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Method of Forecasting Medicine Requirements Based on Consumption Data and Disease Patterns in Hospitals

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Abstract

Effective drug inventory management is crucial for maintaining service quality and cost efficiency in hospitals. Inaccurate procurement planning can lead to stock shortages or surpluses, which disrupt healthcare operations. This study presents several forecasting methods to improve the accuracy of demand predictions. Various forecasting methods have been developed based on two types of forecasting approaches, namely qualitative and quantitative. Qualitative methods produce forecasts based on assessments or opinions, while quantitative techniques largely rely on data to generate prediction models. In the pharmaceutical industry, time series models are most commonly used. Forecasting demand for pharmaceutical products by exploring artificial intelligence technologies improves the forecasting process and the accuracy of demand forecasts. However, classical univariate time series methods, such as exponential smoothing and autoregressive integrated moving average (ARIMA), generally provide good results. The ARIMA method is the best method to use compared to the Exponential Smoothing method because the MAPE and MSE calculation results show that the ARIMA method has the smallest error value. Field studies and survey results show that the use of human judgement adds value to the estimates produced by quantitative/statistical models. Implementing better forecasting models and refining inventory control mechanisms based on consumption data and disease patterns in hospitals can significantly reduce stock imbalances, optimise procurement decisions, and improve hospital financial performance.

Keywords: *Forecasting Methods, Drug Availability, Hospitals, ARIMA.*

INTRODUCTION

Hospital drug management constitutes one of the most strategic components of healthcare administration because it directly influences the quality, continuity, and equity of healthcare services. Medicines are not merely logistical commodities but essential healthcare resources that determine whether patients receive timely and appropriate treatment. Inadequate medicine availability may lead to treatment delays, therapeutic failure, increased morbidity, and declining public trust in healthcare institutions. From a social perspective, shortages of essential medicines can widen disparities in healthcare access, particularly among vulnerable populations who depend heavily on public hospital services. Consequently, effective pharmaceutical management is closely associated not only with operational efficiency but also with the broader principles of health equity and social justice within healthcare systems.

In hospital settings, pharmaceutical expenditure represents one of the largest components of operational costs outside clinical services. Therefore, ineffective medicine management can significantly burden hospital finances and reduce service efficiency. Drug management aims to ensure that medicines are consistently available in sufficient quantities, appropriate types, guaranteed quality, and at the right time while promoting rational drug use. Hospital pharmacy departments play a central role in achieving these objectives through systematic procurement planning and formulary management processes (Binsar & Mauritsius, 2020). The availability of medicines is one of the factors that must be considered by the Indonesian government because national medicine consumption accounts for 40% of total health expenditure. If medicine management is ineffective, high costs will lead to inefficiency in medicine management, which in turn will have a negative impact both medically and non-medically (Indonesia Ministry of Health, 2006).

Research conducted by the WHO and various global health organisations indicates that approximately 25–40% of pharmaceutical expenditure in healthcare facilities could be saved if drug planning were carried out systematically and based on data (WHO, 2003). Two data sources that have great potential in supporting rational drug planning in hospitals are patient disease patterns and drug consumption data. Disease patterns provide an overview of the prevalence and trends of diseases occurring in the hospital environment, which can be used as a basis for predicting the types and quantities of medicines that will be needed. Meanwhile, medicine consumption data reflects the actual use of medicines during a certain period, which reflects the effectiveness of previous planning and can be used to estimate future needs. Studies in several hospitals in Indonesia also show that an approach based on disease patterns and drug consumption can reduce stockouts by up to 60% and increase budget efficiency by up to 30%. These findings indicate that the implementation of a structured planning system can provide significant benefits, both in terms of service and managerial efficiency (Priyandani & Setiawan, 2016). Nevertheless, forecasting medicine demand in hospitals remains highly complex because healthcare systems operate within dynamic social environments influenced by changing disease trends, physician prescribing behavior, patient demographics, policy adjustments, and emergency situations.

