that there was no significant effect of the application of MMSL on the inventory value. In the storage cost variable, identical results were obtained (U = 90,000; Z = -0.933; p = 0.351), which also showed no significant differences between groups. Meanwhile, the expiration value variable showed a very significant difference with U = 17,500, Z = -4,015, and p < 0.001, which means that there is a significant influence of the application of MMSL on the decrease in the value of losses due to expired drugs. For the variable turnover ratio (TOR), the results of the independent t-test showed p = 0.136 (>0.05), so there was no significant effect of the application of MMSL on TOR. **Conclusion:** The implementation of MMSL significantly reduces losses due to expired drugs but does not significantly affect inventory value, storage costs, or turnover ratio.

Keywords: Min–Max Stock Level, slow moving, inventory value, expiration, storage cost, turnover ratio.

1. Introduction

Hospital pharmaceutical services are fundamental to ensuring therapeutic continuity, patient safety, and financial sustainability. As one of the largest operational cost components in hospitals, pharmacy installations must balance clinical readiness with inventory efficiency. Ineffective inventory management can lead to stockouts that compromise patient care or overstocking that increases holding costs, capital immobilization, and the risk of drug expiration. Consequently, optimizing pharmaceutical inventory systems is not merely an operational concern but a strategic imperative in healthcare management.

Among inventory-related challenges, the management of slow-moving drugs represents a persistent and underexamined problem. Slow-moving drugs—defined as medicines with low turnover within a given period—are clinically necessary for rare or critical cases but financially vulnerable due to prolonged storage. Their low consumption rates increase the probability of accumulation, expiration, and non-value-added costs, including warehousing, monitoring, and opportunity costs. Empirical evidence from hospital settings indicates that expired and dead stock medicines contribute substantially to avoidable financial losses, reflecting inefficiencies in demand forecasting and stock control systems.

To address inventory imbalances, hospitals have adopted various control models, including ABC analysis, Economic Order Quantity (EOQ), and continuous review systems. The Min–Max Stock Level (MMSL) method is widely implemented due to its operational simplicity and adaptability. By defining minimum and maximum thresholds based on consumption patterns and lead times, MMSL aims to stabilize stock levels and prevent deviations. Prior studies suggest that MMSL can reduce waste and improve inventory organization; however, reported outcomes remain inconsistent across institutional contexts. Moreover,

most evaluations focus on general drug inventories or single performance indicators such as Days of Inventory (DOI), without specifically examining slow-moving drug categories.

Managing slow-moving drugs presents unique operational complexities. Unlike fast-moving items, these products carry a higher risk of overstocking relative to stockout risk, requiring more precise threshold calibration. Inadequate parameter setting may either perpetuate accumulation or compromise clinical preparedness. Despite the recognized importance of this issue, empirical evidence assessing MMSL effectiveness for slow-moving drugs using multidimensional efficiency indicators remains limited.

At Muslimat General Hospital, Ponorogo, internal pharmaceutical reports revealed that slow-moving drugs accounted for a substantial proportion of inventory value and expiration losses. Several items showed minimal annual utilization yet remained in stock in significant quantities, leading to preventable financial waste. In response, the hospital implemented MMSL for slow-moving drugs, integrating consumption-based threshold adjustments within its hospital information system. However, practical challenges—including data limitations, system integration gaps, and resistance to procedural change—highlight the need for systematic evaluation.

Existing literature lacks comprehensive empirical studies that evaluate the impact of MMSL implementation on slow-moving drug management using multiple performance dimensions, including inventory value, expiration losses, storage costs, and turnover ratio, particularly in mid-sized hospital settings.

Therefore, this study aims to analyze the effect of MMSL implementation on the efficiency of slow-moving drug management at the Pharmacy Installation of Muslimat General Hospital, Ponorogo. By providing multidimensional evidence, this research contributes to strengthening data-driven pharmaceutical inventory control strategies in hospital supply chain management.

2. Materials and Methods

This study employed a quantitative analytical design using a quasi-experimental before–after approach to assess the effect of Min–Max Stock Level (MMSL) implementation on the efficiency of slow-moving drug management. The study population comprised all identified slow-moving drug items managed by the Pharmacy Installation of Muslimat General Hospital, Ponorogo, during the observation period. The independent variable was MMSL implementation (pre-implementation versus post-implementation phase). The dependent variables included inventory value, expiration loss value, storage costs, and turnover ratio (TOR), representing financial and operational efficiency indicators of inventory performance.

