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Reducing Stockouts and Improving Inventory Performance of Category a Cardiovascular Drugs Through Kraljic Matrix and MMSL in Pharmacy in Indonesia

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ABSTRACT
Cardiovascular medicines require continuous availability because treatment interruptions may compromise chronic disease management. However, community pharmacies often experience stockouts, supply uncertainty, and inefficient inventory investment. This study aimed to evaluate the effectiveness of integrating the Kraljic Matrix and Minimum–Maximum Stock Level (MMSL) methods in improving the inventory performance of category A cardiovascular medicines at a community pharmacy in Bandung, Indonesia. A quasi-experimental pre–post design without a control group was applied using retrospective data from August–December 2025 and prospective data from January–May 2026. Thirty category A medicines were classified using the Kraljic Matrix, followed by quadrant-specific procurement strategies and MMSL calculations. Performance was assessed through stockout incidents, stockout duration, stockout losses, average inventory value, and Inventory Turnover Ratio (ITOR), with differences tested using the Wilcoxon signed-rank test. Stockout incidents decreased from 31 to 8, while median stockout duration and losses declined from four days and IDR 106,546 to zero. Median ITOR increased from 0.99 to 1.17, although average inventory value increased due to additional safety stock requirements. All indicators showed significant changes with large effect sizes. The integrated approach effectively reduced stockouts and improved inventory utilization, supporting risk-based procurement strategies for cardiovascular medicines in community pharmacies while maintaining treatment continuity and operational resilience.

INTRODUCTION

Cardiovascular drugs are critical components of pharmacy inventory, particularly for chronic disease management within insurance programs (Endarti et al., 2025; Nugraheni et al., 2023). Category A items within this group represent a significant proportion of inventory investment (Gizaw & Jemal, 2021), and mismanagement, whether through excess stock or shortages, can directly affect financial liquidity, sales opportunities, and service quality (Balkhi et al., 2022; Jaju et al., 2023). Given these implications, establishing robust inventory management systems is essential for maintaining both financial sustainability and continuity of patient care (Dewi et al., 2023; Jamil et al., 2022).

Pharmacies frequently encounter these challenges, which are further intensified by demand fluctuations and supply-chain disruptions (Cornelissen et al., 2026; George & Elrashid, 2023). Although methods such as Minimum–Maximum Stock Level (MMSL) are widely adopted due to their simplicity in maintaining inventory within acceptable ranges (Mohammed & Workneh, 2020; Chen et al., 2022), they primarily rely on historical demand patterns and may not adequately address critical supply risks (Rincón-Valenzuela & Gómez-Ardila, 2024; Barros et al., 2021). Conversely, the Kraljic Matrix provides a strategic framework for managing items based on supply risk and organizational impact (Arantes et al., 2022) ; however, its application remains largely separate from operational replenishment techniques such as MMSL (Tip et al., 2021).

Despite its practical value, MMSL is fundamentally a consumption-based operational approach and may not fully capture strategic risks associated with pharmaceutical procurement. Two products with similar consumption levels may differ substantially in supplier concentration, market availability, substitutability, price volatility, delivery reliability, and clinical importance. Therefore, relying solely on historical demand may generate stock parameters that appear mathematically sufficient but remain vulnerable to supply interruptions. Chen et al. (2022) demonstrated that pharmaceutical inventory performance can be improved through models incorporating operational constraints and uncertainty into inventory decisions. Similarly, George and Elrashid (2023) found that inventory management practices significantly influence pharmaceutical supply-chain performance in hospital pharmacies. These studies highlight the need to complement quantitative stock calculations with systematic assessments of supply risk and the organizational importance of each medicine.

The Kraljic Portfolio Matrix provides a strategic approach by positioning purchased items according to two dimensions: supply risk and profit or organizational impact. The resulting strategic, bottleneck, leverage, and non-critical quadrants support differentiated procurement decisions. Strategic products require close supplier collaboration and supply assurance; bottleneck products require risk mitigation and contingency planning; leverage products provide opportunities for negotiation and purchasing consolidation; and non-critical products can be managed through simplified procurement procedures. Medeiros and Ferreira (2018) adapted a purchasing portfolio model to the hospital context and demonstrated its usefulness in differentiating purchasing strategies. Tip et al. (2021) further showed that the Kraljic perspective helped explain hospital procurement responses during the COVID-19 pandemic, particularly when supply competition and scarcity increased. These findings suggest that Kraljic Matrix classification is relevant to health-care procurement, where supply failures may result in both financial and clinical consequences.

