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ADVANCES IN SOCIAL HUMANITIES RESEARCH

Integration of Multicriteria Matrix and Drug Need Forecasting in Support of Budget Policy: Literature Review

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Abstract

Drug expenditure represents a significant proportion of healthcare facility costs, and budget constraints directly affect pharmaceutical spending. Therefore, appropriate policies are needed to balance economic considerations, clinical priorities, and future medication requirements. This study aims to examine the implications of budgetary policies for pharmaceutical inventory management through ABC-VEN classification and drug demand forecasting. A literature review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. Seven articles met the inclusion criteria and were included in the review. The findings indicate that ABC-VEN classification identifies drug categories accounting for 70%–93.41% of the total pharmaceutical budget, representing 10%–70% of all drug items. These classification results provide a basis for prioritizing inventory monitoring and identifying drug categories requiring targeted demand forecasting. Forecasting results subsequently inform budget-based inventory management policies, contributing to improvements in operational efficiency, including a 17.63%–30% reduction in total annual inventory costs, an 88.5% monthly reduction in stockout occurrences, and a decrease in pharmaceutical waste from 0.91% to 0.21%. These findings highlight the importance of integrating ABC-VEN multicriteria classification with drug demand forecasting to optimize pharmaceutical budget allocation, enhance inventory control, and support evidence-based budgetary decision-making in healthcare facilities.

INTRODUCTION

Drug expenditure is a significant component of healthcare spending, representing the third-largest category of expenditure after inpatient and outpatient services (OECD, 2025). Inaccuracies in inventory planning and control can lead to stockouts, inventory accumulation, drug expiration, and inefficient budget utilization. These challenges are exacerbated by variations in drug characteristics, including consumption frequency, cost, and clinical importance (Deressa et al., 2022; Kurdiana et al., 2026). ABC and VEN analyses are methods used to control drug inventories by establishing drug management priorities. ABC analysis categorizes drugs according to their annual consumption value, whereas VEN analysis classifies drugs based on their clinical criticality as Vital, Essential, or Nonessential. These approaches are integrated into the ABC-VEN matrix to

prioritize drugs according to their expenditure and importance in healthcare delivery (Mfizi et al., 2023; Nguyen et al., 2022; Zulpadly & Aulia, 2024). The results of ABC-VEN classification demonstrate that drug expenditures can be categorized into distinct groups, facilitating the identification of items requiring closer monitoring and stricter budgetary oversight (Deressa et al., 2022; Fatimah Agus et al., 2024; Sitanggang et al., 2025; Suhailah et al., 2025). However, the ABC-VEN classification method primarily provides insights into historical drug consumption and expenditure patterns and has limited capacity to predict future drug requirements (Mousnad et al., 2016).

Forecasting methods are used to estimate drug requirements based on historical data and provide projections of the quantities needed in subsequent periods, thereby supporting pharmaceutical procurement and inventory planning (Fourkiotis & Tsadiras, 2024; Mu'min et al., 2024; Wiedyaningsih et al., 2024). Selecting the most appropriate forecasting method involves evaluating predictive performance using established error metrics. Commonly used measures include Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE). Models demonstrating lower forecasting errors are generally considered more suitable for estimating future drug requirements, provided that their assumptions and applicability to the available data are satisfied (Wiedyaningsih et al., 2024). Research employing ABC-VEN analysis primarily emphasizes the classification of drugs according to their economic value and clinical importance, whereas forecasting studies focus on assessing predictive accuracy, estimating future demand, and improving inventory control (Mfizi et al., 2023).

This literature review aims to identify and synthesize existing research on the application of ABC and ABC-VEN analyses to determine drug management priorities, the forecasting methods used to estimate future drug requirements and evaluate predictive accuracy, and the utilization of these analytical approaches in inventory control and resource allocation decisions. The review is expected to identify research gaps and establish a conceptual foundation for developing an integrated approach that combines drug prioritization with demand forecasting. Such an approach may support evidence-based budgetary policies, optimize the allocation of limited pharmaceutical resources, and strengthen inventory management efficiency.

METHOD

This study employed a literature review approach, with articles retrieved from five scientific databases: Scopus, ScienceDirect, SpringerLink, Web of Science, and ProQuest. The search was limited to articles published between 2017 and 2026. Relevant studies were identified using the following search terms: (drug OR pharmaceutical) AND (ABC analysis OR VEN analysis) AND (forecast OR "demand forecasting") AND (budget OR cost).

