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Achieving Hospital Efficiency through Inventory Management Strategies: A Systematic Review

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ABSTRACT

Background: In developing countries, pharmaceutical expenditures account for approximately 40–50% of total hospital costs. Therefore, effective management of medicines and pharmaceutical supplies is essential, as it significantly influences hospital operational efficiency and the quality of healthcare services.

Objectives: This study aims to evaluate the impact of Economic Order Quantity (EOQ), Reorder Point (ROP), and Minimum-Maximum Stock Level (MMSL) inventory management methods on hospital efficiency.

Methods: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were applied to operate this systematic review. The articles published between 2009 and 2024 were identified through searches of Scopus, PubMed, Google Scholar, and the Garuda database. Studies that reported the application of EOQ, ROP, or MMSL methods in hospital pharmaceutical inventory management were included. A total of nine eligible studies were reviewed and synthesized to evaluate their impact on inventory efficiency indicators.

Results: Nine studies met the inclusion criteria. Four studies applied EOQ and ROP methods, while five studies implemented the MMSL methods. The efficiency indicators evaluated inventory value, dead stock, stock out, inventory turnover ratio (ITOR), and customer service level. EOQ and ROP methods were associated with reductions in inventory value and stockouts, as well as improvements in ITOR and customer service levels. The MMSL generally reduced inventory value, stockout frequency, stockout value, and dead stock, either significantly or non-significantly, and increased ITOR. However, one study reported an increase in inventory value due to unstable supply conditions before implementation, and another reported a decrease in ITOR related to ordering policy constraints. Overall, the findings suggest that the EOQ, ROP, and MMSL methods generally improve inventory efficiency; however, several studies reported inconsistent or non-significant effects on certain indicators, such as the inventory turnover ratio and inventory value, under specific operational conditions.

Conclusion: This systematic review indicates that the Minimum–Maximum Stock Level and Economic Order Quantity, Reorder Point methods are potentially beneficial strategies for enhancing inventory efficiency in hospital settings.

Keywords: Inventory Management; Hospital; EOQ ROP; MMSL

INTRODUCTION

A hospital is a service unit that provides medical services and pharmaceutical supplies. As part of healthcare services, pharmaceutical supplies support patient treatment. Pharmaceutical supplies, which include drugs, medical devices, and other medical materials, consume a significant portion of the hospital's operational budget. In developing countries, pharmaceutical expenditures account for approximately 40-50% of a total

hospital's budget.[1] The implementation of hospital pharmaceutical services must ensure that drugs, consumable medical materials, and all medical supplies are available, safe, of good quality, beneficial, and affordable.[2]

Pharmaceutical inventory management is not only related to procurement but also involves a management process, including selection, planning, storage of the goods, distribution, and control.[2] Effective and efficient management of pharmaceutical supplies is needed as part of quality and cost controls because pharmaceutical supplies have specific characteristics, such as suitability for indications, storage under certain conditions, and an expiration period. Excessive inventory levels can increase the risk of product expiration, thereby causing financial losses for hospitals.[3,4]

The effectiveness of pharmaceutical inventory management is also related to customer satisfaction levels. Fast and accurate pharmaceutical services contribute to high patient satisfaction, which in turn enhances the hospital's image.[5] Therefore, effective strategies are required to prevent stockouts and ensure the availability of medicine in appropriate conditions, for the right patient, at the right time, and at the right cost. Several challenges, such as limited storage space, budget constraints, and the need to ensure product quality and patient satisfaction, make pharmaceutical inventory management in hospitals a complex process that requires a well-planned and systematic approach. Consequently, as an essential part of hospital management, pharmaceutical inventory control has a valuable impact on cost efficiency and the quality of healthcare services.

Previous studies have shown that pharmaceutical inventory management strategies such as EOQ, ROP, and MMSL are effective in reducing inventory costs, minimizing stockouts, and improving inventory turnover in hospital settings. These methods are widely recognized as key approaches to enhancing efficiency and ensuring continuous drug availability.[6,7,8] Although numerous primary studies have examined the application of MMSL and EOQ, ROP methods in hospital pharmacy settings, systematic reviews that comprehensively synthesize their effects on inventory efficiency indicators remain limited, especially in developing countries. This study aims to evaluate the impact of the EOQ, ROP, and the MMSL inventory management procedures on hospital inventory efficiency.