However, previous research has generally examined strategic procurement classification and operational stock control as separate domains. Studies applying ABC analysis, VEN analysis, MMSL, economic order quantity, or simulation-based optimization have primarily focused on consumption value, inventory quantities, procurement costs, or inventory turnover. Conversely, Kraljic Matrix-based studies have concentrated on supplier relationships, supply risk, competitive conditions, and purchasing strategies without directly translating classifications into item-level minimum and maximum stock parameters. Research on category A cardiovascular medicines has also calculated MMSL values without formally differentiating replenishment policies according to the supply-risk characteristics of each Kraljic quadrant. Consequently, empirical evidence remains limited regarding whether the integration of a strategic purchasing portfolio with an operational replenishment method can simultaneously reduce stockouts, improve inventory turnover, and maintain appropriate inventory investment in Indonesian community pharmacies.

Addressing this gap is important because neither uniform replenishment policies nor expenditure-based classifications adequately represent the heterogeneous risks of category A cardiovascular medicines. Products with high consumption and multiple reliable suppliers should not necessarily receive the same safety-stock treatment as clinically important products obtained from limited suppliers with longer or unstable lead times. Excessive inventory can tie up working capital and increase expiration risk, whereas insufficient inventory can result in lost sales and interruptions in chronic therapy. Therefore, a risk-sensitive inventory system is required to balance medicine availability and inventory efficiency. Integrating the Kraljic Matrix with MMSL may achieve this balance by using strategic classification to determine appropriate procurement responses and operational calculations to establish measurable replenishment limits for each medicine.

The novelty of this study lies in integrating Kraljic Matrix-based supply-risk classification with MMSL calculations for category A cardiovascular medicines and evaluating the combined intervention through before-and-after inventory performance indicators. Rather than using the Kraljic Matrix only to describe purchasing positions, this research translates its four quadrants into differentiated procurement and inventory strategies. MMSL parameters, including safety stock, minimum stock, maximum stock, and replenishment frequency, are aligned with consumption levels, lead times, and quadrant-specific supply risks. The intervention is evaluated using stockout occurrence, stockout duration, stockout-related financial losses, average inventory value, and the Inventory Turnover Ratio (ITOR). This framework connects strategic procurement decisions with measurable operational outcomes, an integration that remains limited in community-pharmacy research.

Accordingly, this study aims to develop and evaluate an integrated Kraljic Matrix–MMSL inventory management model for category A cardiovascular medicines at a community pharmacy in Bandung, Indonesia. Specifically, it seeks to classify selected medicines according to supply risk and organizational impact, calculate appropriate minimum and maximum stock levels, implement procurement strategies corresponding to each Kraljic quadrant, and compare inventory performance before and after the intervention. The study contributes theoretically by linking purchasing portfolio management with operational inventory control and contributes practically by providing pharmacy managers with a reproducible framework for prioritizing procurement resources. The expected benefits include improved medicine availability, reduced stockout duration, lower stockout-related losses, more efficient inventory investment, and stronger continuity of cardiovascular pharmaceutical services.

METHOD

This quasi-experimental study employed a quantitative before-and-after design without a control group to evaluate the integration of the Kraljic Matrix with the MMSL method at Pharmacy X. Retrospective data from August–December 2025 and prospective data from January–May 2026 were collected for category A cardiovascular drugs, selected through total sampling based on consumption value. Inclusion criteria required complete stock and transaction records, while incomplete or inconsistent data were excluded. The intervention was implemented through eight structured steps:

Step 1: Category A Determination. Consumption values for 2025 were calculated to identify items representing 70–80% of total expenditure.