Article Selection

The article selection process was carried out by conducting a search based on the criteria set to determine the suitability and relevance of the research, the search was

carried out on 5 scientific article data sources, namely Scopus, Sciencedirect, pro Quest, Web of Science, and Springer. The results of the search on five article data sources resulted in 776 articles. From all the results of article discovery, a selection was made based on the inclusion criteria and exclusion criteria that have been set as in Table 1 about the inclusion and exclusion criteria of articles. After going through the article selection process, 6 articles were obtained that were considered to meet the criteria and relevant to be used in research.

Table 1. Article Inclusion and Exclusion Criteria

	INCLUSION CRITERIA	EXCLUSION CRITERIA
•	Articles according to the set search keywords	Articles in the form of books, *book chapters*, *conferences*, *systematic reviews*
•	Articles published in the period 2017-2026	Articles that are not accessible in full-text form
•	Articles sourced from Scopus, Science Direct, Springer, Web of Science and proQUEST	Articles in languages other than English
•	The article discusses the integration of ABC-VEN/VED classification and forecasting to support decision-making related to inventory management, procurement, or allocation of drug resources	Articles that discuss other than drugs
•	Articles that discuss budgets, costs, and budget limitations in pharmaceutical management	

Data Extraction

The data extraction process is carried out on articles that meet the inclusion criteria. It begins with reading and comprehensively understanding the methods, amount of data, and research results of each artiel, and then comparison. Furthermore, the data obtained is systematically arranged into results that include several points, namely Table 2 contains the author's name, year of research, classification method used and the results of the classification method. Table 3 contains the name and year of the author, the forecasting method used, and the measure of the accuracy of the forecasting method. Table 4 presents the name of the author and the year of the article, as well as the policy implications of the use of the drug spending budget, the budget scenario that will be generated in the research, and the control of the inventory. The next stage is to conduct data analysis, compile results, and discuss the research. The process of searching, identifying, screening, and determining articles in accordance with the inclusion criteria is described in Figure 1. Literature Review Flow Chart.