Medicine demand forecasting management is an important aspect of strategic and operational decision-making. In the context of management, forecasting can be divided into two main approaches: quantitative and qualitative. The quantitative approach focuses on the use of historical data and mathematical models to predict the future, while the qualitative approach relies more on expert judgement, opinion, and non-numerical information (Tumiwa et al., 2014). Perfect forecasting is impossible due to uncertainty in various factors, so it is necessary to choose the best method (Nopita Putri et al., 2024). The purpose of this article review is to discuss the most accurate or efficient forecasting method for determining the type of drug requirements based on consumption data and disease patterns in hospitals. The benefits of this paper are to reduce the risk of drug stock shortages and expiry, improve procurement efficiency and pharmacy budgets, and strengthen the *Hospital Information System* (HIS).

The research gap in hospital medicine demand forecasting systems is characterized by the limited integration of consumption data and disease pattern analysis within existing frameworks. Prior studies have largely concentrated on historical consumption trends or manual estimation methods, frequently examining disease patterns independently rather than incorporating them systematically into predictive models (Restyana et al., 2021; Syahrir et al., 2022). Despite indications that advanced forecasting techniques can reduce shortages and optimize budgets, no universal agreement exists on the superior method for addressing volatile disease trends and patient demands (Siddiqui et al., 2022; Thaiudomsap & Sribundit, 2022). Hence, additional research is imperative to assess integrated forecasting methodologies that combine these data sources more holistically to promote efficacious, cost-effective, and evidence-based hospital drug management.

The purpose of this study is to analyse and identify the most accurate and efficient forecasting methods for determining hospital medicine requirements based on drug consumption data and disease patterns. This research seeks to evaluate how quantitative and qualitative forecasting approaches can support systematic drug planning in order to ensure the availability of medicines in the right quantity, type, quality, and time. Furthermore, the study aims to explore the role of disease prevalence trends and historical medicine consumption in improving the effectiveness of pharmaceutical management and reducing inefficiencies in hospital drug procurement systems. Through this approach, the research is expected to contribute to minimising the risks of drug shortages and medicine expiration, enhancing procurement and budget efficiency, and strengthening the integration of forecasting systems within Hospital Information Systems (HIS).

Accordingly, the current research gap is not merely related to the lack of integration between disease pattern data and medicine consumption data, but rather to the limited understanding of how quantitative forecasting models can be integrated with expert judgment to address dynamic healthcare realities. Previous research has yet to comprehensively explain how hospitals can bridge the rigidity of mathematical forecasting systems with the social complexity of healthcare service delivery, particularly in maintaining medicine availability, improving public trust, and ensuring equitable healthcare access (Siddiqui et al., 2022; Thaiudomsap & Sribundit, 2022). This issue becomes increasingly relevant as hospitals are required to make responsive and evidence-based pharmaceutical decisions under conditions of uncertainty and fluctuating patient demand.

Therefore, this study aims to analyse and identify forecasting approaches for determining hospital medicine requirements based on medicine consumption data and disease patterns while emphasizing the complementary role of expert judgment in pharmaceutical decision-making. The study seeks to evaluate

how quantitative forecasting methods, qualitative considerations, and Hospital Information Systems can interact synergistically to support adaptive and evidence-based medicine planning. Furthermore, this research aims to explore how integrated forecasting systems may contribute to reducing medicine shortages and expiration, improving procurement efficiency, strengthening public trust in healthcare institutions, and promoting more equitable healthcare services through sustainable pharmaceutical management practices.

METHOD

This study employed a qualitative systematic literature review approach using narrative synthesis to identify, compare, and interpret various forecasting methods for hospital medicine requirements based on drug consumption data and disease patterns. The qualitative approach was selected because the study emphasizes the managerial, organizational, and behavioral implications of forecasting practices rather than merely evaluating mathematical accuracy. Through narrative synthesis, empirical findings from multiple scientific sources were systematically integrated to obtain a comprehensive understanding of how forecasting methods contribute to decision-making processes and pharmaceutical inventory management in hospital settings.

Research Design

The research design was descriptive-analytical with a qualitative systematic review orientation. The study focused on synthesizing previous research concerning medicine demand forecasting in hospitals, particularly studies discussing the implementation of quantitative forecasting methods such as Exponential Smoothing and Autoregressive Integrated Moving Average (ARIMA), as well as the managerial adaptation of pharmacy personnel toward forecasting outcomes. The review emphasized how forecasting systems support planning effectiveness, inventory control, and organizational responsiveness within healthcare institutions.