METHODS

Study design

This study is a systematic review to evaluate the impact of MMSL, EOQ, and ROP inventory management procedures on hospital inventory efficiency

Search strategy

In this study, we searched for journal articles that described pharmaceutical inventory management methods in hospital settings and their effects on inventory efficiency indicators. The search strategy was guided by research questions structured using the PICO framework, which defined the population as hospital pharmacy settings, the intervention as inventory management methods, comparators as pre- and post-implementation conditions or alternative inventory practices, and outcomes as hospital inventory efficiency indicators. We searched four online databases in November 2024: Scopus, PubMed, Google Scholar, and the Indonesian database Garuda. These databases were selected to ensure comprehensive coverage of both international and regional literature on hospital pharmaceutical inventory management, as Scopus and PubMed provide access to high-quality, peer-reviewed biomedical studies. In contrast, Google Scholar and the Garuda database capture relevant regional and local publications, particularly from developing countries. The following keywords were used in this search: "inventory", "management", "hospital", "MMSL", "EOQ", "Minimum Maximum Stock Level", and "Economic Order Quantity". Search terms and phrases were combined using the Boolean operators "OR" and "AND" to maximize the retrieval of relevant studies.

Eligibility criteria

In this study, our articles were selected based on specific inclusion criteria. Only articles that explicitly convey variables of interest were selected. The EOQ, ROP, and MMSL methods were selected for this review due to their frequent application in hospital pharmacy inventory management and the availability of clearly defined and measurable efficiency indicators reported in previous studies. Inclusion and exclusion criteria are shown in Table I.

Table I. Inclusion and Exclusion Criteria for Reviewed Articles

	Inclusion criteria		Exclusion criteria
1	Text in English or Indonesian	1	Review articles, case reports, dissertations, or theses
2	Reporting Pharmaceutical inventory management in a hospital setting using EOQ, ROP, or MMSL methods	2	There is no output of the Inventory indicator
3	Time frame 2009 – 2024	3	Not relevant topics
4	Available in full text		

Data Extraction

PRISMA guidelines were applied to operate this systematic review.[9] Data extraction was performed using a structured data extraction form. First, relevant articles were identified and screened derived from the titles and abstracts, resulting in 108 articles from the initial search. Using Zotero reference management software, seven duplicate articles were removed. Second, full-text articles were appraised for eligibility according to inclusion and exclusion criteria, yielding nine articles for analysis and review. Third, the eligible studies were extracted and reviewed. The extracted data included author information, study design, study objectives, research samples, inventory management methods, efficiency indicators, and study outcomes. All of them were reviewed to ensure accuracy and consistency across the studies included (Figure 1).

Data Analysis

The quality and risk of bias of the reviewed studies were appraised utilizing the Joanna Briggs Institute (JBI) Critical Appraisal tools,[10,11,] according to the checklist that is appropriate to each study design. Data classification is done according to the inventory control methods. Each study describes the outcome of efficiency indicators before and after the intervention, as well as the value of statistical analysis. This study was reviewed using descriptive analysis.