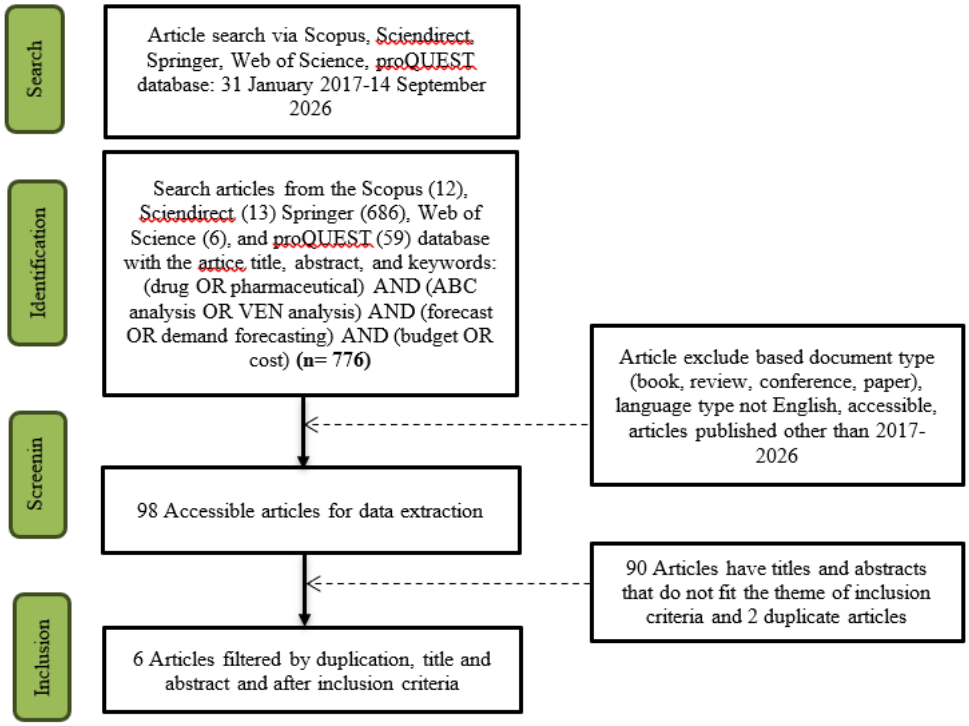


Figure 1. Literature Review Flow Chart

RESULTS AND DISCUSSION

Based on the search results conducted through 5 sources of scientific article data in the 2017-2026 search year using article titles, abstracts, and keywords (drug OR pharmaceutical) AND (ABC analysis OR VEN analysis) AND (forecast OR "demand forecasting") AND (budget OR cost), overall 776 articles were obtained. Furthermore, a screening process was carried out to classify articles based on the year of publication of the article, the type of document, the language used, and the availability of access to the article, and 98 articles were produced. Of the 98 articles produced, the suitability of inclusion criteria was reviewed through titles and abstracts, and the exclusion of duplicate articles was examined, so that a total of 90 articles were eliminated. The results of the screening were obtained in a total of 6 articles. The document was then further analyzed to answer 3 research questions, namely about the inventory classification and prioritization methods used to identify priority drugs based on economic value, level of clinical criticality, and/or consumption characteristics. The second question is about the forecasting method used to provide an estimate of future drug needs, and the amount of accuracy value obtained from each forecasting method. As well as how the results of forecasting drug needs and inventory priorities for each study are used in optimizing the use of limited drug spending budgets and inventory control.

From figure 2. Chart of the Number of Selected Articles based on the year of publication, it can be seen that the most found articles are articles published in 2026 as many as 3 articles from the research Stuart et al., 2026.; Singh et al., (2026) ; Chihaoui (2026) with research locations conducted in Indonesia, Ethiopia, and India. 1 article

published in 2025 is an article (Ayalew et al., 2025) with research conducted in Ethiopia. 2 other articles will be published in 2024 with the research locations being in Saudi Arabia and Turkey. This shows that research develops every year from 2024 to 2026, which is characterized by an increase in the number of research articles published.

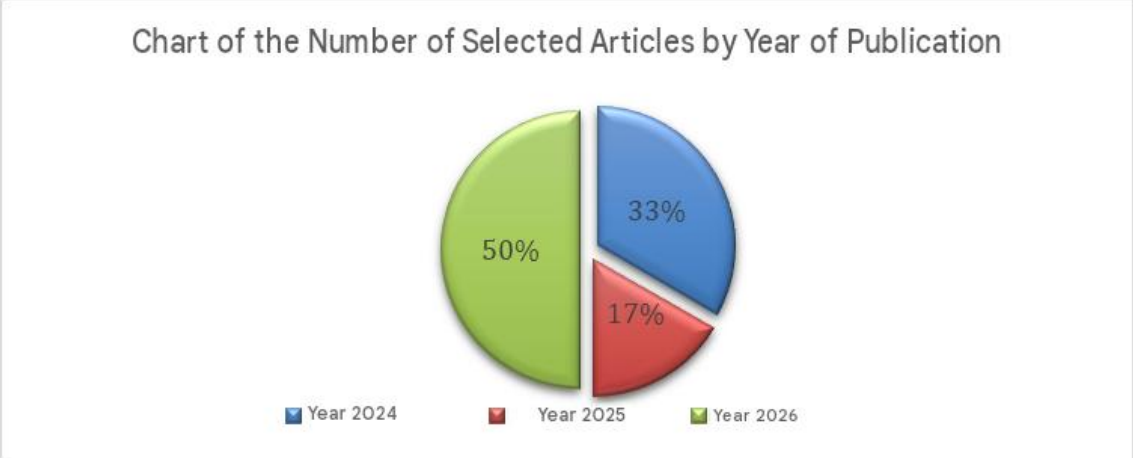


Figure 2. Chart of Number of Selected Articles

Table 2 describes the drug prioritization classification method used by each article, namely ABC, VED, ABC-VEN/VED integration, and ABC-XYZ. One article uses the ABC-VEN combination method (Alanazi et al., 2024), ABC method 2 articles (Andawaningtyas et al., 2026; Saracoglu, 2024), one article using the ABC-VED method, namely the Ayalew et al., (2025), one article using the VED method (Chihaoui, 2026), and 1 aticel using the ABC-XYZ integration method (Singh et al., 2026). In a study conducted by Ayalew et al., (2025) and Chihaoui, (2026) using the VED classification method. VED is a classification method that groups drug items by category vital (V), Essential (E), and desirable (D). The term VED refers to the same classification method as the term VEN. The two terms can be used interchangeably in the method of classification of pharmaceutical items based on their level of clinical use (Chihaoui, 2026). The XYZ method used in conjunction with the ABC method in Singh et al.'s (2026) study is a method of classifying drug items based on the level of demand fluctuation patterns, where category X is a drug with low demand fluctuations, Y is a drug with moderate demand fluctuations, and Z is a drug with uncontrollable, highest, and unpredictable demand fluctuations.

