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The Optimization tools of the pharmaceutical supply chain downstream: A literature review

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Introduction

Hospital logistics plays a central role in the proper functioning of healthcare facilities, particularly when it comes to ensuring the availability and traceability of pharmaceutical products. Optimizing the pharmaceutical supply chain in hospitals has become a priority to meet increasing demands for quality of care, patient safety, and cost control.

In this context, inventory management represents a strategic lever. Poor management can lead to critical shortages or, conversely, costly overstocking. Various restocking policies and product classification methods (ABC, VED, MASTA, etc.) have been developed to ensure optimal availability of medications while managing resources efficiently.

Beyond storage, logistical performance also depends on the effectiveness of internal pharmaceutical distribution. Different restocking modes—such as the kanban system (full-empty), level-based approaches, trolley exchange, or unit-dose distribution (DIN) have been adopted to improve the speed, reliability, and traceability of deliveries within care units.

Finally, the digital transformation of the hospital sector opens new opportunities to strengthen traceability and security in the supply chain. Technologies such as barcoding and RFID are increasingly integrated into hospital logistics systems, with measurable impacts on error reduction, process optimization, and improved product tracking.

This article offers a structured review of tools and methods for optimizing the hospital pharmaceutical supply chain. It aims to identify current practices in inventory management, internal distribution, and supporting technologies, in order to provide a critical synthesis and potential avenues for improving hospital logistics performance.

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2. Inventory Management Tools

Pharmaceutical inventory management in hospitals is crucial to ensure the availability of medications and maintain the quality of care. Poor management can lead to critical shortages or costly overstocking. Restocking policies and inventory classification methods are essential levers for optimizing this management.

2.1 Replenishment Policies

Replenishment policies are mainly divided into three categories:

- Periodic review policies ((T, S) or (R, S)): Inventory levels are reviewed at regular intervals, and an order is placed to reach a predefined stock level. This method is suitable for low-criticality items with stable consumption.
- Continuous review policies ((s, Q) and (s, S)): An order is triggered as soon as the stock reaches a threshold level s. Replenishment may be for a fixed quantity (Q) or variable up to level S. These policies are appropriate for critical items requiring constant monitoring.
- Hybrid policies ((R, s, Q)): Combining elements of both previous approaches, they offer increased flexibility based on the monitoring frequency (R), reorder point (s), and order quantity (Q).

		WHEN? ?	
		Fixed Period	**Variable Period**
HOW MUCH?	Fixed Quantity	-	Continuous Review Policy (s, Q)
	Variable Quantity	Periodic Review Policy (T, S)	Continuous Review Policy (s, S)

Table 1: Replenishment Policies

Authors	Type of Review	Policy Studied

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Vincent and Ranton (1984)	T	(R, s, Q), (T, s, Q)
Dellaert and Van de Poel (1996)	T	(R, s, Q)
Nicholson et al. (2004)	T	(R, S)
Lapierre and Ruiz (2007)	T	(R, s, Q)
Little and Coughlan (2008)	T	(R, S)
Marco Bijvank (2012)	T	(R, s, Q)
Kelle et al. (2012)	C	(s, S)
Vila-Parrish et al. (2012)	T	(T, S)
Uthayakumar and Priyan (2013)	C	(s, Q)
Priyan and Uthayakumar (2014)	C	(s, Q)
Gebicki et al. (2014)	T	(R, S)
Rosales et al. (2015)	C	(s, Q)
Roni et al. (2015, 2016)	C	(s, Q)
Visentin et al. (2022)	T	(R, s, S)
Visentin et al. (2020)	T	(R, s, S)
Medjani et al. (2020)	C	(s, S)
Rahal (2023)	C	(s, Q)
Bandi et al. (2018)	T	Robust periodic-affine policies
Tang & Anane (2023)	T	(s, Q)
Saddikuti et al. (2024)	C	Multi-criteria simulation (s, Q)
Atcha et al. (2024)	T	Inventory sharing / Just-In-Time (JIT)

Table 2. Inventory Management Policies in Hospitals

2.2 Stock Classification Methods

To prioritize logistics resources, several classification methods are used:

- **ABC Method**: Categorizes items into three groups (A, B, C) based on their annual consumption value.
- **VED Method**: Categorizes items according to their criticality: Vital (V), Essential (E), Desirable (D).