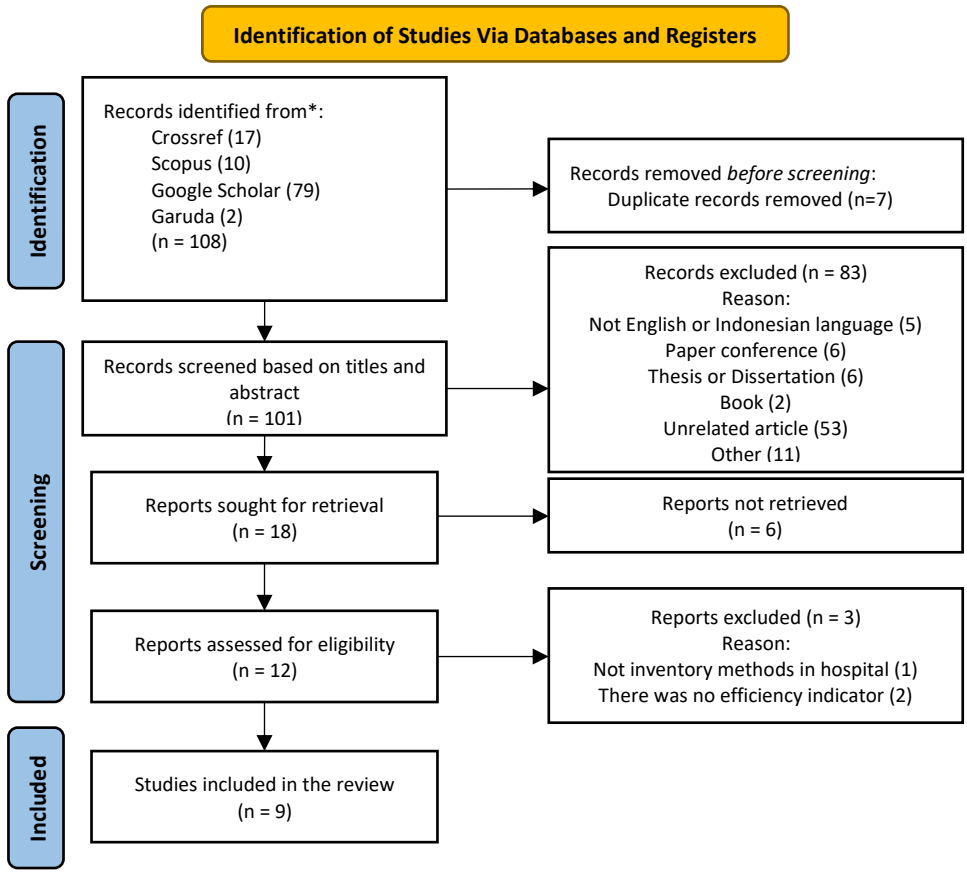

Figure 1: Prisma Diagram for Reviewed Study

RESULTS AND DISCUSSION

The Quality of Individual Studies

In this study, we obtained articles from Indonesia and India, five in English and four in Bahasa Indonesia. These articles were published on different websites between 2009 and 2024. Out of the nine studies reviewed, eight used a Quasi-experimental study design, while one study used a descriptive cross-sectional design. The JBI Critical Appraisal guidelines were used to evaluate the studies [10,11]

Derived from the JBI checklist, eight quasi-experimental studies were of good methodological quality, as indicated by a higher proportion of "Yes" responses (Table II). These studies implemented inventory control methods by measuring several outcomes, including inventory value, inventory turnover ratio (ITOR), stock-out frequency, stock-out value, dead stock value, and customer service level before and after the intervention. Measurements were conducted using standardized procedures and were analyzed using statistical tests in accordance with data distribution. The Wilcoxon Signed-Rank Test or the Paired t-test, and the McNemar test were used for data analysis.

Table II. Critical Appraisal for Quasi-experimental Study with JBI Checklist

Internal validity	Relevant Study (Yes/No/Unclear/NA)							
	Burhan et al., 2019	Agustina et al., 2024	Darmawan et al., 2021	Darmawati et al., 2023	Indarti et al., 2019	Paramesthi et al., 2024	Sofia et al., 2024	Hartih et al., 2013
Bias related to temporal precedence								
Is it clear in the study what the "cause" is and what the "effect" (i.e., there is no confusion about which variable comes first)?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bias related to selection and allocation								
Was there a control group?	No	No	No	No	No	No	No	No
Bias related to confounding factors								
Were participants included in any comparisons similar?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bias related to the administration of the intervention/exposure								
Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Bias related to the assessment, detection, and measurement of the outcome								
Were there multiple measurements of the outcome, both pre- and post-intervention/exposure?								
Inventory value	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ITOR	NA	NA	NA	NA	Yes	Yes	Yes	Yes
Stockout frequency	Yes	NA	NA	NA	Yes	Yes	NA	NA
Stockout value	NA	NA	NA	NA	Yes	Yes	Yes	NA
Deadstock value	NA	NA	NA	NA	NA	NA	Yes	NA
Customer service level	NA	NA	Yes	NA	NA	NA	NA	Yes
Were the outcomes of participants included in any comparisons measured in the same way?								
Inventory value	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ITOR	NA	NA	NA	NA	Yes	Yes	Yes	Yes

Continuing of Table II. Critical Appraisal for Quasi-experimental Study with JBI Checklist

Internal validity	Relevant Study (Yes/No/Unclear/NA)							
	Burhan et al., 2019	Agustina et al., 2024	Darmawan et al., 2021	Darmawati et al., 2023	Indarti et al., 2019	Paramesthi et al., 2024	Sofia et al., 2024	Hartih et al., 2013
Stockout frequency	Yes	NA	NA	NA	Yes	Yes	NA	NA
Stockout value	NA	NA	NA	NA	Yes	Yes	Yes	NA
Deadstock value	NA	NA	NA	NA	NA	NA	Yes	NA
Customer service level	NA	NA	Yes	NA	NA	NA	NA	Yes
Were outcomes measured in a reliable way?								
Inventory value	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ITOR	NA	NA	NA	NA	Yes	Yes	Yes	Yes
Stockout frequency	Yes	NA	NA	NA	Yes	Yes	NA	NA
Stockout value	NA	NA	NA	NA	Yes	Yes	Yes	NA
Deadstock value	NA	NA	NA	NA	NA	NA	Yes	NA
Customer service level	NA	NA	Yes	NA	NA	NA	NA	Yes
Bias related to participant retention								
Was the follow-up complete, and if not, were the differences between groups in terms of their follow-up adequately described and analyzed?								
Inventory value	NA	NA	NA	NA	NA	NA	NA	NA
ITOR	NA	NA	NA	NA	NA	NA	NA	NA
Stockout frequency	NA	NA	NA	NA	NA	NA	NA	NA
Stockout value	NA	NA	NA	NA	NA	NA	NA	NA
Deadstock value	NA	NA	NA	NA	NA	NA	NA	NA
Customer service level	NA	NA	NA	NA	NA	NA	NA	NA
Statistical Conclusion Validity								
Was an appropriate statistical analysis used?								
Inventory value	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ITOR	NA	NA	NA	NA	Yes	Yes	Yes	Yes
Stockout frequency	Yes	NA	NA	NA	Yes	Yes	NA	NA
Stockout value	NA	NA	NA	NA	Yes	Yes	Yes	NA
Deadstock value	NA	NA	NA	NA	NA	NA	Yes	NA
Customer service level	NA	NA	Yes	NA	NA	NA	NA	Yes