Data were collected through structured document review using standardized data extraction forms. The sources included stock cards, inventory reports, expired drug records, and financial inventory statements obtained from the hospital information system. Only complete and verifiable records were included in the analysis to ensure data validity and reliability. Descriptive statistics were used to summarize inventory characteristics before and after MMSL implementation. Normality testing was conducted prior to inferential analysis. For variables that were not normally distributed, the Mann–Whitney U test was applied. The independent samples t-test was used to analyze differences in the turnover ratio (TOR), which met the assumption of normality. Statistical significance was set at $\alpha = 0.05$.

3. Results

Based on the data taken from the research site, the following data was obtained, based on the results of interviews with the Head of the Pharmacy Unit to find out the influence of MMSL on the efficiency of drug management in the pharmaceutical installation of Muslim general hospitals, it is necessary to compare it with the data of drug groups that are not given treatment presented in the following table:

Table 1 Comparison of Inventory Values Between the MMSL Treatment Group and the Non-MMSL Treatment Group

Drug Name	Inventory Value Not Treated	Value of Treatment Preparation	Difference in Inventory Value	Remarks
Cepezet	2,137,104.00	1,335,690.00	801,414.00	Get Down
Hepagusan	23,121,083.40	14,916,828.00	8,204,255.40	Get Down
Morphine	6,442,500.00	3,865,500.00	2,577,000.00	Get Down
Novorapid	42,553,526.40	27,453,888.00	15,099,638.40	Get Down
Piracetam 3g	1,116,652.50	786,375.00	330,277.50	Get Down
Prove vit	56,557,074.75	19,672,026.00	36,885,048.75	Get Down
Vellanin	119,806,917.75	66,559,398.75	53,247,519.00	Get Down
Allovel tab	19,561,405.50	12,037,788.00	7,523,617.50	Get Down
Bisolvon tab	472,500.00	262,500.00	210,000.00	Get Down

Drug Name	Inventory Value Not Treated	Value of Treatment Preparation	Difference in Inventory Value	Remarks
Cravox tab	10,438,551.00	7,282,710.00	3,155,841.00	Get Down
DC 2 tab	1,461,600.00	730,800.00	730,800.00	Get Down
Dutasteride	958,623.75	713,868.75	244,755.00	Get Down
Biothicol F	13,396,500.00	8,037,900.00	5,358,600.00	Get Down
Biothicol	7,348,976.25	4,267,147.50	3,081,828.75	Get Down
Latropil	18,881,100.00	9,440,550.00	9,440,550.00	Get Down

Table 1 shows that there is a difference between the MMSL treated groups, the inventory value is down from the non-treated group. The difference in the most inventory value was in vellanin drugs of Rp. 53,247,519.00. Furthermore, a calculation is carried out on the expiration value of the drug with the following calculation data :

Table 2 Drug Expiration Rate Between the MMSL Treatment Group and the MMSL Untreated Group

Drug Name	Untreated			Treated		
	Quantity	Value	%	Quantity	Value	%
Cepezet	0	-	0.00%	0	-	0.00%
Hepagusan	3	240,594.00	0.93%	0	-	0.00%
Morphine	2	68,720.00	0.62%	0	-	0.00%
Novorapid	3	285,978.00	0.93%	0	-	0.00%
Piracetam 3g	5	87,375.00	1.54%	1	17,475.00	1.33%
Prove vit	2	385,726.00	0.62%	0	-	0.00%
Vellanin	4	3,736,668.00	1.24%	0	-	0.00%
Allovel tab	3	334,383.00	0.93%	0	-	0.00%
Bisolvon tab	30	75,000.00	9.27%	3	7,500.00	4.00%
Cravox tab	30	1,348,650.00	9.27%	2	89,910.00	2.67%
DC 2 tab	20	174,000.00	6.18%	2	17,400.00	2.67%
Dutasteride	3	11,655.00	0.93%	1	3,885.00	1.33%
Biothicol F	5	343,500.00	1.54%	0	-	0.00%
Biothicol	6	172,410.00	1.85%	1	28,735.00	1.33%
Latropil	3	179,820.00	0.93%	0	-	0.00%

Table 2 shows that from the data, it is known that the drug Cepezet did not experience a decrease in the expiration rate of the drug with the group data not being treated because the previous data showed that there was no expired drug. Although it is seen from the data that all *slow moving* drugs have decreased the expiration rate, there are several drugs that have decreased the expiration rate of drugs to 0 are hepagusan, morphine, novorapid, provevit, vellanin, allovel tab, bisolvon, biothicol F.