Step 2: Content Validity Assessment. A three-member expert panel reviewed the Kraljic questionnaire. Validity was quantified using I-CVI, S-CVI, and CVR indices.
Step 3: Kraljic Matrix Classification. Drug positioning used a fuzzy multi-attribute decision-making approach and Multidimensional Scaling (MDS) to assess supply risk and profit impact.
Step 4: Procurement Strategy Implementation. Customized strategies (e.g., supplier development, inventory control) were applied based on quadrant classification.
Step 5: MMSL Calculation. Minimum and maximum stock levels were established for high-risk items using average daily usage and Safety Lead Time (SLT).
Step 6: Performance Indicator Recording. Data on stockout frequency, duration, loss value, average inventory, and ITOR were recorded for comparison.
Step 7: Data Validation. Validity was maintained through cross-checking system data with physical stocktaking results.
Step 8: Statistical Analysis. Data were processed using IBM SPSS Statistics software (version 26.0). Descriptive statistics were expressed as median and interquartile range (IQR) or mean and standard deviation, as appropriate. Differences in inventory performance indicators between the pre- and post-intervention periods were analyzed using the non-parametric Wilcoxon signed-rank test. To evaluate the practical significance of the intervention, the effect size (r) was calculated using the formula $r = Z / \sqrt{N}$ (Cohen, 1988). A p-value of <0.05 was considered statistically significant (Field, 2018).

Secondary operational data was used with written permission from Pharmacy X. Data remained de-identified; thus, formal ethical approval was not required.

RESULT AND DISCUSSION

Based on the ABC analysis results of cardiovascular drug investments in Table 1, there is a significant disparity between the number of drug items and their investment value. Group A consists of 30 drug items (12.19% of the total 246 items), but absorbs an investment of IDR 682,616,291 or 71.52% of the total drug usage value. This indicates that a small number of drug items consume a large portion of the budget, so this group requires the strictest inventory control through accurate demand planning, regular stock monitoring, and special oversight of stockout and overstock risks.

Table 1. ABC analysis based on investment in cardiovascular drugs

Group	Number of Drugs	%	Value of Usage (IDR)	%
A	30	12,19	682.616.291	71,52
B	61	24,79	211.404.964	22,15
C	155	63,02	60.349.976	6,33
Total	**246**	**100**	**954.371.231**	**100**

The content validity of the instrument was evaluated by three experts with competence in the relevant field. Table 2 showed that all items received an I-CVI score of 1.00, indicating full agreement among the experts regarding the relevance of each item. The S-CVI/Ave and S-CVI/UA scores were also 1.00; the instrument is considered to have very good content validity, and all items were retained.

Table 2. The summary items (I-CVI, UA and CVR) which were retained for the understanding domain of Kraljic Mapping Questionnaire

Dimension	Aspect	Item	Number of Panel Agree on the Relevancy of Item	I-CVI	UA	CVR	Comments	Decision
Impact on profits	Impact on pharmacy	The availability of this drug greatly affects the smoothness of service and the pharmacy's revenue.	3	1	1	1	-	Retained
	Total purchase	The purchase volume is relatively smaller compared to other medications at the pharmacy.	3	1	1	1	-	Retained
	The importance of drug	This medication is important and frequently prescribed in pharmacy services.	3	1	1	1	-	Retained
	Price	The price of this medicine is relatively high and imposes a significant burden on pharmacy inventory costs.	3	1	1	1	-	Retained
Supply risk	Market risk	The market for this drug often experiences shortages or fluctuations, making it difficult for pharmacy to plan their procurement.	3	1	1	1	-	Retained
	Availability of drug	This drug is generally available at distributors when pharmacy need it.	3	1	1	1	-	Retained
	Drug substitution	This drug does not have an equivalent	3	1	1	1	-	Retained

		substitute in case of a pharmacy shortage.						
	Number of alternative suppliers	The pharmacy has more than one distributor that can supply this drug.	3	1	1	1	-	Retained
	Time required for delivery	The delivery of this drug from the distributor often experiences delays.	3	1	1	1	-	Retained
	Quality risk	The quality of this drug is relatively guaranteed because it comes from a trusted distributor.	3	1	1	1	-	Retained
	S-CVI/UA			1				
	S-CVI/Ave			1				

Ave: Average; CVR: Content Validity Ratio; I-CVI: Item-level Content Validity Index; S-CVI: Scale-level Content Validity Index; UA: Universal Agreement

Based on the analysis using the Kraljic Portfolio Matrix on 30 cardiovascular system drug items, the distribution of items into four quadrants based on supply risk and profit impact was obtained. The mapping results show that most drug items are in the Non-Critical and Bottleneck quadrants, while a small portion is in the Leverage and Strategic quadrants.