The JBI Checklist for Analytical Cross-Sectional Studies was utilized to appraise another study. The study compared existing data with the results of the inventory control method measurement. The JBI appraisal indicated that the study was suitable for inclusion in this review, as reflected by a higher number of "Yes" responses. The study applied clear inclusion and exclusion criteria, provided a description of the study subjects and settings, also employed outcome measurements using the Wilcoxon Signed-Rank test for statistical analysis. Confounding factors were identified, but the strategies used to address these confounders were not described in detail. The results of the critical appraisal are displayed:

Details of the selected studies

Two inventory management methods were identified across the included articles: four articles applied the EOQ and ROP methods, while five studies employed the MMSL method. The study settings encompassed various hospital classes in Indonesia, including class A, B, C, and D hospitals (primary, secondary, and tertiary hospitals), as well as medical stores of tertiary care government hospitals in India. The type and number of samples varied across studies. However, most studies focused on items classified as category A in the ABC or Pareto classification, which represent high-cost, high-volume, vital, or critical products. The characteristics of the reviewed studies are displayed:

Table III. Critical Appraisal for Analytical Cross-Sectional study with JBI checklist

	Questions	Relevant study of Kausar et al., 2017			
		Yes	No	Unclear	NA
1	Were the criteria for inclusion in the sample clearly defined?	√			
2	Were the study subjects and the setting described in detail?	√			
3	Was the exposure measured in a valid and reliable way?	√			
4	Were objective, standard criteria used for measurement of the condition?	√			
5	We're confounding factors identified?	√			
6	Were strategies to deal with confounding factors stated?			√	
7	Were the outcomes measured in a valid and reliable way?	√			
8	Was an appropriate statistical analysis used?	√			

Table IV. Characteristics of the Reviewed Studies

Study	Objective	Study design	Inventory management methods	Sample criteria	Number of Samples	Data analysis tool
Burhan et al., 2019	Find out the effect of the use of inventory control methods of ABC, EOQ, also ROP assisted by a computer-based daily stock information system of drugs and consumable medical devices on the emptiness of drug frequency and vital types of medical devices use	Quantitative, quasi-experimental design	EOQ, ROP	total drug/medical device	1860	T-Test
				critical drug/medical device	250	
Agustina et al., 2024	To determine the implementation effect of the MMSL method on the inventory value of generic drugs Pareto A in the outpatient pharmacy unit of PKU Muhammadiyah Gamping Hospital, Sleman, D.I. Yogyakarta.	Quantitative, quasi-experimental, Non-equivalent without control	MMSL	generic drugs Paretto A	23	Wilcoxon test
Darmawan et al., 2021	Conduct an analysis of the control of BPJS medications in the AE category using the ABC and VEN methods, analyze the control of medication availability for BPJS with EOQ and ROP to improve the efficiency of drug inventory, and evaluate the level of pharmaceutical service.	Quantitative, quasi-experimental, Non-equivalent without control	EOQ, ROP	BPJS drugs, AE category	29	Paired T-Test