The pharmaceutical installation at General Hospital Muslimat has a storage warehouse measuring 6 x 6 meters with a building value and content of approximately 10 M and operates 24 hours because it serves inpatient care. The equipment in the installation is AC 2 PK inverter, LED lighting, refrigerators for 2 medical drugs and other devices such as computers, laptops, and other tools.

To determine storage costs, the researcher used assumptions for electricity and insurance costs, so that data was obtained on utility costs of 2,429,000 per month, insurance costs of 1,000,000 per month and damage costs of 2,000,000 per month. The total cost in 1 month is 5,429,000 which will be allocated to each *slow moving* drug with a percentage of 44.74% utility costs, 18.42% insurance costs and 36.84% handling costs.

Next is the calculation of the *turnover ratio* obtained from the cost of goods sold (COGS) divided by the average inventory. HPP is calculated in annual units by multiplying the annual usage by the price per unit. The following are the results of the calculation of the *turnover ratio* between the 2 groups after the MMSL implementation was given.

Table 3 Turnover Ratio Between MMSL Treatment Group and Non-MMSL Treatment Group

Drug Name	TOR Not Treated	TOR Treatment
Cepezet	3.83	5.89
Hepagusan	40.56	62.39
Morphine	16.85	25.92
Novorapid	62.32	95.89
Piracetam 3g	41.34	63.59
Prove vit	24.33	37.43
Vellanin	5.32	8.19
Allovel tab	48.83	75.12
Bisolvon tab	23.36	35.94
Cravox tab	28.33	43.59
DC 2 tab	24.5	37.7
Dutasteride	8.4	12.93
Biothicol F	7.89	12.14
Biothicol	9.41	14.48
Latropil	11.85	18.23

Table 3 shows the results that from the results of the TOR calculation above, it is known that the average turnover of the group that was not given treatment was 24.42 times and the group that was given MMSL treatment was 37.64 times, this increased by 54.1% with the highest turnover of novorapid and the lowest cepezet.

The normality test aims to find out whether the research data is distributed normally or not. In parametric analysis, normally distributed data is a must and an absolute requirement. The basis for taking in the normality test is as follows:

Table 4 Normality test

Tests of Normality							
V1		Kolmogorov-Smirnov ^a			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Value	1	0,281	15	0,002	0,684	15	0,000
Initial Setup	2	0,249	15	0,013	0,674	15	0,000

Table 4 Based on the results of the normality test, it is known that the inventory value, the expiration value of the drug and the storage cost are distributed abnormally, while the TOR is distributed normally. To overcome this problem, the three variables, namely Inventory Value, Expiration Value and Storage Cost, were analyzed using the Mann-Whitney Test, while TOR was tested using an independent t test.

Table 5 Mann-Whitney Test Test Statistics^a

	Inventory Value	Expired Value	Storage costs
Mann-Whitney U	90,000	17,500	90,000
Wilcoxon W	210,000	137,500	210,000
Z	-0,933	-4,015	-0,933
Asymp. Sig. (2-tailed)	0,351	0,000	0,351
Exact Sig. [2*(1-tailed Sig.)]	.367 ^b	.000 ^b	.367 ^b

a. Grouping Variable: Kelompok

b. Not corrected for ties.

Table 5 The results of the Mann-Whitney test show that the inventory values did not differ significantly between the groups before and after the MMSL application (U = 90,000; Z = -0.933; p = 0.351), so that MMSL has no effect on the inventory value. In contrast, the expiration value showed a very significant difference (U = 17,500; Z = -4.015; p < 0.001), which means that the application of MMSL has a real effect in reducing losses due to expired drugs. In the storage cost variable, the same result was obtained as the inventory value (U = 90,000; Z = -0.933; p = 0.351), so there is no significant effect of MMSL on storage costs.