Data Collection Techniques

The study utilized secondary data obtained through documentation and literature review techniques from various scientific sources, including:

1. National and international peer-reviewed journal articles;
2. Reports from health organizations, such as the World Health Organization (WHO);
3. Academic books and publications related to pharmaceutical management, health services, and forecasting systems.

The literature selection process was conducted purposively based on relevance, publication credibility, and contextual suitability to hospital pharmaceutical management. Inclusion criteria included:

1. Articles discussing forecasting methods for hospital medicine requirements;
2. Studies examining the integration of drug consumption data and disease patterns;
3. Research documenting managerial responses, staff adaptation, or organizational decision-making related to forecasting results;
4. Publications issued within the last ten years to ensure contextual relevance.

Meanwhile, exclusion criteria included:

1. Studies focusing solely on mathematical model development without discussing managerial or operational implications;
2. Non-scientific publications lacking empirical evidence;
3. Articles unrelated to hospital pharmaceutical services or healthcare management contexts.

Research Instrument

The primary research instrument was a literature review matrix designed to classify, organize, and synthesize findings from selected studies systematically. The matrix consisted of several components, including:

1. Research identity (author, year, publication source);
2. Forecasting methods applied;
3. Types of variables analyzed, such as drug consumption data and disease patterns;
4. Managerial and organizational findings;
5. Reported implications for pharmaceutical inventory planning and hospital decision-making.

Indicators of forecasting accuracy, such as Mean Absolute Percentage Error (MAPE) and Mean Squared Error (MSE), were reviewed only as supporting information to understand the practical implications of forecasting performance rather than as the primary analytical focus of the study.

Data Analysis Techniques

Data analysis was conducted using qualitative content analysis and narrative comparative synthesis. The analytical stages included:

1. Data reduction by selecting literature relevant to the research objectives;
2. Categorization of forecasting approaches and their managerial applications;
3. Comparative interpretation of forecasting methods in terms of operational effectiveness, adaptability, and decision-support capacity;
4. Narrative synthesis to formulate integrated conclusions regarding the contribution of forecasting systems to efficient and data-driven pharmaceutical management in hospitals.

The analysis also considered the role of expert judgment and organizational experience as complementary elements in forecasting implementation. This perspective was important because forecasting effectiveness in healthcare management is influenced not only by statistical performance but also by human adaptation, institutional policy, and decision-making processes within hospital pharmaceutical services.

Through this methodological approach, the study is expected to provide a comprehensive social and managerial perspective regarding the implementation of forecasting methods for medicine requirement planning in hospitals.

RESULT AND DISCUSSION

Result

1. Effectiveness of Forecasting Methods Based on Consumption Data and Disease Patterns

   The findings of the literature review demonstrate that forecasting medicine requirements based on consumption data and disease patterns provides a higher level of accuracy compared to conventional estimation approaches. Conventional methods, which generally rely on subjective estimation and routine procurement habits, often fail to accommodate dynamic changes in patient needs and disease prevalence. In contrast, forecasting approaches that utilize historical medicine consumption and epidemiological trends are able to generate more rational, measurable, and evidence-based estimates of medicine requirements.

   The reviewed studies indicate that the implementation of this approach contributes significantly to improving pharmaceutical management performance in hospitals. Several studies reported that the application of data-based forecasting methods reduced medicine stockout occurrences by approximately ±60% and improved procurement budget efficiency by up to ±30%. These improvements occur because hospitals are able to predict medicine demand more accurately, thereby minimizing excessive inventory accumulation and reducing the risk of medicine expiration. Furthermore, systematic forecasting enables pharmacy departments to align procurement planning with actual patterns of disease prevalence and patient treatment needs.

   The integration of disease pattern analysis into forecasting activities also strengthens the responsiveness of hospitals toward seasonal and epidemiological changes. By identifying dominant disease trends within a certain period, hospitals can anticipate future medicine requirements more effectively. Consequently, forecasting based on both consumption data and disease patterns not only supports operational efficiency but also contributes to improving the quality and continuity of healthcare services.

