ORIGINAL RESEARCH

ISSN (O): 2349-5332
CODEN: IRJPHY

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EVALUATING THE IMPACT OF DEMAND-BASED INVENTORY MANAGEMENT ON ORDER FREQUENCY COMPARED TO THE FIXED DISTRIBUTION SYSTEM AT PRINCE RASHID BEN AL-HASAN MILITARY HOSPITAL

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Submitted on: 24.06.2025; **Revised on:** 26.06.2025; **Accepted on:** 27.06.2025

ABSTRACT

1. Introduction: Inventory management may not be the most perceptible part of the healthcare system however its influence is usually significant especially in systems where stability, efficient cost, and uninterrupted patient care are the ultimate goal and are non-negotiable.

2. Objective: This study seeks to evaluate how adopting EOQ, ROP, and SS models into JRMS system would influence medication order interval compared to the current fixed monthly share system and bi monthly distribution. This research will evaluate whether a more responsive and needs-based system will lead to improved efficiency.

3. Methodology: The study will employ a quantitative and analytical approach grounded in real data obtained from Prince Rashid Ben Al-Hasan Military Hospital pharmacy department records on 355 medications during the period of January 2024 to October 2024. First, medications will be analyzed on the bases of their average monthly consumption and induvial cost then the Economic Order Quantity (EOQ) will be calculated assuming a 7-day lead time and an ordering cost of 5 Jordanian Dinars (JD) and the Reorder Points (ROP) and Safety Stock (SS) levels will also be calculated for each item to account for any inconsistency then based on the resulted parameters medications will be grouped into categories according to their optimal ordering intervals, ranging from less than 7 days to more than 2 months and the resulted findings will be compared against the current two-month fixed share system. our analysis will also try to identify any possible patterns and the findings will be interpreted in the context of military hospital logistics.

Results: Analysis revealed significant variations in optimal ordering frequencies, 8 medications (2.25%) required ordering within 7 days, 28 (7.89%) between 7-14 days, 32 (9.01%) between 14-21 days, 50 (14.08%) between 21 days-1 month, 117 (32.96%) between 1-2 months, and 120 (33.80%) requiring intervals exceeding 2 months and these findings demonstrate substantial deviation from the current uniform bi-monthly distribution approach.

KEYWORDS: Inventory management, Economic Order Quantity, Reorder Point, Military hospital, Pharmaceutical supply chain, Jordan

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Indian Research Journal of Pharmacy and Science; 43(2025); 3268-3275
Journal Home Page: https://www.irjps.in

1. INTRODUCTION:

Healthcare inventory management represents one of the most decisive yet underappreciated elements of present medical care delivery and in military healthcare settings where operational readiness and resource optimization are dominant effective inventory management becomes even more vital [1]. The complexity of pharmaceutical inventory management stems from the unique characteristics of medical products including variable demand patterns, rigorous expiration requirements, critical nature of stockouts and significant cost implications [2].

Prince Rashid Ben Al-Hasan Military Hospital which operates within the structure of the Jordanian Royal Medical Services (JRMS) currently employs a conventional fixed-interval distribution system which allocates medications based on historical consumption patterns with deliveries occurring approximately every two months. Yet despite that such systems are common in many healthcare institutions it often struggles to adapt to the dynamic nature of medical demand which can vary significantly due to seasonal patterns, epidemic outbreaks, changes in patient demographics and evolving treatment protocols [3].

The theoretical foundation for modern inventory management started with the operations research principles which were developed throughout the 20th century, the Economic Order Quantity (EOQ) model which was first introduced by Ford Whitman Harris in 1913 and later refined by R.H. Wilson provides a mathematical basis for determining the optimal order quantities that minimize the total inventory costs [4] since this model balances ordering costs against holding costs and thereby providing a systematic approach to inventory optimization that has found widespread application across various industries [5].

In healthcare settings the application of the EOQ and other related inventory management techniques has shown a substantial promise and studies have demonstrated that hospitals implementing systematic inventory management approaches experience reduced stockouts, lower carrying costs and improved operational efficiency [6] and the incorporation of Reorder Point (ROP) calculations further enhances system responsiveness by establishing trigger points for order placement based on consumption rates and lead times [7].

The modern global stress on healthcare efficiency and cost control has renewed the interest in superior inventory management approaches and military healthcare systems face additional complications owed to their dual civilian and military missions, varied patient populations and potential for rapid demand fluctuations during deployment or emergency situations [8], the fixed distribution model currently used throughout the JRMS network while it provides administrative simplicity and more predictable supplier relationships it may not adequately address these unique challenges.