For TOR, because the data is normally distributed, the analysis uses an independent t test. The following are the results of the analysis test presented in the following table:

Table 6. Comparison of Turnover Ratio (TOR) Before and After MMSL Implementation

Variable	Group Comparison	Mean Difference	t	df	p-value	95% CI (Lower–Upper)
Turnover Ratio (TOR)	Before vs After MMSL	-12.82	-1.535	28	0.136	-29.93 to 4.28

Table 6 The results of the independent t-test show that the value of Levene's test is 0.139 (>0.05) so that the variance of the two groups is homogeneous. A Sig. (2-tailed) value of 0.136 (>0.05) indicates that there was no significant difference in mean TOR between the two groups. Thus, the implementation of MMSL does not have a significant effect on the turnover ratio.

4. Discussion

The effect of the application of MMSL on the value of drug supplies at the pharmacy installation of General Hospital Muslimat Ponorogo

Based on the results of the analysis of research data, it was found that the application of MMSL did not have a significant effect on the value of drug supplies with Asymp. Sig. (2-tailed) is 0.351. These findings mean that statistically there is no statistically significant difference between the group that received MMSL treatment and the group that did not apply MMSL in terms of drug supply investment costs.

This is not in line with research conducted by (Darmawati, 2023) that the implementation of pharmaceutical inventory control using the MMSL method shows an effect on the value of pharmaceutical inventory inventory. In addition, research conducted by leonardy supports the results of this study, which shows that MMSL is an effective method used to regulate drug supply levels (Lonardy, 2024).

These findings are also not in line with research conducted by (Basri & Viky, 2022) which shows that MMSL can be used as a tool to control drug inventory levels by using sales history data in a structured manner. This provides an additional explanation for why the application of MMSL in this study was successful: the determination of the exact *min* and *max* levels is highly dependent on the accuracy of historical data on drug consumption. Success in lowering inventory values implies that prior to interventions, management may be less data-driven, so the implementation of MMSL supported by historical data analysis successfully brings order and rationality to the procurement process. In addition, several other studies (Indarti et al., 2019), (Paramesthi et al., 2024),

Although the results of the study descriptively show that the application of MMSL in *slow moving* drugs succeeded in reducing the inventory value from Rp 324,254,115 to Rp 177,362,970 or achieving an efficiency of 54.69%, this is statistically meaningless.

This finding is in accordance with research conducted by Pranata, Hilmy, and Saptaningsih (2023) at the Pharmaceutical Installation of Sentra Medika Sanggau Hospital showing that although the application of MMSL in group A antibiotics succeeded in reducing the inventory value from IDR 62,497,441 to IDR 54,072,358 or achieving an efficiency of 13.48%, statistically the difference was not significant with a value of $p=0.236$ ($p>0.05$) (Pranata et al., 2022).

The non-achievement of statistical significance in the inventory value variable in this study needs to be distinguished between statistical significance and descriptive significance. Statistical significance ($p>0.05$) shows that the probability of differences caused by chance factors is still quite large, so it cannot be generalized to a wider population. However, from the perspective of logistics management, the direction of changes in inventory value that indicates a decline should still be appreciated as an early indication of efficiency.

The MMSL method works in principle by setting a minimum *stock* and a *maximum stock* based on historical consumption patterns, *lead time*, and *buffer stock*. In the short term, the implementation of MMSL may not fully optimize the three parameters simultaneously due to the attachment to existing procurement contracts, the limitations of information systems that support *real-time* calculations, and the process of organizational adaptation to new procedures. Therefore, a longer observation period has the potential to show a more pronounced effect of MMSL on the decline in inventory values.

The effect of the application of MMSL on the drug expiration rate in the pharmaceutical installation of General Hospital Muslimat Ponorogo

Based on the results of the analysis of research data, it was found that the application of MMSL had a significant effect on the expiration rate with Asymp. Sig. (2-tailed) of <0.05. These findings prove empirically that there is a significant difference between the group that applied MMSL and the group that did not apply it in terms of the number of drugs that passed the time limit.