2. Inventory Control through ABC and VEN Analysis

   The literature review further reveals that inventory control plays an essential role in supporting forecasting effectiveness and medicine availability. One of the most widely implemented approaches in hospital pharmaceutical management is the combination of ABC and VEN analyses. These methods assist hospitals in prioritizing medicine procurement and monitoring inventory utilization systematically.

ABC analysis classifies medicines into three categories based on their consumption value and financial contribution. Category A consists of medicines with the highest consumption value and budget impact, although the number of items is relatively small. Category B includes medicines with moderate consumption value, while Category C represents medicines with low financial contribution but relatively large quantities. Through this classification, hospitals can focus monitoring and budget allocation on medicines with the greatest economic significance.

Meanwhile, the VEN method categorizes medicines according to their clinical urgency into Vital, Essential, and Non-essential groups. Vital medicines are those that must always be available because they are directly related to life-saving treatment. Essential medicines are important for standard healthcare services, whereas non-essential medicines have lower priority in procurement planning. The integration of ABC and VEN analyses produces a more structured inventory management system because hospitals can simultaneously consider both economic value and clinical importance in determining procurement priorities.

The reviewed studies indicate that the combined application of ABC-VEN analysis improves inventory efficiency, reduces unnecessary medicine accumulation, and strengthens medicine distribution control within hospital pharmacy systems. As a result, pharmaceutical resources can be managed more effectively while ensuring the continuous availability of critical medicines for patients.

3. Performance of Quantitative Forecasting Methods

The findings also show that quantitative forecasting methods based on time series analysis are widely utilized in predicting hospital medicine requirements. Several commonly applied methods include moving average, exponential smoothing, and the Autoregressive Integrated Moving Average (ARIMA) model. These methods rely on historical consumption data to identify trends and predict future medicine demand.

Among the reviewed forecasting techniques, the ARIMA method demonstrates the highest level of forecasting accuracy compared to other statistical approaches, particularly exponential smoothing. This superiority is reflected in lower forecasting error values obtained from model evaluation indicators such as Mean Absolute Percentage Error (MAPE) and Mean Squared Error (MSE).

The forecasting evaluation indicators are formulated as follows:

$$MAPE = \frac{1}{n}\sum_{t=1}^{n} \left| \frac{A_t - F_t}{A_t} \right| \times 100\%$$

$$MSE = \frac{1}{n}\sum_{t=1}^{n} (A_t - F_t)^2$$

Lower MAPE and MSE values indicate smaller deviations between forecasted and actual medicine demand data, thereby reflecting a higher level of forecasting precision. The reviewed literature consistently demonstrates that ARIMA models produce more stable and reliable forecasting outcomes because they are capable of capturing data trends, seasonality, and fluctuations in medicine consumption patterns.

In addition to conventional statistical methods, the literature also highlights the growing use of artificial intelligence (AI)-based forecasting approaches, including machine learning and artificial neural networks. These approaches are capable of processing large datasets and identifying complex relationships among variables, resulting in improved forecasting accuracy. However, AI-based models still face several limitations, particularly regarding the availability of high-quality data, computational complexity, and the need for specialized technical expertise. Therefore, although AI methods show promising potential, their implementation in hospital pharmaceutical systems requires adequate technological infrastructure and data management readiness.

4. Integration of Quantitative Models and Human Judgment

Another important finding of this review is the significance of integrating quantitative forecasting models with human judgment in medicine requirement planning. Although quantitative methods provide objective and data-driven estimations, human expertise remains necessary to interpret forecasting outcomes within the context of real healthcare conditions.

The reviewed studies reveal that pharmacist experience, physician input, and managerial considerations contribute substantially to improving estimation quality, particularly under conditions of uncertainty and rapidly changing disease patterns. Situations such as disease outbreaks, policy changes, seasonal epidemics, and unexpected healthcare emergencies often cannot be fully predicted using historical data alone. Therefore, professional judgment is essential to complement statistical forecasting results.

The integration of quantitative analysis and expert judgment creates a more adaptive forecasting system because decision-makers can adjust procurement strategies according to contextual healthcare conditions. This combined approach not only improves forecasting accuracy but also strengthens strategic decision-making in hospital pharmaceutical management. Consequently, hospitals can achieve a better balance between medicine availability, operational efficiency, and budget optimization.