Continuing of Table IV. Characteristics of the Reviewed Studies

Study	Objective	Study design	Inventory management methods	Sample criteria	Number of Samples	Data analysis tool
Darmawati et al., 2023	determine the inventory control effect using the Minimum-Maximum Stock Level method on the value of the Pareto A pharmaceutical inventory in the Central Surgical Installation Pharmacy Unit of PKU Muhammadiyah Gamping Hospital	Quantitative, quasi-experimental, Non-equivalent without control	MMSL	Pareto A in the CSI (Central Surgical Installation) pharmacy unit	49	Wilcoxon test
Indarti et al., 2019	To determine the impact of the Minimum-Maximum Stock Level (MMSL) method on the efficiency and effectiveness of medication inventory at the Pharmacy Installation of RSUP Dr. Sardjito Yogyakarta.	Quantitative, quasi-experimental, Non-equivalent without control	MMSL	Pareto: A high-cost, high-volume, clinically important drug	35	Wilcoxon test, McNemar
Paramesthi et al., 2024	to examine the effect of the MMSL method controls IVF medications and embryology laboratory CMS at Department of Pharmacy Hospital "X"	Quantitative, quasi-experimental, Non-equivalent without control	MMSL	In vitro fertilization medications embryology laboratory consumables	12 56	Wilcoxon test, McNemar
Sofia et al., 2024	To know the influence of the MMSL method on efficiently supplying drugs in the Pharmacy Installation RSU Muhammadiyah Siti Aminah Bumiayu	Quantitative, quasi-experimental, Non-equivalent without control	MMSL	all items ABC drug classification	499	Wilcoxon test
Hartih et al., 2013	To determine the impact of implementing the EOQ and ROP methods on the medication inventory value, inventory turnover ratio (ITOR), and customer service level at the IFRSUD Lasinrang Hospital in Pinrang Regency, South Sulawesi.	Quantitative, quasi-experimental, Non-equivalent without control	EOQ, ROP	Group A of regular drugs	84	Paired T-Test

Continuing of Table IV. Characteristics of the Reviewed Studies

Study	Objective	Study design	Inventory management methods	Sample criteria	Number of Samples	Data analysis tool
Kausar et al., 2017	To calculate the benefits of EOQ and its applicability for A-class and AV-category items in tertiary care government hospitals in India	A cross-sectional descriptive study	EOQ, ROP	Group A	53	Wilcoxon test
				AV category	16	

Table V. Efficiency Indicators Inventory Controls with EOQ, ROP methods

Study	Intervention	Efficiency Indicator with EOQ Methods				
		Inventory value	ITOR (time)	Stock out incident (time)	Customer service level (%)	Opportunity cost
Burhan et al., 2019[1]	Pre	NA	NA	254.8 ± 47.33	NA	NA
	Post	NA	NA	47.33 ± 21.197	NA	NA
	p-value	NA	NA	p = 0.002	NA	NA
Burhan et al., 2019[2]	Pre	NA	NA	12.4 ± 7.859	NA	NA
	Post	NA	NA	0.33 ± 0.577	NA	NA
	p-value	NA	NA	p = 0.027	NA	NA
Darmawan et al., 2021	Pre	IDR 403,114,341	NA	NA	91.7	NA
	Post	IDR 331,170,915	NA	NA	94.3	NA
	p-value	p = 0.043	NA	NA	p = 0.025	NA
Hartih et al., 2013	Pre	IDR 485,071,623	0.47	NA	99.65	NA
	Post	IDR 395,712,319	1.24	NA	99.93	NA
	p-value	p = 0.048	p = 0.003	NA	p = 0.017	NA
Kausar et al., 2017[3]	Pre	INR 55,582,769	NA	NA	NA	INR 4,446,622
	Post	INR 19,855,440	NA	NA	NA	INR 1,588,435
	p-value	P = 0.05	NA	NA	NA	P = 0.05
Kausar et al., 2017[4]	Pre	INR 10,904,143	NA	NA	NA	INR 872,331
	Post	INR 6,805,157	NA	NA	NA	INR 544,413
	p-value	P = 0.057	NA	NA	NA	P = 0.057

[1 = Total drug/medical device; [2 = Critical drug/medical device; [3 = A Class; [4 = AV Category; IDR =Indonesian Rupiah; INR = Indian Rupee

Inventory control management

Inventory control is a system designed to ensure the continuous availability of medicines over a specified period and is an essential component of the pharmaceutical supply system.[6] The primary objective of inventory control is to achieve an optimal balance between supply and demand.[12] Various methods are applied in inventory control, including EOQ and MMSL. To evaluate the effectiveness of inventory control, specific performance parameters are required, which are reflected in efficiency indicators such as planning accuracy, drug availability, overstock, stockouts, dead stock, and inventory turnover ratio.[6] In addition, performance can be assessed using service level and inventory level indicators[7]

Economic Order Quantity (EOQ), Reorder Point (ROP) methods

EOQ is one of the most widely used inventory-control techniques.[8] Excess inventory or purchasing in large quantities increases holding costs, whereas purchasing smaller quantities with higher ordering frequency increases ordering costs. The EOQ is employed to find out the optimal order quantity by balancing ordering and holding costs to minimize total inventory cost. The calculations can be performed using the following formulas.[7]

$$EOQ = \sqrt{\frac{2 \, x \, U \, x \, O}{H \, x \, C}}$$

Where: U = Annual use, in units; O = Ordering Cost; H = Average Holding Cost (percentage of average inventory value); C = projected net acquisition costs

Once the optimum order quantity has been determined, a reorder point (ROP) must be established to indicate the appropriate time for ordering. The ROP can be calculated using the following formula.[7,14]

ROP = (d x L) + SS

Where: d = daily demand; L = waiting time (lead time); SS = safety stock

Based on the included studies, four articles applied the EOQ and ROP methods in inventory control. Data extraction comprised the outcomes of variables measured before and after intervention, as well as the corresponding statistical significance values. The extracted data related to the EOQ and ROP methods are present in Table V.