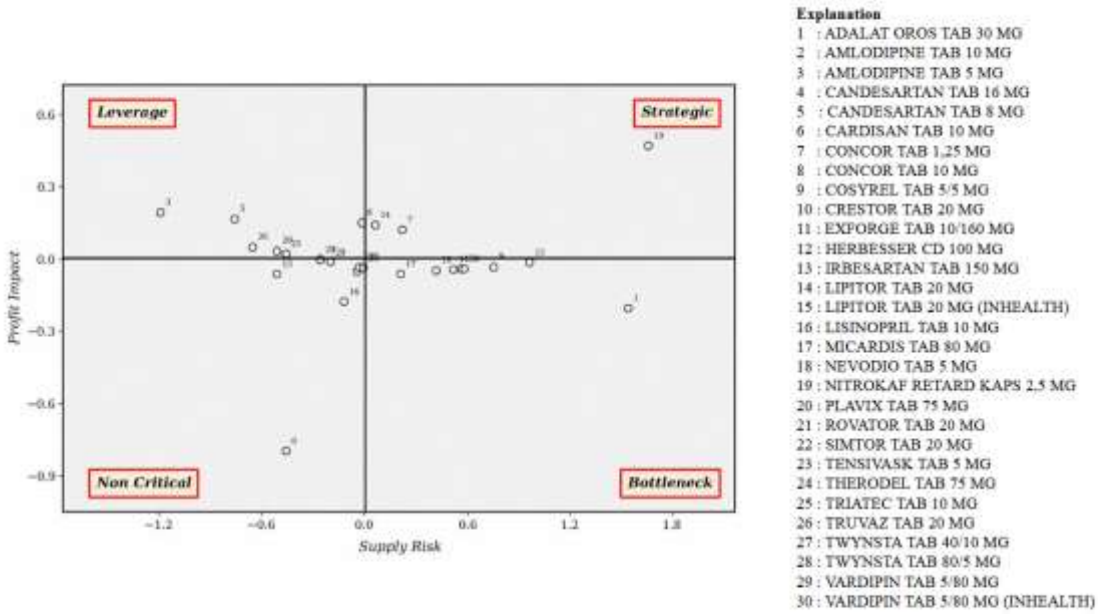

Figure 1. Cardiovascular drugs in the pareto category A position in Kraljic Portofolio Model

The identity of cardiovascular drugs in the pareto category A is coded to simplify visualization (Figure 1). As many as 3 drug items (10.0%) fall into the Strategic quadrant. Items in this quadrant have a positive profit impact value and high supply risk, thus making a significant contribution to service while also having relatively high supply risk. As many as 8 drug items (26.7%) are in the Leverage quadrant. This group has a high profit impact but a low supply risk, providing an opportunity for the organization to achieve cost efficiency through price negotiations, long-term purchase contracts, or volume purchase consolidation. As many as 8 drug items (26.7%) fall into the Bottleneck quadrant. Items in this group have a high supply risk but a low profit impact, so although their economic contribution is relatively small, the risk of stockouts can disrupt service continuity. Therefore, risk mitigation strategies such as increasing safety stock, diversifying suppliers, or appropriate therapy substitution are needed. As many as 11 drug items (36.6%) are in the Non-Critical quadrant. This group has a low profit impact and low supply risk, so it can be managed through routine procurement procedures with a focus on administrative efficiency and simple stock control. Overall, the mapping results show that 36.7% of cardiovascular drug items fall into the category that requires special attention (Strategic and Bottleneck). This condition indicates that inventory management cannot be conducted with a uniform approach. Procurement strategies need to be adjusted according to the characteristics of each quadrant, especially for Strategic and Bottleneck items that have a higher supply risk compared to other groups. Thus, the application of the Kraljic Portfolio Matrix can help prioritize procurement resources to ensure the availability of medicines while also improving inventory cost efficiency.

Based on the Kraljic Portfolio Matrix classification, a total of 30 cardiovascular drug items classified as Strategic (n = 3), Bottleneck (n = 8), Leverage (n = 8) and Non-Critical (n = 11) categories in Pareto category A were further analyzed using the minimum–maximum stock method. The analysis incorporated average consumption (CA), lead time (LT), procurement period (PP), safety stock (SS), minimum stock (Smin), and maximum stock (Smax).