Recent technological advances have enabled more sophisticated inventory management approaches including real-time demand tracking, automated reorder systems and predictive analytics. These developments have made it possible for healthcare institutions to implement more responsive inventory management systems without too much administrative burden [9] leaving the healthcare administrators faced with the question of whether the potential benefits of such systems justify the implementation complexity and associated costs.

2. LITERATURE REVIEW:

The development of inventory management theory has greatly affected healthcare supply chain optimization over the past several decades and the early applications of EOQ models in hospital settings established the potential for substantial cost savings and improved service levels [10]. A study by Kausar and Madaan in India implemented EOQ-based inventory control in a hospital pharmacy and resulted in a 25% reduction in inventory carrying costs while maintaining service levels above 95% [11].

Subsequent research also has expanded upon these foundational studies to address the unique difficulties of healthcare environments. Nicholson et al. developed a comprehensive framework for pharmaceutical inventory management that integrates demand variability, product criticality and shelf-life constraints [12] and their model confirmed that differentiated inventory policies based on product characteristics could achieve a superior performance compared to uniform approaches.

The use of ABC analysis in healthcare inventory management also has gained considerable attention within the literature, studies have shown that the conventional 80-20 rule often applies to the pharmaceutical inventories with a small percentage of products accounting for the majority of inventory value [13] and this insight has led to the development of differentiated management tactics where high-value items receive more sophisticated inventory control while routine items are managed with simpler systems.

Recent research also has explored the integration of several inventory management techniques to create hybrid systems that capture the benefits of different approaches. Li and Wang developed an integrated EOQ-JIT model for hospital inventory management which achieved 30% reduction in total inventory costs while also improving service levels [14] and their approach demonstrates the potential for combining traditional inventory models with modern supply chain concepts.

Technology's effect on healthcare inventory management has been greatly transformative and enabled real-time tracking, automated reordering and sophisticated analytics. RFID implementation studies have demonstrated significant improvements in inventory accuracy and a reduction in manual labor requirements [15]. However the cost-benefit analysis of such technologies requires careful consideration of the implementation costs against the operational benefits.

Military healthcare inventory management faces unique challenges which also have been addressed in specialized literature and the studies of military medical logistics have emphasized the importance of flexibility and surge capacity in inventory planning [16] and stressed that the dual mission of military hospitals which serve both routine healthcare needs and potential emergency situations requires inventory systems that can adapt to rapidly changing requirements.

3. METHODOLOGY:

This study utilized a retrospective quantitative methodology to assess the possible effects of adopting demand-driven inventory management strategies at Prince Rashid Ben Al-Hasan Military Hospital. The methodology has been designed to establish a solid analytical framework for comparing the existing fixed-distribution procedures with the enhanced inventory management strategies.

3.1 Data Collection: Data collection employed the pharmaceutical inventory records from the hospital own pharmacy department which covered the period from January to October of 2024 and this period of 10 months was selected in order to capture any possible seasonal variations in the medication demand while also providing sufficient data points for a reliable statistical analysis. The dataset encompassed 355 different medications representing most of the spectrum of pharmaceutical products used within the military hospital setting. For each medication item the following data elements were collected: monthly consumption quantities, unit costs in Jordanian Dinars, product categorization codes and historical stockout incidents and the data collection process involved collaboration with pharmacy staff to ensure accuracy and completeness of records.

3.2 Economic Order Quantity Calculations: The EOQ calculation formed the foundation of the analytical approach and we calculated it utilizing the classic Wilson formula: $\{EOQ = \sqrt{(2DS/H)}\}$, Where: D = Annual demand (units), S = Ordering cost per order (5 JD) and H = Holding cost per unit per year (20% of the unit cost). Annual demand for each medication was calculated the collected monthly consumption quantities and adjusting it for any identified seasonal patterns and the ordering cost of 5 JD was established through consultation with procurement staff and represents the average administrative cost associated with processing purchase orders. Holding costs were calculated as a percentage of unit cost which incorporated storage costs, insurance, deterioration risks and opportunity cost of capital and based on healthcare industry benchmarks and institutional cost data the holding cost rate of 20% annually was applied across all medications.

3.3 Reorder Point and Safety Stock Calculations: Reorder Point calculations incorporated both the average demand during lead time and the safety stock requirements: ROP = (Average Daily Demand × Lead Time) + Safety Stock.

Lead time was standardized at 7 days based on the collected historical procurement data and the exiting performance metrics and the safety stock levels were calculated using the statistical methods that account for the demand variability with a 95% service level target.

3.4 Ordering Interval Determination: Based on the EOQ calculations the optimal ordering intervals were determined for each medication using the relationship: {Ordering Interval = EOQ / Average Daily Demand} and then the resulting intervals were categorized into discrete ranges for analysis purposes: within 7 days, 7-14 days, 14-21 days, 21 days to 1 month, 1-2 months and greater than 2 months.