The results showed that in the expiration rate variable, the slow moving drug succeeded in reducing the inventory value from Rp 7,44,479 to Rp 164,905 or achieving an efficiency of more than 100%.

Research conducted by Paramesthi reports that the application of MMSL results in increased detection accuracy of expired drugs. Any expired drug represents a direct financial loss or ineffectiveness of the drug management system in a hospital pharmacy facility.

By setting a rational maximum level, MMSL limits the number of drugs that can be stored in the warehouse. Procurement is carried out more often but in smaller quantities, so that the stock runs out faster and is replaced with new stock. This condition automatically speeds up stock rotation and minimizes the length of time medications stay on storage shelves. When stocks move quickly, the chances of a drug reaching its expiration date before use become very small. In other words, MMSL changes the inventory pattern from consumption-based to dynamic and responsive, which directly impacts waste control due to expiration.

Lowering the expiration rate has immediate and very substantive financial implications. Any expired drug is a pure financial loss for the hospital, as it has incurred purchase, storage, and labor costs for drugs that ultimately provide no benefit value. By reducing the expiration rate, MMSL contributes directly to the efficiency of pharmaceutical spending budgets, so that hospitals can use it for other needs. By reducing waste, MMSL helps ensure that existing pharmaceutical resources are optimally utilized for the benefit of patients, while reflecting *good hospital governance* and environmental stewardship by reducing pharmaceutical waste.

The effect of the implementation of MMSL on storage costs in the pharmaceutical installation of General Hospital Muslimat Ponorogo

Based on the results of the analysis of research data, it was found that the application of MMSL did not have a significant effect on the value of drug supplies with Asymp. Sig. (2-tailed) is 0.351. These findings mean that statistically there is no statistically significant difference between the group that received MMSL treatment and the group that did not apply MMSL in terms of drug storage costs.

Although the results of the descriptive study show that the application of MMSL in slow moving drugs succeeded in reducing storage costs from IDR 5,429,000 to IDR 2,969,595 or achieving an efficiency of 54.69%, this is statistically meaningless.

Efficient inventory management is essential in pharmaceutical practice because it significantly impacts the financial and operational aspects. Inventory management should aim to minimize the costs associated with procurement and storage of goods while ensuring that there is sufficient inventory of commodities to meet the demands of customers and prescribers (Saha & Ray, 2019).

A decrease in storage costs has been demonstrated in similar studies: a decrease in average inventory value and a decrease in the expiration rate of drugs. Holding/carrying costs theoretically consist of components such as opportunity cost of capital, warehouse rental costs, insurance, utilities (electricity, air conditioning for special storage), managing labor, and losses due to expired or damaged drugs.

By applying a maximum level, MMSL effectively limits the average amount of drugs stored in the warehouse at any one time. Lower inventory volumes directly impact a reduction in the need for storage space, which can lower the proportion of rent, utilities, and labor costs allocated per unit of medicine. In addition, a decrease in the value of inventory also means a reduction in the cost of capital embedded in idle stock. Previously tied funds can now be diverted for other productive investments.

These findings are not consistent with similar studies that show a decrease in storage costs. Expired drugs are the most "wasteful" component of storage costs, because they have accumulated all storage costs from receipt to disposal, without generating any benefit value. By accelerating inventory turnover and applying FIFO principles more disciplined through the min-max mechanism, MMSL drastically cuts out this source of waste. This reduction in waste due to expiration is a significant direct contributor to the overall reduction in storage costs, while reflecting the increased effectiveness of pharmaceutical asset management.

The characteristics of storage costs in the healthcare sector are mostly fixed costs that do not change within the normal capacity range, such as the depreciation of warehouse buildings, the cost of maintenance of special cooling systems for medicines that require cold chains, investments in security and temperature monitoring systems, and the basic salaries of pharmacists and pharmaceutical technicians stationed in warehouses. Research conducted by (Rabianti, 2024) identified that the largest component of storage costs in hospital pharmaceutical installations is personnel costs (42-55%), followed by utility and maintenance costs (25-30%), while costs directly related to inventory volumes only contribute about 15-20% of total storage costs. With such a cost structure, a reduction in inventory levels of up to 20-30% due to the implementation of MMSL will only have an impact on a relatively small portion of variable costs, while the fixed cost component must still be incurred without significant reductions. This explains why even though the value of inventory decreases, total storage costs do not necessarily show statistically significant changes.