Table 3 Result of minimum and maximum stock calculation for non-critical and leverage cardiovascular drugs in the category A

No	Drug Name	Dosage Form	Kraljic Category	CA	LT (Day)	PP (Day)	SS	Smin	Smax
1	Amlodipine 10 mg	Tablet	Leverage	263	4	7	1,138	2,277	4,117
2	Amlodipine 5 mg	Tablet	Leverage	333	4	7	1,384	2,768	5,102
3	Candesartan 16 mg	Tablet	Leverage	67	2	7	128	257	725
4	Candesartan 8 mg	Tablet	Leverage	70	2	7	118	235	728
5	Concor® 10 mg	Tablet	Leverage	13	3	7	35	70	160
6	Plavix® 75 mg	Tablet	Leverage	10	1	7	10	19	87
7	Triatec® 10 mg	Tablet	Leverage	2	2	7	3	5	17
8	Truvaz® 20 mg	Tablet	Leverage	2	2	7	3	5	17
9	Cardisan® 10 mg	Tablet	Non-Critical	2	2	7	4	9	22
10	Herbesser CD® 100 mg	Capsule	Non-Critical	4	2	7	8	16	44
11	Irbesartan 150 mg	Tablet	Non-Critical	25	2	7	59	118	293
12	Lisinopril 10 mg	Tablet	Non-Critical	73	3	7	197	393	903
13	Rovator® 20 g	Tablet	Non-Critical	10	1	7	15	30	101
14	Simtor® 20 mg	Tablet	Non-Critical	2	1	7	2	4	19
15	Tensivask® 5 mg	Tablet	Non-Critical	3	1	7	3	6	27
16	Therodel® 75 mg	Tablet	Non-Critical	1	1	7	1	3	12

17	Twynsta® 40/10 mg	Tablet	Non-Critical	1	1	7	1	2	9
18	Twynsta® 80/5 mg	Tablet	Non-Critical	4	2	7	6	13	39
19	Vardipin® 5/80 mg	Tablet	Non-Critical	6	1	7	6	11	50

CA: Consumption Average (average daily usage); LT: Lead Time (order waiting time); PP: Procurement Period; SS: Safety Stock; Smin: Stock Minimum; Smax: Stock Maximum

Table 3 showed considerable variation in inventory requirements among drug items. Average daily consumption ranged from 1 to 333 units/day, while lead time varied between 1 and 4 days. Safety stock values ranged from 1 to 1,384 units, minimum stock levels ranged from 2 to 2,768 units, and maximum stock levels ranged from 9 to 5,102 units.

Among all items, Amlodipine 5 mg demonstrated the highest inventory requirement, with a safety stock of 1,384 tablets, minimum stock of 2,768 tablets, and maximum stock of 5,102 tablets, followed by Amlodipine 10 mg with a safety stock of 1,138 tablets, minimum stock of 2,277 tablets, and maximum stock of 4,117 tablets. Both drugs also exhibited the highest average consumption rates, namely 333 tablets/day and 263 tablets/day, respectively.

In contrast, the lowest inventory requirements were observed in Therodel® 75 mg and Twynsta® 40/10 mg, which recorded safety stock values of only 1 tablet, minimum stock levels of 2–3 tablets, and maximum stock levels of 9–12 tablets. These values reflect their relatively low consumption rates.

Within the Leverage category, Amlodipine and Candesartan products consistently showed higher safety stock, minimum stock, and maximum stock values than other items. Meanwhile, in the Non-Critical category, Lisinopril 10 mg presented the highest inventory requirement, with a safety stock of 197 tablets, a minimum stock of 393 tablets, and a maximum stock of 903 tablets.

Overall, the calculated stock levels indicate that inventory requirements among non-critical and leverage cardiovascular drugs are primarily influenced by average consumption and lead time, resulting in substantial differences in safety stock and stock control limits between items.