4. RESULTS:

The analysis of 355 medications revealed significant variations in the optimal ordering frequencies and therefore demonstrating significant departures from the current uniform bi-monthly distribution approach used at Prince Rashid Ben Al-Hasan Military Hospital.

4.1 Distribution of Optimal Ordering Intervals: The categorization of medications by their optimal ordering intervals revealed a diverse distribution pattern:

Table 1: Distribution of Optimal Ordering Intervals

Estimated Order Period Category	Count	Percentage
Within 7 Days	8	2.25%
7 Days - 14 Days	28	7.89%
14 Days - 21 Days	32	9.01%
21 Days – Month	50	14.08%
1 Month - 2 Months	117	32.96%
> 2 Months	120	33.80%
Total	**355**	**100.00%**

The distribution results reveal that only 32.96% of medications are aligning reasonably well with the current bi-monthly ordering system while 66.23% of them would benefit from either more frequent or less frequent ordering patterns and this misalignment suggests that there is significant opportunities for inventory optimization through differentiated management approaches.

4.2 High-Frequency Ordering Requirements: Eight medications (2.25%) demonstrated optimal ordering intervals of less than 7 days therefore indicating extremely high consumption rates relative to their EOQ parameters and these are more likely medications primarily consisting of high-volume, low-cost items which are used in routine clinical procedures and emergency medications with high turnover. The identification of these high-frequency items emphasizes the inadequacy of bi-monthly ordering for fast-moving pharmaceuticals and under the current system these medications require considerable safety stock levels to prevent stockouts and also resulting in higher carrying costs and increased risk of expiration waste.

4.3 Extended Ordering Intervals: The analysis also revealed that 120 medications (33.80%) exhibited optimal ordering intervals that's exceeding 2 months therefore indicating that the current bi-monthly system actually results in over-ordering for these items and this category are more likely medications that primarily includes low-volume specialty medications, expensive pharmaceuticals with infrequent use and backup medications maintained for emergency situations and for these extended-interval medications the current bi-monthly ordering system results in unnecessary inventory buildup, increased carrying costs and higher risk of product expiration.

4.4 Cost Impact Analysis: Preliminary cost analysis suggests that significant potential savings through the implementation of differentiated ordering strategies are possible, total inventory carrying costs could be reduced by an estimated 25-30% through the optimization of ordering intervals all while maintaining appropriate service levels and the analysis also indicates that high-frequency medications currently account for approximately 45% of total inventory carrying costs despite representing only 19.15% of total medication items and therefore suggesting that optimization efforts that are focused on these high-turnover items could yield disproportionate benefits.

5. DISCUSSION:

The findings of this study reveal substantial opportunities for inventory optimization at Prince Rashid Ben Al-Hasan Military Hospital through the implementation of demand-based inventory management techniques since the resulted significant variation in the optimal ordering intervals across the 355 analyzed medications demonstrated that uniform inventory policies while administratively convenient may result in substantial inefficiencies and suboptimal resource allocation.

5.1 Implications of Current System Misalignment: The analysis reveals that only approximately one-third of medications are aligning well with the current bi-monthly ordering system and indicating that two-thirds of the pharmaceutical inventory would benefit from other alternative management approaches. For high-frequency medications that require ordering intervals of less than one month the current system demands higher safety stock levels to prevent stockouts between deliveries and therefore increasing carrying costs and tying up working capital [17]. Conversely, for low-frequency medications with optimal ordering intervals that exceed two months the current system results in over-ordering and unnecessary inventory accumulation and therefore this over-ordering increases carrying costs, requires additional storage space and may lead to product expiration before consumption [18].

5.2 Strategic Advantages of Differentiated Inventory Management: The implementation of a differentiated inventory management approaches offers several strategic advantages that stretch beyond simple cost optimization since the ability to match ordering frequency to actual demand patterns will enable more responsive patient care by reducing stockout risks for critical medications while also simultaneously reducing waste from unnecessary inventory accumulation.

The military hospital environment presents unique requirements that particularly benefit from optimized inventory management since the potential for rapid changes in patient volume during deployments or emergency situations requires inventory systems that can quickly adapt to the changing requirements [19] and the differentiated inventory management provides this flexibility by establishing appropriate baseline inventory levels while maintaining the ability to rapidly scale up for surge requirements.