In the study conducted by Burhan, Winarsih, and Harijanto, the EOQ and ROP methods were applied to assess the frequency of stockouts for both overall medicines and medical devices, as well as for critical items.[13] The results demonstrated a significant reduction in stockout frequency for both critical and overall items, decreasing from 12.4 ± 7.859 per month to 0.33 ± 0.577 per month (p = 0.027) and from 254.8 ± 47.33 per month to 47.33 ± 21.197 per month (p = 0.002), respectively. These findings are consistent with those reported by Laurensia, Achmad, Dihniya, and Soeliono, who found that the implementation of the EOQ method reduced stockout rates from 55.26% to 38.15%.[14] In the study by Burhan, Winarsih, and Harijanto, all medicines and medical devices (n = 1,860 items) were included in the analysis, with a substantial number of critical items totaling 250 products. According to Sugiyono, a sample size that closely approximates the population reduces the risk of generalization error.[15] Furthermore, before intervention, data were collected over nine months, while after intervention, data were obtained over three months, which may further support the validity of the study findings. However, the study did not fully account for external factors that could influence the availability, such as supply chain disruptions or seasonal fluctuations in demand.

Three studies assessed inventory levels. The study by Darmawan, Peranginangin, and Herowati evaluated samples in category AE.[16] Meanwhile, the study by Hartih, Satibi, and Widodo measured category A items.[17] In addition, the study by Kausar, Madaan, and Arya analyzed class A items and the AV category.[18] Although these studies employed different sample sizes, all demonstrated a significant reduction in inventory levels after implementation of the EOQ and ROP methods, except for the AV category in the study by Kausar et al., for which the reduction was not statistically significant ($p > 0.05$). These findings align with a study conducted by Widhayunita, which reported a 47.91% reduction in inventory value after the implementation of the EOQ and ROP methods.[19] Furthermore, studies by Nopiana and Nurwahyuni,[20] Yudianti, Lestari, Darma, and Suardana,[21] as well as Soraya, Surwanti, and Pribadi,[22] reported reductions in total costs of 17.91%, 19.4%, and 41.8%, respectively. The Total cost represents the sum of ordering and holding costs, while the inventory value is calculated by multiplying the remaining stock of medicines by their respective unit prices. Higher inventory levels are associated with increased holding costs; therefore, controlling total costs directly contributes to improved inventory level management. The ideal inventory model is characterized by an optimal stock movement pattern that maintains the inventory level.[7]

The studies conducted by Darmawan, Peranginangin, and Herowati[16], as well as by Hartih, Satibi, and Widodo,[17] evaluated customer service levels. Customer service level is defined as the proportion of prescriptions dispensed relative to the total number of prescriptions acquired by the pharmacy department. The results demonstrated a statistically significant increase in customer service levels ($p < 0.05$). These improvements are consistent with the findings of Rofiq, Oetari, and Widodo, who reported customer service levels exceeding 99% each month.[23] In hospital pharmacy practice, customer service level is a critical indicator for meeting the Indonesian government's minimum hospital service standards, which require a threshold of ≥ 80%.[24] A high customer service level also reflects a high degree of patient satisfaction.[25]

Hartih, Satibi, and Widodo also assessed the Inventory Turnover Ratio (ITOR).[17] ITOR represents the rate of medication turnover over one year and is calculated by comparing the value of medicines dispensed with the average inventory value.[6] The study reported a significant increase in ITOR from 0.47 to 1.24 after the

implementation of the EOQ and ROP methods (p = 0.003). However, the intervention period was limited to one month. Despite this limitation, the findings are consistent with those of Widhayunita[19], who reported an improvement in ITOR from 12.83 to 17.34 after applying the EOQ and ROP methods. A higher ITOR value indicates more efficient pharmaceutical inventory management.[7]

The study conducted by Kausar, Madaan, and Arya also assessed opportunity cost and reported a reduction in class A (p = 0.05) and the AV category (p = 0.057).[18] Opportunity cost refers to the value of resources lost as a result of capital being tied up in inventory. Such costs may arise from ordering and holding costs, particularly when excess inventory leads to dead stock.[26] Dead stock is defined as inventory that has remained unused for three months or longer.[7] Dead stock can result in financial losses for hospitals. Overall, these findings indicate that the application of the EOQ and ROP methods is associated with a reduction in opportunity costs.