Table 4. Result of minimum and maximum stock calculation for bottleneck and strategic cardiovascular drugs in the category A

No	Drug Name	Dosage Form	Kraljic Category	CA	LT* (Day)	PP (Day)	SS	Smin	Smax
1	Adalat Oros® 30 mg	Tablet	Bottleneck	32	4	7	140	279	506
2	Cosyrel® 5/5 mg	Tablet	Bottleneck	2	4	7	6	12	23
3	Crestor® 20 mg	Tablet	Bottleneck	6	3	7	15	30	70
4	Exforge® 10/160 mg	Tablet	Bottleneck	2	4	7	8	16	31
5	Lipitor® 20 mg (Inhealth)	Tablet	Bottleneck	7	4	7	26	51	97
6	Micardis® 80 mg	Tablet	Bottleneck	1	6	7	7	15	24
7	Nevodio® 5 mg	Tablet	Bottleneck	4	3	7	10	21	48
8	Vardipin® 5/80 mg (Inhealth)	Tablet	Bottleneck	6	3	7	15	30	69
9	Concor® 1,25 mg	Tablet	Strategic	27	5	7	127	255	445
10	Lipitor® 20 mg	Tablet	Strategic	8	3	7	26	52	110

11	Nitrokaf Retard® 2,5 mg	Capsule	Strategic	48	9	7	415	830	1,164

CA: Consumption Average (average daily usage); LT*: Lead Time (order waiting time) calculated based on the formula developed by Ayala et al (2024); PP: Procurement Period; SS: Safety Stock; Smin: Stock Minimum; Smax: Stock Maximum

Table 4 revealed substantial variation in inventory requirements among the analyzed items. Average daily consumption ranged from 1 to 48 units/day, while lead time varied between 3 and 9 days. Safety stock values ranged from 6 to 415 units, minimum stock levels ranged from 12 to 830 units, and maximum stock levels ranged from 23 to 1,164 units.

Among all items, Nitrokaf Retard® capsule 2.5 mg, classified as a Strategic item, exhibited the highest inventory requirement, with a safety stock of 415 units, minimum stock of 830 units, and maximum stock of 1,164 units. This item also showed the highest average daily consumption (48 units/day) and the longest lead time (9 days), indicating a greater need for inventory buffering to mitigate supply disruption risks.

The second-highest inventory requirement was observed for Adalat Oros® 30 mg, a Bottleneck item, with a safety stock of 140 units, minimum stock of 279 units, and maximum stock of 506 units. Meanwhile, Concor® 1.25 mg, categorized as Strategic, recorded a safety stock of 127 units, a minimum stock of 255 units, and a maximum stock of 445 units.

Conversely, the lowest inventory requirements were found in Cosyrel® 5/5 mg and Exforge® 10/160 mg, which had safety stock values of 6–8 units, minimum stock levels of 12–16 units, and maximum stock levels of 23–31 units. These lower stock levels were associated with relatively low consumption rates despite their classification as high supply-risk items.

Overall, the calculated inventory parameters indicate that strategic and bottleneck cardiovascular drugs require higher safety stock levels and broader inventory control limits compared with other Kraljic categories. The variation in stock requirements was primarily influenced by differences in average consumption and lead time, particularly among strategic items characterized by both high clinical importance and elevated supply risk.

Table 5. Comparison of inventory performance indicator before and after implementation Kraljic and MMSL

Indicator	Before implementation (august – december 2025)	After implementation (january – may 2026)
Incident of stockout (times)	31	8
Duration of stockout (days)	4 [0-12] [a]	0 [0-1] [a]
Value of stockout loss per incident (IDR)	106,546 [0-1,032,649] [a]	0 [0-18,796] [a]
Inventory Turnover Ratio (times/year)	0.99 [0.95-1.04] [a]	1.17 [1.16-1.17] [a]
Average inventory value (IDR)	824,385 ± 790,920 [b]	2,198,599 ± 2,609,904 [b]

Description: a = median [interquartile range]; b = mean ± standard deviation

Table 5 shows a comparison of inventory performance indicators before and after the implementation of the procurement strategy based on the Kraljic Matrix and MMSL. After the intervention, all indicators related to stockout occurrences showed improvement.

The incident of stockout decreased from 31 times to 8 times. A more noticeable reduction was observed in the duration of stockouts, which decreased from a median of 4 days (IQR 0-12) to 0 days (IQR 0-1) after the implementation of the intervention.

The value of losses due to stockouts also decreased. The median value of stockout loss per incident decreased from IDR 106,546 (IQR 0-1,032,649) in the pre-implementation period to IDR 0 (IQR 0-18,796) in the post-implementation period.