Discussion

This literature review highlights that forecasting systems for hospital drug requirements cannot rely solely on mathematical or statistical calculations. Although quantitative forecasting models such as ARIMA, Exponential Smoothing, and consumption-based analyses provide important analytical foundations for estimating future medicine needs, the planning process in hospital pharmacy management remains strongly influenced by human judgement, organizational dynamics, and socio-environmental uncertainty. Consequently, forecasting drug requirements should be understood not merely as a technical computation process, but also as a managerial and behavioral decision-making activity embedded within complex healthcare systems.

Effective pharmaceutical supply management aims to ensure the continuous availability of safe, effective, and essential medicines through integrated processes of selection, quantification, procurement, distribution, and rational use of drugs. Several studies emphasize that hospital pharmacies commonly combine consumption data with morbidity or disease-pattern analysis to estimate future drug needs (Migbaru et al., 2016). The ABC-VEN matrix approach remains widely applied because it allows hospitals to prioritize medicines based on both financial value and clinical urgency (Almahdy et al., 2021). However, despite the availability of structured forecasting tools, practical implementation in hospitals frequently encounters challenges caused by incomplete data, changing disease patterns, administrative pressures, and sudden policy shifts.

Research by Indrayanti and Megasari (2025) demonstrates that forecasting based on disease patterns and actual drug consumption tends to produce more rational and accurate planning outcomes. Nevertheless, the study also stresses the importance of integrating information systems across hospital units and strengthening managerial interpretation of forecasting results. This finding supports the argument that quantitative models alone cannot fully represent the complexity of healthcare demand because hospital service environments are highly dynamic and socially influenced.

The integration between quantitative forecasting models and human judgement can be theoretically explained using Herbert Simon's Theory of Bounded Rationality. Simon argues that decision makers operate under limitations of information, time, organizational pressure, and cognitive capacity. In the context of hospital pharmacy management, pharmacists and physicians rarely make decisions based solely on complete and perfectly rational information. Instead, they must interpret limited historical data while simultaneously considering contextual realities such as seasonal disease outbreaks, physician prescribing behavior, budget constraints, and sudden changes in healthcare regulations. Therefore, forecasting models such as ARIMA may statistically identify historical consumption trends, but they cannot independently capture tacit clinical knowledge and social intuition possessed by healthcare professionals.

This limitation becomes particularly evident during periods of crisis or rapid policy change. Historical forecasting methods rely heavily on assumptions that future demand patterns will resemble previous trends. However, in healthcare systems, medicine demand is often disrupted by sociological and organizational factors that are difficult to quantify statistically. Changes in national health insurance policies under the BPJS Kesehatan system, for example, may significantly alter prescribing patterns, patient access to medicines, and hospital reimbursement mechanisms within a short period. Likewise, social panic during pandemic situations can trigger sudden increases in medicine consumption that are not reflected in previous historical data. Consequently, forecasting systems that depend entirely on historical time-series calculations risk generating substantial inaccuracies during extraordinary situations.

Field observations and previous studies indicate that data used in hospital forecasting systems are also vulnerable to institutional bias. Bureaucratic pressure in budget planning may encourage units to overestimate medicine needs in order to avoid future shortages, while concerns regarding audit evaluations

may result in conservative reporting practices. In addition, differences in coordination between pharmacy units, procurement divisions, and clinical departments often produce inconsistencies in medicine utilization records. These organizational realities reinforce the importance of professional judgement in interpreting forecasting outputs rather than mechanically accepting numerical predictions generated by software systems.

The first stage of forecasting analysis generally involves collecting data on disease prevalence, medicine consumption, stock availability, procurement cycles, and historical expenditure reports. Secondary data derived from inventory reports, expired medicine records, and stock opname documents are commonly used to evaluate planning accuracy and support ABC-VEN analysis (Widyapratiwi et al., 2024). In practice, many hospitals apply annual forecasting cycles because they align with institutional budgeting systems and government procurement regulations. Forecasting calculations are often supplemented with buffer stock policies to reduce the risk of shortages, particularly for vital medicines and seasonal diseases.