Minimum-Maximum Stock Level methods

The MMSL method is widely applied in hospital settings. MMSL is an inventory management system that establishes minimum and maximum stock levels for each item to ensure sufficient availability to meet demand while preventing excess inventory that may increase holding costs.[7] The minimum stock level represents the lowest quantity that must be maintained to prevent stockouts. The formula used to calculate the MMSL method is presented below.[6,7]

Minimum Stock = $(LT \times C_A) + SS$

Maximum Stock = $(S_{min}) + (PP \times C_A)$

Where: LT = Lead time; C_A = average consumption; SS = Safety Stock; PP = Procurement Periods

Five articles applied the MMSL method in inventory control. The extracted data related to the MMSL method are presented in Table VI.

Table VI. Efficiency Indicators of Inventory Controls with MMSL Methods

Study	Intervention	Efficiency Indicator with MMSL Methods				
		inventory value (IDR)	ITOR (time)	stockout incident (time)	stockout value (IDR)	dead stock incident (%)
Agustina et al., 2024	Pre	15,175,340,000	NA	NA	NA	NA
	Post	11,864,748,000	NA	NA	NA	NA
	p-value	p = 0.000	NA	NA	NA	NA
Darmawati et al., 2023	Pre	244,588,361	NA	NA	NA	NA
	Post	135,852,139	NA	NA	NA	NA
	p-value	p = 0.004	NA	NA	NA	NA
Indarti et al., 2019	Pre	500,221,204	20.776	8	75,569,317	NA
	Post	287,879,269	8.494	2	46,346,300	NA
	p-value	p = 0.007	p = 0.003	p = 0.03	p = 0.068	NA
Paramesthi et al., 2024*	Pre	21,514,537	1.89	6	11,656,679	NA
	Post	49,635,116	1.41	2	7,464,448	NA
	p-value	p = 0.043	p = 0.075	p = 0.125	p = 0.917	NA
Paramesthi et al., 2024**	Pre	117,421,528	0.82	12	8,032,202	NA
	Post	105,318,804	0.84	9	7,994,754	NA
	p-value	p = 0.005	p = 0.032	p = 0.375	p = 0.6	NA
Sofia et al., 2024	Pre	289,756,421	8.74	NA	141,841,056	11.8
	Post	184,725,126	13.21	NA	1,530,561	8.48
	p-value	p = 0.002	p = 0.01	NA	p = 0.027	p = 0.002

* In vitro fertilization medications

** Embryology laboratory consumable medical supplies

Four studies—Agustina, Utami, and Suprapti,[27] Darmawati, Saputra, and Dhirisma;[28] Indarti, Satibi, and Yuniarti;[29] and Sofia, Perianginangin, and Herdwiani[30]—as presented in Table VI, demonstrated that the MMSL method significantly reduced inventory value (p < 0.05). Similar findings were reported by Wijayanto, Sriatmi,

and Jati,[31] who observed a reduction in the inventory value of antibiotics from IDR 13,460,159 to IDR 503,938 following the implementation of the MMSL method (p = 0.000). In contrast, the study by Paramesthi, Jati, and Suryoputro[32] reported an increase in inventory value for in vitro fertilization (IVF) medications. This increase was attributed to frequent stockouts before MMSL implementation, with 50% of items experiencing stockouts at the end of the observation period. The low inventory value observed before MMSL implementation reflected the hospital pharmacy's inability to meet the high demand for IVF medications. Conversely, the inventory value of consumable medical supplies (CMS) in the embryology laboratory decreased, consistent with findings from other studies. Overall, most studies indicate that the MMSL method has a positive impact on the efficiency of hospital pharmaceutical inventory value.

Inventory Turnover Ratio (ITOR) is an efficiency indicator that reflects the rate of inventory turnover, with lower turnover indicating a higher proportion of unsold inventory value. Studies conducted by Sofia, Perianginangin, and Herdwiani[20] and by Paramesthi, Jati, and Suryoputro[31] on CMS demonstrated a significant increase in ITOR following the implementation of the MMSL method (p = 0.01). These findings are consistent with those reported by Wijayanto, Sriatmi, and Jati,[31] who observed an increase in antibiotic ITOR from 15.02 to 32.40. In contrast, the study by Indarti, Satibi, and Yuniarti[29] reported a decrease in ITOR after MMSL implementation, which was attributed to a quarterly ordering schedule (every 90 days). Additionally, the intervention was implemented at the end of the year, which may have posed challenges to its effective application. Similarly, Paramesthi, Jati, and Suryoputro[31] reported a non-significant decrease in ITOR for in vitro fertilization (IVF) medications (p = 0.075), suggesting unstable inventory conditions before MMSL implementation that may have influenced ITOR outcomes.