In addition, there was an improvement in inventory turnover performance. The Median Inventory Turnover Ratio (ITOR) increased from 0.99 times/year (IQR 0.95-1.04) to 1.17 times/year (IQR 1.16-1.17) after the implementation of the Kraljic Matrix and MMSL strategies.

On the other hand, the average inventory value increased from IDR 824,385 ± 790,920 to IDR 2,198,599 ± 2,609,904. This increase in inventory value indicates the addition of safety stock and buffer inventory as a consequence of a more conservative procurement strategy for items with high supply risk, which, in turn, contributes to a decrease in stockout occurrences and an increase in ITOR.

Table 6. Effect of Kraljic and MMSL implementation on inventory performance indicator: A pre-post analysis

Indicator	Z	p-value	Effect size (r)
Incident of stockout (times)	-3.157	0.002	0.576
Duration of stockout (days)	-3.180	0.001	0.581
Value of stockout loss per incident (IDR)	-3.376	0.001	0.616
Inventory Turnover Ratio (times/year)	-4.783	0.000	0.873
Average inventory value (IDR)	-4.083	0.000	0.745

Table 6 presents the results of the Wilcoxon Signed-Rank test, showing that the implementation of the procurement strategy based on the Kraljic Matrix and MMSL resulted in significant changes in all inventory performance indicators ($p < 0.05$). The frequency of stockouts ($Z = -3.157$; $p = 0.002$), the duration of stockouts ($Z = -3.180$; $p = 0.001$), and the value of losses due to stockouts ($Z = -3.376$; $p < 0.001$) experienced significant reductions. Additionally, the Inventory Turnover Ratio (ITOR) increased significantly ($Z = -4.783$; $p < 0.001$), while the Average Inventory Value also experienced significant changes ($Z = -4.083$; $p < 0.001$). The effect size values indicate a significant impact on all indicators ($r = 0.576$-0.873), with the largest influence found on ITOR ($r = 0.873$).

The present study demonstrated that the integration of the Kraljic Matrix procurement strategy with the MMSL method significantly improved inventory management performance across all evaluated indicators. The most notable finding was the substantial reduction in stockout-related indicators, as reflected by the decline in median stockout occurrence from 1 to 0 events, median stockout duration from 4 days to 0 days, and median stockout loss value from IDR 106,546 to IDR 0. These findings suggest that the intervention successfully enhanced medicine availability and service continuity by improving supply assurance for category A cardiovascular drugs. A systematic review conducted by Sulistioningsih et al (2026) reported that inventory control interventions can reduce the frequency of stockouts and improve service levels; however, the simultaneous improvements observed in stockout occurrences, duration, and financial losses in this study indicate a broader strengthening of inventory resilience and replenishment performance. More importantly, the decrease in the stockout indicator was accompanied by a significant increase in the Inventory Turnover Ratio (ITOR), which rose from a median of 0.99 to 1.17 times per year and showed the largest effect size among all evaluated outcomes ($r = 0.873$). ITOR is an important indicator of inventory efficiency because it reflects how effectively the working capital invested in inventory is used. A higher ITOR indicates that the available stock is converted into consumption or sales more quickly, thereby reducing the risk of idle capital and increasing inventory productivity. Suprapto et al (2023) conducted a study on the pharmaceutical inventory system during the COVID-19 pandemic and reported that low ITOR values are often associated with an imbalance between inventory availability and drug consumption patterns. Therefore, the increase in ITOR observed in this study indicates that inventory availability has improved without sacrificing operational efficiency, as the available stock continues to circulate productively to meet patient demand.

A particularly interesting finding of this study was the simultaneous increase in average inventory value from IDR 824,385 ± 790,920 to IDR 2,198,599 ± 2,609,904 and Inventory Turnover Ratio (ITOR) from 0.99 to 1.17. Conventional inventory management theory suggests that increasing inventory investment may reduce inventory turnover when stock accumulation is not accompanied by a proportional increase in inventory utilization, as larger amounts of working capital become tied up in inventory holdings. Under such circumstances, higher inventory levels may lead to slower stock movement and lower inventory efficiency. However, the findings of the present study demonstrated a different pattern, indicating that the additional inventory generated through the intervention was effectively utilized rather than remaining as idle stock. One possible explanation for this phenomenon lies in the characteristics of the study population, which consisted exclusively of category A cardiovascular medicines. Category A medicines typically represent a relatively small proportion of total inventory items but account for the majority of inventory expenditure and consumption, making them the primary focus of inventory control interventions (Gizaw & Jemal, 2021). Because these medicines are characterized by consistently high demand and utilization rates, the additional inventory introduced through the intervention was likely absorbed rapidly through routine dispensing activities. Consequently, although inventory investment increased, inventory utilization increased proportionally, resulting in improved medicine availability, reduced stockout events, and a higher ITOR. These findings suggest that the increase in average inventory value should not be interpreted as evidence of overstocking, but rather as a strategic inventory investment that enhanced service continuity while maintaining inventory efficiency.