Table 2. Drug Group Classification Method

No.	Author, Year of publication, and Country	Drug Group Classification Method					Number of items with high category	Percentage of budget absorption by high-category items
		ABC	FRI/ VED	XYZ	ABC-FRI/VED	ABC-XYZ		
1	Alanazi et al., (2024)	✓	✓		✓		262 items (22.7%)	82.6% of the total monetary value of waste (0.16% of the budget)
2	Saracoglu, (2024)	✓					4 items of Class A drugs	Not explained
3	Ayalew et al., (2025)	✓	✓		✓		29 items (40.3%)	67.4%
4	Stuart et al., 2026., Indonesia	✓					42 items of category A drugs	70.4%
5	Chihaoui (2026)		✓				25.0% Vital item (*25% Vital, 35% Essential, 40% Desirable*)	Not explained
6	Singh et al., (2026)	✓		✓		✓	AX-AZ (28 items) 9.83 %	70%

In each research study, the results of studies that apply a single ABC or VEN/VED method and a combined method (ABC-VEN/VED and ABC-XYZ). Each classification method produces a category of drugs with the highest category of use and/or importance, as well as the highest need and demand. The number of items with a high category is known to be 4 items (Saracoglu, 2024) - 262 items (Alanazi et al., 2024) with a budget absorption percentage of 67.4% (Ayalew et al., 2025) – 70,4% (Andawaningtyas et al., 2026) of the total expenditure of the pharmaceutical budget. In the study Alanazi et al., (2024) Analysis of the percentage of classification on inventory waste showed that high-category drug items also accounted for the largest portion of financial losses of (82.3% of the value of inventory waste).

Based on the results of the study, it is shown that increased supervision of managerial interventions (Stringent day-to-day control) does not need to be done on all drug items, but can be focused proportionately on the high-category drugs that are most used, which absorb the most budget and or are most needed in services. This is done to prevent capital lock-up (budget tie-up) in the form of supplies and scarcity of essential medicines in health services (Kheder et al., 2020). The use of two-method integration is starting to be widely applied, compared to the use of a single method. This can happen

because the use of a single classification analysis has weaknesses that can cause operational bottlenecks due to ignoring clinical factors and demand variables. In the use of the single ABC classification method, it can only show drug item categories based on the level of need and budget uptake, and has the limitation of not being able to estimate the urgency of the drug and the risk Stockout in vital drugs, where vital drugs with low prices will appear in category C that is not a priority in supervision. Meanwhile, the single VEN/VED classification ignores the financial impact because it does not account for the price of drugs absorbed by each drug group, has uncertainty of inventory control because all vital drugs are given high monitoring even though they are not high-cost, and triggers budget overcrowding due to overallocation of non-essential drugs that are misinterpreted as vital drugs due to subjective criteria (Ayalew et al., 2025).

Table 3. Forecasting Methods and Value Accuracy Methods

No.	Author, Year of publication, and Country	Forecasting Methods	Accuracy Values	Amount of data used
1.	(Alanazi et al., 2024), Saudi Arabia	Quarterly *Consumption & Inventory Movement Tracking*	Inventory *turnover rate* and percentage decrease in the monetary value of waste	7 years of historical data on *the Health Enterprise Resource Planning* (ERP) system
2.	(Saracoglu, 2024), Turkey	Stochastic Demand Modeling (Fitting Probability Distribution*)*	Performance evaluation via GAP (%) between MILP and GA (0% to -0.79%) and *Service Level* (81%–100%, average 94% in Scenario 1)	4 items of drug A
4.	(Ayalew et al., 2025), Ethiopia	*Quantitative Time-Series Forecasting* includes *Linear Regression*, *Exponential Smoothing*, *Simple Moving Average*, and *Weighted Moving Average*	*Linear Regression* Drug 1 (MAD = 400, MSE = 164,500, MAPE = 3.73%); *Exponential Smoothing* Drug 4 (α=0.1: MAD=186.9, MSE=128.207, MAPE=15.5%)	29 items of category A drugs
3.	(Andawaningtyas et al., 2026), Indonesia	*Weighted Moving Average* (WMA) (period 5, weights 0.4; 0.25; 0.25; 0.05; 0.05) combined with *EOQ Continuous Review model*	MAPE Data Training = 11.73%, MAPE Data Testing = 10.32% (Good Category)	42 category A items A stationary test of monthly demand data was carried out, using *the Augmented Dickey-Fuller* (ADF) *test*. Calculation of 5-period WMA forecasting with optimal weighting [0.4; 0.25; 0.25; 0.05; 0.05]. The forecast results are fed into *the EOQ Continuous Review model*
5.	(Chihaoui, 2026), Tunisia	**Deterministic** *demand modeling*	Automatic integration through *the Optimization Engine* tool on *Decision*	Usage history data grouped from *weekly demand grouping* for 2 years, which