Stockouts represent a critical issue that can negatively impact customer satisfaction and result in financial losses for hospitals. Indarti, Satibi, and Yuniarti's study reported a significant reduction in stockout occurrences from 8 to 2 events (p = 0.003).[31] Likewise, Sofia, Perianginangin, and Herdwiani observed a substantial decrease in stockout value from IDR 141,841,056 to IDR 1,530,561 following MMSL implementation (p = 0.027).[28] Paramesthi, Jati, and Suryoputro also reported reductions in stockout occurrences; however, these changes were not statistically significant (p > 0.05).[32] Similar trends were observed in studies by Laurensia, Achmad, Dihniya, and Soeliono, which reported a decrease in stockout rates from 42.76% to 22.7%,[14,] and by Wijayanto, Sriatmi, and Jati, in which no stockouts were observed for antibiotic samples following MMSL implementation.[31]

In addition, the study by Sofia, Perianginangin, and Herdwiani assessed dead stock and reported a significant reduction from 11.84% to 8.48% after MMSL implementation (p = 0.002). These findings are consistent with those reported by Dewi, Dahlui, Chalidyanto, and Rochmah, who demonstrated that the MMSL method is effective in reducing opportunity losses associated with stagnant drugs. Notably, the study by Sofia, Perianginangin, and Herdwiani employed a relatively large sample size (n = 499) and was conducted over three months, whereas the study by Dewi, Dahlui, Chalidyanto, and Rochmah involved 126 items and was conducted as a simulation. Overall, the evidence indicates that the MMSL method could improve inventory efficiency by minimizing stockouts and dead stock occurrences.

Overall, the findings of this review are considered valid and reliable, as the majority of included studies employed consistent pre–post measurement of inventory efficiency indicators using established methods and appropriate statistical analyses. However, synthesis across studies was primarily descriptive due to heterogeneity among study settings, outcome measures, and baseline inventory systems. The structured comparison indicates that EOQ and ROP methods were more consistently associated with reductions in inventory value and stockout frequency, as well as improvements in inventory turnover ratio and customer service levels, particularly in hospitals with relatively stable demand patterns and procurement processes. In contrast, the MMSL method demonstrated more variable effects, with most studies reporting reductions in inventory value and stockouts, while some reported non-significant or contradictory changes in inventory turnover, especially in settings with unstable supply chains or rigid procurement schedules.

The heterogeneity observed among the included studies may be explained by several contextual factors. Differences in hospital type (tertiary vs. secondary hospitals), country context, and baseline inventory management systems likely influenced the effectiveness of the implemented methods. Studies conducted in developing countries, particularly Indonesia and India, highlighted challenges such as limited supplier reliability, budget constraints, and centralized procurement policies, which may affect inventory turnover and stock stability despite the application of standardized control methods. Previous literature has highlighted that the effectiveness of inventory control methods in hospital pharmacies is highly dependent on contextual factors such as procurement systems, demand variability, and institutional policies, particularly in developing countries, which may explain the heterogeneity observed across studies.[16, 26,33] Therefore, while the available evidence is

sufficient to support the conclusion that EOQ, ROP, and MMSL methods can improve hospital pharmaceutical inventory efficiency, the magnitude and consistency of their effects vary across settings. These outcomes underscore the significance of contextual adaptation when implementing inventory control strategies.

This systematic review has some limitations that should be considered when interpreting the findings. First, heterogeneity across the involved studies in terms of study design, sample size, hospital settings, and efficiency indicators limited the possibility of direct comparisons and quantitative synthesis. Second, the geographic scope of the included studies was largely confined to developing countries, particularly Indonesia and India, which may restrict the generalizability of the findings to other healthcare systems. Future research incorporating more diverse settings and robust study designs is warranted to strengthen the evidence base

CONCLUSION

This systematic review indicates that EOQ, ROP, and MMSL methods are potentially beneficial strategies for improving pharmaceutical inventory efficiency in hospital settings. Most included studies reported reductions in inventory value, stockout occurrences, and dead stock, as well as improvements in inventory turnover and customer service levels; however, the magnitude and consistency of these outcomes varied across studies. Pharmacy practitioners may consider implementing EOQ, ROP, or MMSL as part of a broader inventory management strategy, tailored to hospital type, demand patterns, procurement systems, and resource availability. Careful monitoring of key efficiency indicators and periodic adjustment of inventory parameters are essential to optimize performance and minimize unintended effects.

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