Several statistical forecasting approaches, including ARIMA and Exponential Smoothing, have demonstrated relatively good performance in predicting medicine demand. Previous studies found that ARIMA frequently produces lower forecasting errors, particularly in terms of MAPE and MSE values, when compared with other conventional time-series methods (Zahra & Putra, 2019). Nevertheless, the superiority of statistical accuracy does not automatically guarantee managerial suitability in hospital settings. Forecasting effectiveness also depends on data quality, staff competency, institutional readiness, and the ability of decision makers to interpret model outputs appropriately.

Recent developments in artificial intelligence and machine learning have introduced forecasting methods such as Long Short-Term Memory (LSTM) and Recurrent Neural Networks (RNN). Although these approaches offer opportunities to improve forecasting automation and pattern recognition, their implementation in hospitals remains constrained by several practical limitations. Many hospitals, particularly in developing countries, still face challenges related to human resource competency, data integration infrastructure, and technological readiness. Advanced machine learning systems generally require large and consistent datasets, specialized technical expertise, and substantial computational resources. Consequently, their adoption in hospital pharmacy management cannot be separated from organizational readiness and workforce capability.

Furthermore, several scholars criticize artificial intelligence forecasting systems because they often function as “black box” models that are difficult for healthcare practitioners to interpret transparently. In healthcare decision-making environments, transparency and accountability are critical because forecasting outcomes directly influence patient safety and medicine availability. For this reason, many pharmaceutical institutions continue to prefer simpler statistical methods combined with professional judgement rather than relying entirely on highly complex artificial intelligence systems (Merkuryeva et al., 2019). This finding suggests that technological sophistication should not be viewed as the sole indicator of forecasting quality. Instead, forecasting systems must be evaluated based on their contextual suitability, interpretability, and adaptability within hospital organizations.

The second stage of forecasting analysis involves correlational and comparative evaluation between disease incidence and medicine utilization patterns. Hospitals commonly compare planned procurement quantities with actual consumption data to identify overstock, understock, or appropriate inventory conditions. This evaluation process not only measures forecasting accuracy but also becomes an organizational learning mechanism for improving future planning policies. Forecasting errors are inevitable because healthcare demand is inherently uncertain; however, continuous evaluation allows hospitals to minimize inefficiencies and improve responsiveness to changing patient needs.

Overall, the findings of this literature review strengthen the argument that effective medicine forecasting requires an integration of quantitative analysis and human judgement. Statistical methods such as ARIMA remain valuable tools for identifying historical consumption trends and improving planning accuracy. Nevertheless, forecasting systems in hospital pharmacies cannot be separated from the experiential knowledge, clinical intuition, and contextual interpretation of pharmacists and healthcare professionals. From a theoretical perspective, this study reinforces the relevance of bounded rationality theory in explaining decision-making processes within healthcare organizations. Practically, the findings are expected to support hospital pharmacists and healthcare managers in developing adaptive, evidence-based, and context-sensitive medicine planning systems capable of responding to both routine operational conditions and unexpected healthcare crises.

CONCLUSION

This study concludes that forecasting-based drug requirement planning, grounded in consumption data and disease patterns, constitutes a more accurate and efficient approach compared to conventional methods. Empirical evidence from the literature indicates that such a data-driven approach significantly reduces stock imbalances, particularly stockouts, while simultaneously enhancing budget efficiency and operational effectiveness in hospital pharmaceutical management. Among the various forecasting methods examined, time series models particularly ARIMA demonstrate superior performance in predicting drug demand, as reflected by lower forecasting error indicators such as MAPE and MSE. Despite the growing potential of artificial intelligence-based models, their practical implementation remains constrained by data availability and model complexity. Consequently, classical statistical models remain highly relevant, especially in resource-constrained healthcare settings.

Furthermore, the integration of quantitative forecasting models with expert judgment emerges as a critical factor in improving estimation quality, particularly under conditions of uncertainty and dynamic disease patterns. This finding reinforces the importance of adopting a hybrid decision-making framework that combines analytical rigor with professional experience. In practical terms, the study underscores the necessity for hospitals to strengthen their data management systems, enhance analytical capabilities, and adopt appropriate forecasting techniques tailored to their operational context. Such measures are essential to achieving optimal drug inventory control, improving service quality, and ensuring the sustainability of healthcare delivery systems.

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