		repetitive computing in DSS/CPLEX systems)	*Support System* (DSS) based on JavaFX, CPLEX, and MySQL, by increasing order sensitivity when inventory touches the *reorder point*	is used to set the average demand value parameter (D_{it}) on the *Mixed Integer Linear Programming* (MILP) constraint function
6.	(Singh et al., 2026), India	*Consumption-based forecasting* for volatile drugs (AZ/BZ) & Coefficient of Variation analysis to establish a purchase schedule on stable drugs (AX/BX)	Statistical analysis of before and after intervention (*pre-post test* with SPSS) on the frequency of *stockout* and the cost of wastage of expired drugs. Intervention reduced the frequency of *stockout* by 88.5%, $p < 0.001$	High cost and demand category (AZ/BZ) drugs with prevention

The results of a systematic search of 6 scientific articles show a clear methodological presence in the pharmaceutical inventory management literature that has shifted to mathematical optimization modeling and stochastic simulation forecasting. The determination of forecasting methods with accuracy is carried out first before determining inventory parameters. Articles Andawaningtyas et al., (2026); Ayalew et al., (2025) with the deterministic time series permasing method provides very effective results for data with stationary/stable consumption patterns, using linear regression forecasting methods (MAPE = 3.73%) or WMA (MAPE = 10.32%) to provide an estimate of the need for precise exact numbers for the calculation of reorder points (Re-order point) and Economic Order Quantity (EOQ). Research conducted by (Saracoglu, 2024) shows that the model of the normal probability distribution function into the CCP stochastic program (Chance-Constrained Programming) can be applied to data with high fluctuations. While in research Chihaoui, (2026); Singh et al., (2026); and Alanazi et al., (2024) focuses on processing consumption history data directly connected to the ERP/DSS system or combined with demand variability analysis (XYZ) to provide ease of procurement on a daily/monthly basis in healthcare facilities.

The accuracy of the forecasting method is determined based on the selection of the right error accuracy metrics including the Mean Absolute Percentage Error (MAPE), Mean Absolute Deviation (MAD), and Mean Squared Error (MSE). In the study Andawaningtyas et al. (2026), the use of the WMA model on 42 Category A drugs resulted in MAPE data Training by 11.73% and data Testing by 10.32%. In terms of standard forecasting statistics, the MAPE value is in the range of 10%–20%, indicating good predictive performance (Good forecasting performance) and free from indications Underfitting or Overfitting (Andawaningtyas et al., 2026). In research Ayalew et al., (2025) shows that Linear Regression produces highly precise accuracy on drugs with constant consumption trends (Drug 1: MAPE = 3.73%, MAD = 400), whereas Exponential Smoothing (α=0.1) is more optimal for drugs with fluctuating use data (MAPE = 15.51%, MAD = 186.9) (Ayalew et al., 2025).

Research Ayalew et al., (2025) which uses a long historical data volume, namely the data on the use of 29 category A drug items for 4 years, resulting in a MAPE of 3.73% for drug items with constant consumption data with a Linear Regression model, and resulting in MAPE = 15.51% in drug items with fluctuating consumption data using the Exponential Smoothing method (Simple Exponential Smoothing) proves that the combination of efficient data size and stable annual time sequence is able to produce accurate demand forecasting (MAPE 3.73%–15.51%) while optimizing value Economic Order Quantity (EOQ) and Re-order point (ROP) for hospital cost efficiency. Meanwhile, in the study Chihaoui, (2026) With the research objectives are central pharmacies and emergency pharmacies, used model development Mixed Integer Linear Programming (MILP) that uses the basis of a recurring booking policy is integrated into the Decision Support System (DSS). This model uses data shortage cost penalty based on VED weighting (Vital = 20, Essential = 10, Desirable = 5) to ensure the availability of emergency medicines. In Saracoglu's (2024) study, stochastic modeling was used Chance-Constrained Programming (CCP) and Genetic Algorithm (GA) to conduct budget simulations as a basis for making procurement policies under budget limits.