The observed increase in inventory value may also reflect the implementation of a risk-based inventory allocation strategy through the integration of the Kraljic Matrix and MMSL. Rather than applying a uniform inventory policy across all medicines, the Kraljic Matrix enables organizations to identify medicines with higher supply risk and strategic importance (Gelderman & Van Weele, 2003). Consequently, inventory resources can be allocated more selectively toward medicines that are more vulnerable to supply disruption. In the present study, this approach likely resulted in larger safety stock allocations for strategic and bottleneck items, contributing to the increased variability in inventory value observed after implementation. This finding is consistent with the principle of risk-based procurement, which advocates allocating inventory resources according to supply vulnerability and operational impact rather than applying a uniform stocking policy across all items. Therefore, the observed increase in inventory value should not necessarily be interpreted as overstocking, but rather as a deliberate risk-mitigation strategy designed to reduce stockout events and improve service continuity (Tip et al., 2021).

The practical significance of the intervention was further supported by the large effect sizes observed across all performance indicators (r = 0.576–0.873), indicating that the improvements were not only statistically significant but also operationally meaningful. Notably, the strongest effect was observed for ITOR, suggesting that the intervention was particularly effective in improving inventory efficiency rather than merely reducing stockout events. From a managerial perspective, these findings support the complementary role of the Kraljic Matrix and MMSL within pharmaceutical inventory management. While the Kraljic Matrix provides a framework for identifying which medicines require prioritization based on supply risk and strategic importance, MMSL determines the appropriate stock levels required to maintain availability. Therefore, the novelty of this study lies in demonstrating that combining a risk-based procurement framework with a stock-level optimization method can simultaneously improve service level, reduce stockout-related losses, and enhance inventory efficiency. The findings suggest that effective pharmaceutical inventory management should not focus exclusively on minimizing stock levels but rather on strategically allocating inventory according to both consumption patterns and supply risk characteristics.

CONCLUSION

The integration of the Kraljic Matrix procurement strategy with the Minimum–Maximum Stock Level (MMSL) method significantly improved inventory management performance for category A cardiovascular drugs at Pharmacy X. Following the intervention, stockout occurrences decreased from 31 incidents to 8 incidents, while the median stockout duration decreased from 4 days to 0 days. The median stockout loss value also decreased from IDR 106,546 to IDR 0, indicating a substantial reduction in inventory shortages and associated financial losses

Inventory efficiency improved significantly after the intervention, as reflected by the increase in the Inventory Turnover Ratio (ITOR) from 0.99 to 1.17 times per year ($p < 0.001$). Although the average inventory value increased from IDR 824,385 ± 790,920 to IDR 2,198,599 ± 2,609,904 ($p < 0.001$), this increase was accompanied by higher inventory turnover and lower stockout-related indicators, suggesting that the additional inventory was effectively utilized to support medicine availability.

The Wilcoxon signed-rank test demonstrated significant differences between the pre- and post-intervention periods across all evaluated indicators, including stockout occurrence, stockout duration, stockout loss value, ITOR, and average inventory value ($p < 0.05$). Effect-size analysis showed large effects for all indicators (r = 0.576–0.873), indicating that the intervention produced meaningful operational improvements. These findings indicate that integrating the Kraljic Matrix with MMSL was effective in reducing stockout-related problems while improving inventory utilization among category A cardiovascular drugs.

Future studies should evaluate the long-term sustainability of Kraljic Matrix and MMSL integration and assess its effectiveness across different therapeutic categories and health-care settings. Further research may also compare this approach with other inventory-control methods to determine the most effective strategies for improving pharmaceutical inventory performance.

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