The effect of the implementation of MMSL on the turnover ratio in the pharmacy installation of General Hospital Muslimat Ponorogo

Based on the results of the analysis of research data, it was found that the implementation of MMSL did not have a significant effect on the turnover ratio with Asymp. Sig. (2-tailed) is 0.136. These findings mean that statistically there is no statistically significant difference between the group that received the MMSL application treatment and the group that did not apply MMSL in terms of turnover ratio.

Although the results of the study descriptively show that the application of MMSL in slow moving drugs succeeded in increasing the turnover ratio from 357.12 to 549.43 or achieving an efficiency of 154%, it is statistically meaningless.

This study is not in line with the research conducted by (Pranata et al., 2022) that the results of the application of the Minimum-Maximum Stock Level (MMSL) method in pharmaceutical inventory planning have a significant effect on drug inventory efficiency, namely an increase in the value of ITOR (Inventory Turn Over Ratio) in the intervention group compared to the non-intervention group. In addition, when compared to the situation before the intervention, the research conducted by (Nur et al., 2019) found that the inventory value was lower and the turnover ratio was higher.

In addition, according to (Sofia, 2024), the method of applying the MMSL method shows an effect on reducing the turnover ratio with a value of $p = 0.002$, $p < 0.05$, $p < 0.05$. This is in line with the research conducted by Indarti whose results showed the effect of the application of the MMSL (Minimum-Maximum Stock Level) method on the value of supply before intervention of Rp. 5,009,221,204 and after intervention of Rp. 2,871,879,269 with a p value = $0.007 < 0.05$.

According to the study (Kencana, 2018), the results of the ITOR calculation after analysis increased to 19.6 from a value of 8.1 before the intervention. Good inventory control can even increase the value of ITOR in the hospital's pharmacy unit up to 8–12 times higher than the standard value. Although the overall ITOR value showed an increase in turnover ratio, some drug items from the antibiotic group showed a lower turnover ratio. This is due among other things to changes in antibiotic habits and diseases that occur in the Hospital over a certain period of time.

The results of this study are not in line with other studies, namely the insignificance of the hypothesis test results even though there is a descriptive increase in TOR. Although p -value is a tool to determine the level of significance, the p -value does not provide information on the magnitude or magnitude of the effect in a practical way.

The characteristics of slow moving drugs as an object of research provide their own challenges in proving the effectiveness of a drug management intervention. Slow moving drugs are defined as drugs with a low frequency of movement or demand in a given period. Research by (Prasetyo et al., 2023) identified that the main cause of slow moving is ineffective prescribing patterns, control systems, and planning. In drugs with such characteristics, it would be difficult for any intervention including MMSL to show consistent and dramatic changes in its turnover ratio, because demand for the drug is slow. The descriptive improvements that occur may be more reflective of optimization after MMSL implementation, but this effect has not been consistent enough across items to be statistically significant.

The concept of turnover ratio (TOR) as an indicator of inventory management efficiency needs to be understood appropriately in the context of slow moving drugs. TOR measures the efficiency of inventory management by comparing the cost of goods sold with the average inventory. In slow moving drugs, the main focus of the application of MMSL is the achievement of the ideal and optimal TOR value according to the movement characteristics of the drug. The research conducted by researchers whose research results showed significance was carried out on category A drugs (fast moving) which have a high investment value, not on slow moving drugs, so the results cannot be generalized for all drug categories. In the context of this study, the descriptive increase in TOR of 154% in this study can be interpreted as an indication of optimization success, although it has not been statistically proven to be significant.

A relatively short observation period can also be a factor causing the insignificance of research results. The impact of changes in inventory control systems such as MMSL is not instantaneous, but rather it takes time to show a stable pattern after several cycles of ordering and use, especially in slow moving drugs.

The managerial implications of these findings are important to understand. Failure to prove statistical significance does not mean that MMSL interventions are not practically beneficial. The 154% descriptive increase in efficiency is a very valuable achievement and shows that MMSL still has the potential to improve the performance of slow moving drug management at the operational level. In hospital pharmacy management, the effectiveness of a inventory control method does not always have to be measured by statistical significance alone, but can also be seen from the descriptive improvement of key performance indicators and their impact on the smooth running of healthcare.