Table 4. Implications of Budget Policy and Inventory Control in Articles

No.	Author, and Year of publication	Implications of Budget Policy and Inventory Control
1	Alanazi et al., (2024)	The implementation of *the ABC-VEN-based Zero-Waste to Landfill strategy has succeeded in reducing the prevalence of waste from 0.91% to 0.21% and saving 73.64% of the inventory waste value, with 82.3% of the total monetary value of waste being category I drugs.*
2	Saracoglu, (2024)	The model tests on various combinations of budgets and the probability level of constraint fulfillment. Nine scenarios were selected to determine product policies. Budgets of $210,000, $220,000 and $230,000 were tested with a probability of 90%, 95%, and 99%. Budget increases the number of items that can be purchased and decreases the probability of need. Simulations prove a 10% budget increase ($210k to $220k) drastically reduces *the shortage cost* from $21,242.56 to $14,389.99 with an average *service level* of 94%.
3	Ayalew et al., (2025)	Priority outcomes determine which drugs are focused on forecasting, then forecasting is used with EOQ on 29 category A items to determine needs/inventory. The integration resulted in a 17.63% reduction in total annual inventory costs (from 207,600 to 170,998 ETB.
4	Stuart et al., 2026.	The procurement policy is directed at saving the *Total Inventory Cost* (TIC) of Pharmacies, the integration of WMA and *EOQ Continuous Review* with stochastic parameters (ROP & *Safety Stock*) has succeeded in suppressing ICT and preventing emergency orders due to short-term demand fluctuations.
5	Chihaoui, (2026)	The implementation of the DSS-MILP combined optimization system resulted in a total cost efficiency of 18%–30%, cut *holding costs* by 40%–50%, reduced *stockout* frequency by 20%, and *stockout duration* by 30%

6	Singh et al., (2026)	Drugs in the AX/BX category (₹3.69 crore) were managed via *scheduled orders* & *buffer stock*; AZ/BZ drugs (₹2.32 crore) were ordered based on consumption forecasting. Monthly *stockout* decreased by 88.5% (28.33 to 6.667) where ($p < 0.001$) and wastage due to expiry by 76.5% (4.33 to 0.50 per month).

The results of the ABC-VEN classification are focused on forecasting, and the results are used as a basis for budget-based inventory policy determination. From the data in Table 4 on policy implications and inventory control from each article, there is a progression from classification based on economic value and clinical importance (ABC-VEN/VED) to an approach that considers demand variability, forecasting, and inventory optimization. ABC-VEN/VED is used to identify drugs that require higher priority and supervision, while the combination of ABC-XYZ, and forecasting methods is used to tailor procurement decisions to consumption patterns and define a policy-making model that integrates demand prediction, demand variability, and inventory allocation optimization. Stuart et al., 2026.; and Ayalew et al., (2025) integrate forecasting results into the EOQ system through the determination of safety stock, and Re-order point, while Chihaoui, (2026) implementing the development of DSS-MILP integration which results in a total cost efficiency of 18%–30%. Research by Saracoglu et al, (2024) shows that changes in budget allocation can affect the number of drugs that can be met, shortage cost, and Service Level. The findings suggest that forecasting not only serves as a need estimation tool, but can also be an input in inventory decision models and cost optimization.