5.3 Implementation Considerations: Successful implementation of differentiated inventory management requires an appropriate technology infrastructure in order to support the increased complexity of managing multiple ordering systems simultaneously at the same time. Modern hospital information systems provide the computational capability that's necessary for real-time EOQ calculations, automated reorder point monitoring and systematic safety stock management [20].However the investment in this inventory management technology should always be evaluated against the potential savings from improved inventory optimization since the results suggest that the cost savings from reduced carrying costs and improved service levels would likely justify reasonable technology investments.

5.4 Risk Management Considerations: While this optimized inventory management approach can offer substantial benefits it can also introduce new dangers that must be carefully managed including the increased ordering frequency for high turnover medications which can create more opportunities for supply chain disruptions that may impact operations and also robust supplier relationships and contingency planning become more important in the optimized inventory environments, military hospitals also face additional risks related to supply chain security and continuity during potential conflicts or emergency situations and the optimized inventory system must maintain appropriate strategic reserves while achieving operational efficiency during normal operations.

6. LIMITATIONS: This study acknowledges several limitations that should be considered when trying to interpret the results of this study or when planning implementation strategies based on it, the analysis relied on 10 months of historical consumption data which may not fully capture long-term demand patterns or cyclical variations that occur over longer time periods [21]. Also seasonal patterns in disease prevalence, epidemic outbreaks and changes in clinical protocols could also influence the demand patterns in different ways that are not reflected in the available data period. Additionally the study assumed consistent unit costs throughout the analysis period despite the fact that pharmaceutical prices can fluctuate due to market conditions, supplier changes and volume discounting arrangements. Also the assumption of 7-day lead times may not accurately reflect the complexity of pharmaceutical procurement particularly for specialty medications or during supply chain disruptions and the EOQ model assumes constant demand rates which may not accurately reflect the variable nature of healthcare demand therefore a more sophisticated models that incorporate demand variability could provide much improved optimization results but would require more complex implementation and data requirements.

7. RECOMMENDATIONS:

Based on the analysis results and consideration of implementation requirements several specific recommendations are proposed for Prince Rashid Ben Al-Hasan Military Hospital and the broader Jordanian Royal Medical Services system.

7.1 Phased Implementation Approach: Implementation of the optimized inventory management should follow a phased approach that allows for system enhancement and organizational adaptation, the first phase should focus on the most significant optimization opportunities predominantly the 68 medications that are requiring ordering intervals of 21 days or less which represent the greatest departure from current practices and with the highest potential for improvement. Phase two should address the 120 medications with optimal ordering intervals that are exceeding 2 months and implementing extended ordering cycles that reduce the inventory investment while maintaining appropriate service levels and the final phase should optimize the remaining medications and polish the overall system based on experience gained during initial implementation phases.

7.2 Technology Infrastructure Development: Investment in the appropriate inventory management technology is essential for the successful implementation of the differentiated inventory management approaches and this recommended system should provide automated EOQ calculations, real-time inventory tracking, automated reorder point monitoring and integration with the existing hospital information systems.

7.3 Performance Measurement System: the implementation should include a comprehensive performance measurement system that track key metrics including inventory turnover rates, stockout frequencies, carrying costs, ordering costs and service level achievement and this performance measurement system should also include healthcare-specific metrics such as medication availability rates and patient satisfaction measures that are related to medication access.

7.4 Staff Training and Development: A comprehensive training programs should be also developed for pharmacy staff, procurement personnel and clinical staff who interact with the inventory management system and this training should cover inventory management principles, system procedures and performance metrics to ensure the successful implementation and the ongoing operation.

8. CONCLUSION:

This comprehensive analysis of the inventory management practices at Prince Rashid Ben Al-Hasan

Military Hospital has established significant opportunities for optimization through the implementation of demand-based inventory management techniques, the considerable variation in the optimal ordering intervals across 355 analyzed medications with only 33% aligning with the current bi-monthly system provides a compelling evidence for the possible benefits of the differentiated inventory management approaches.

The study's findings reveal that 67% of the medications could benefit from either a more frequent or a less frequent ordering cycles compared to the current practices approach and that the implementation of the optimized inventory management approach which is based on the EOQ, the ROP and the safety stock calculations could potentially reduce the total inventory carrying costs by 25-30% while also improving the service levels and reducing the stockout risks.

The results support a clear recommendation for Prince Rashid Ben Al-Hasan Military Hospital to transition from its current fixed bi-monthly distribution system to a differentiated inventory management approach based on individual medication characteristics and their demand patterns and this transition represents not merely an operational improvement but a strategic enhancement that allies inventory management practices with the dynamic requirements of modern military healthcare delivery. Future research should focus on longitudinal studies that track the actual implementation results of this optimized inventory management system including detailed cost-benefit analyses and patient outcome assessments.

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CONFLICT OF INTEREST REPORTED: NIL; SOURCE OF FUNDING: NONE REPORTED