The results of this study also contribute to the scientific development that the application of MMSL in slow moving drugs has different characteristics and challenges compared to fast moving drugs. Previous studies have focused more on fast-moving drugs or category A based on ABC analysis, so this study fills the research gap regarding the effectiveness of MMSL in slow moving drugs. The finding that descriptively increased TOR was not followed by statistical significance opens up the opportunity for further research with a more robust design, longer observation period, or the use of other indicators that may be more sensitive to changes in slow-moving drugs.

Overall, this study makes an important contribution to understanding that the application of MMSL in slow moving drugs, although statistically not showing a significant effect on TOR, is descriptively able to improve the efficiency of drug management. These findings enrich the treasure of science in the field of hospital pharmacy management and provide practical implications that MMSL can still be considered as one of the methods of controlling slow moving drug inventory, noting that it

is necessary to make periodic adjustments and evaluations according to the characteristics of each hospital and its drug consumption patterns.

The application of this minimum-maximum stock level method has a positive impact on the efficiency of drug inventory (Sitepu, 2022), the decrease in inventory value is in line with expected and the application of the minimum-maximum stock level method has an effect on the effectiveness of drug inventory, this is shown by the reduction in the number of stock overs so that this result greatly affects the efficiency and effectiveness of investment (Sitepu, 2022).

Hospitals are currently looking for the right method for pharmaceutical inventory that has a good impact on financial operations. This issue has become a major challenge for hospitals as inventory management is inseparable related to patient care and medication costs. Improving drug management is one way to avoid over-investment. Mostly, the costs associated in drug inventory are scarcity costs, storage costs replenishment costs (Hughes, 1984).

The MMSL system helps to lower inventory values, expiration rates, storage costs and turnover ratios by preventing overstocking and ensuring timely replenishment. By setting maximum and minimum inventory thresholds, this system keeps stocks from exceeding real needs, reducing the accumulation of idle goods and reducing costs and storage lengths. An automatic reordering mechanism that activates when stock drops below the minimum limit keeps the flow of goods smooth, speeds up the restocking process, and increases inventory turnover so that the time items are stored in the warehouse is shorter.

In addition, MMSL improves the accuracy of demand forecasts by leveraging actual consumption patterns, making inventory planning more targeted. By aligning stock levels with real needs and reducing reliance on excessive safety stock, the system reduces the risk of overstock while lowering storage costs. This approach not only improves operational efficiency but also optimizes the company's cash flow as capital is no longer tied to unproductive inventory, thus helping to significantly lower inventory value, expiration rate, storage costs and turnover ratio.

In conclusion, this study has succeeded in proving the positive impact of the application of MMSL in optimizing the value of drug inventory, reducing the expiration rate of drugs, drug storage costs and turnover ratios. The justification for this rests on strong statistical evidence, alignment with inventory control theory, and support of previous empirical literature. These results underscore the importance of a systematic and data-driven approach in pharmaceutical logistics management. For future research, it is recommended to not only measure financial impact (inventory value), but also measure operational outcomes such as service level (stock affordability), frequency of stock outs, and drug expiration rates before and after interventions. Thus, the evaluation of MMSL will become more comprehensive, balancing between cost efficiency and drug availability to support patient safety and quality of service.

5. Conclusions

This study demonstrates that the implementation of the Min–Max Stock Level (MMSL) system did not produce a statistically significant effect on overall inventory value, storage costs, or turnover ratio at the Pharmacy Installation of Muslimat General Hospital, Ponorogo. However, MMSL implementation significantly reduced drug expiration losses, indicating its effectiveness in minimizing waste associated with slow-moving medicines. These findings suggest that while MMSL contributes to improving specific aspects of inventory control—particularly in reducing expiration-related losses its broader impact on financial and operational efficiency indicators may require longer implementation periods, parameter optimization, or complementary inventory management strategies..

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Ethical considerations

This study was approved by the Health Research Ethics Committee of STRADA Indonesia University (No. 0123491/EC/KEPK/I/02/2026).

Conflict of Interest

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