A review of the economic aspects of each of the research articles shows that the use of integrated models provides better budget and clinical analysis results, ROI values (Return on Investment) high prices, a decrease in the value of expired drugs, and the impact of losses due to out-of-stock. In terms of total inventory costs (Total Inventory Cost / TIC), Ayalew et al., (2025) resulted in a reduction in total inventory costs by 17.63% (from 207,600 ETB to 170,998 ETB) at the referral hospital. In the object of the pharmacy-scale research, Chihaoui, (2026) resulting in operational cost efficiencies (Cost gain) by 18% to 30% (equivalent to savings of 360–2,400 TND per month), resulting from a reduction in daily storage costs (Holding Cost) by 25%–50% and the booking fee of 33% using the MILP/DSS model. Meanwhile, in the study Saracoglu, (2024) provide evidence of a non-linear relationship between budget allocation and the risk of scarcity costs, where an increase in the procurement budget by 10% (from $210,000 to $230,000) can reduce total annual storage costs by 70% and reduce estimated out-of-stock costs (Stockout Cost) to 83% (from $21,242 to $3,624). Associated with the decline in the value of waste and stockouts, the research of Singh et al. (2026) shows the results of a decrease in frequency Stockout monthly significantly by 88.5% ($p < 0.001$) and reduced losses due to expired drugs by 76.5% (from ₹28,333 to ₹6,667 per month). This is in accordance with the mechanism Zero-Waste to Landfill evaluated by Alanazi et al., (2024) using data for a 7-year period in Saudi Arabia managed to reduce the value of inventory waste from 0.91% to 0.21% of the total logistics budget of SAR 7.4 billion, which when

accumulated is equivalent to a saving of 73.64% of the inventory value from the risk of drug disposal.

From the results of the 6th research, the article provides managerial policy implications for policy makers in the application of the joint integration model of ABC-VEN/VED or ABC-XYZ as a national drug procurement procedure, especially in high-cost drugs such as cancer or other expensive chronic diseases (Ayalew et al., 2025; Singh et al., 2026). Increased digitalization efforts and the implementation of early warning systems (Early warning system) as a measure to accelerate response to the risk of expiry and reorder points (Edit Point)) need to be integrated or Bridging System between the Hospital Information System (SIMRS) with forecasting methods such as WMA or Linear Regression and the systematic optimization module (MILP/EOQ) (Alanazi et al., 2024; Andawaningtyas et al., 2026; Chihaoui, 2026). Meanwhile, improvement efforts with external parties, in this case pharmaceutical distributors, need to increase supervision of service agreements (Service Level Agreement / SLA) in order to guarantee supply chain processes to reduce the risk of increasing total operating costs by up to 12%, a surge in Stockout 40% in the event of a supply delay (Lead Time Extension) for 2 days (Chihaoui, 2026).

The six articles show a shift in pharmaceutical logistics governance from passive storage to proactive supply chain management based on multicriteria matrices and mathematical modeling. According to the analysis from a health economics perspective, the optimization of drug allocation and inventory management is an instrument used to reduce the risk and adverse impact of the occurrence of drug economic loss and opportunity cost Consequences of expired drugs (expired medicines) and lack of preparation (stock-out), as well as improving the efficiency of the use of drug budgets (Singh et al., 2026). The results of matrix integration classification such as ABC-VED, ABC-XYZ, and ABC-VEN can provide drug item data that needs to be given increased surveillance. There is a combination of time series forecasting and optimization models (such as EOQ Continuous Review, MILP, and Chance-Constrained Programming) shows that a data-driven approach can provide a relationship between operational costs and service quality. So that improvements to the system are proven to improve high budget conditions as well as guarantee the implementation of patient service sustainability.

CONCLUSION

The findings of this literature review indicated that integrating drug classification methods, mathematical modeling, and quantitative demand forecasting could facilitate a transition toward a more proactive, cost-efficient, and clinically responsive healthcare logistics management system. The reviewed studies reported reductions in total inventory costs of up to 17.63% and improvements in operational efficiency of approximately 18%–30%. Furthermore, the integrated approach demonstrated the potential to mitigate economic losses by reducing the risk of stockouts by up to 88.5% and preventing losses associated with drug expiration, with reported savings equivalent to 73.64% of the budget value at risk.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to the conduct of the research, preparation, or publication of this article.

AUTHOR CONTRIBUTION

All authors contributed to the preparation of this article. Nur Khijjatul Meiliyah, Wahyu Aditama Putra Mukti Wibawa, Hariyono, Yuanita, and Rachma Windiyanti, was responsible for the conceptualization of the study, data collection and analysis, interpretation of the results, and manuscript preparation. The other authors contributed to the review, editing, and final approval of the manuscript.

GENERATIVE ARTIFICIAL INTELLIGENCE USAGE STATEMENT

The authors declare that no generative artificial intelligence was used in the preparation of this article.

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