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- **Combined ABC-VED Method**: Combines the previous two approaches to identify items that are both costly and critical.
- **MASTA Approach (Multi-Attribute Spare Tree Analysis)**: Uses a multi-criteria classification structured around a logical tree, incorporating therapeutic criticality, usage frequency, and supply constraints.

Several empirical studies have evaluated the effectiveness of replenishment policies in a hospital setting. Vincent and Ranton (1984), Nicholson et al. (2004), Kelle et al. (2012), and Uthayakumar & Priyan (2013) showed that choosing a replenishment strategy suited to the consumption profile and criticality of products helps improve logistical performance and the quality of care. More recently, Fathollahi-Fard et al. (2025) proposed a model based on Deep Reinforcement Learning to manage perishable drug stocks in a non-stationary demand environment, demonstrating that intelligent approaches can outperform traditional models in complex contexts. Similarly, Sanogo (2024) analyzed the impact of seasonal demand on drug stock management in private pharmacies. She found that seasonal variations, particularly during the rainy season, significantly affect drug availability, highlighting the importance of adapting classification and replenishment methods according to demand fluctuations.

3. Internal Distribution Methods

The internal distribution of pharmaceutical products is a critical link in the hospital supply chain. It encompasses all the operations required to transport medications and medical supplies from storage areas to care units. Ineffective distribution can lead to delays, delivery errors, and compromise the continuity of care. The complexity of this process is increased by the diversity of products, the variability of needs, and the multiple stakeholders involved.

3.1 Replenishment Cycle Activities

Blouin et al. (2000) identify four main activities in the hospital replenishment cycle:

- **Order**: Identifying needs and submitting requests.
- **Pick**: Physically collecting items from the store.
- **Transport**: Delivering products to the care units.
- **Place**: Storing and organizing products in local storage systems.

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These steps are present in all internal distribution methods, though their execution may vary depending on the adopted model.

3.2 Replenishment Methods

Various replenishment methods have been developed to address the organizational and logistical constraints specific to hospitals:

- **Requisition System**: Healthcare staff manually or electronically request replenishment. This system relies heavily on user experience but remains widespread due to its simplicity (Blouin et al., 2001).
- **Trolley Exchange**: Products are stored in mobile trolleys and regularly exchanged with pre-filled trolleys. This method reduces stockouts but generates high capital and logistical costs (Kovacs, 1984).
- **Level-based Approach (or "Topping-up")**: A logistics agent periodically assesses the needs of each unit and orders the necessary quantities to restore the stock to its optimal level. This method allows for good volume control without excessive investment (Ewing-Juul et al., 1989).
- **Full-Empty System (Double Bin)**: Each product is stored in two bins. When one bin is empty, a label is sent to the store for replenishment. This system optimizes stock management while facilitating traceability (Landry & Beaulieu, 2001).
- **Nominal Dispensing (DIN)**: This model organizes personalized medication dispensing by patient name. It can be daily (DJIN) or weekly (DHIN), centralized or decentralized. Although more complex, it secures the medication chain and minimizes administration errors.

Recent studies have highlighted persistent challenges in the internal distribution of medications. Mahfoudh et al. (2023) conducted a survey with 200 patients from two Tunisian university hospitals, revealing that 80% of patients face difficulties in obtaining their medications from public healthcare facilities, often forcing them to turn to private pharmacies. This situation underscores the need to rethink the medication supply and distribution system in Tunisian public hospitals.

Moreover, Akhdari et al. (2023) emphasized the importance of digitizing the pharmaceutical product circuit in hospital settings. Their study highlights the advantages of real-time traceability and the reduction of dispensing errors, promoting coordinated patient care.

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3.4 Impact on Logistical Performance

The performance of different replenishment methods varies according to several criteria: operational cost, service level, workload of staff, and user satisfaction (Bélanger et al., 2018). Therefore, the choice of method depends on the specific context of the hospital, the criticality of the products, and organizational objectives.

4. Logistical Support Technologies

The digital transformation of the healthcare sector has profoundly influenced logistical practices, particularly in terms of traceability, security, and optimization of pharmaceutical flows. Support technologies such as barcode systems, RFID (Radio Frequency Identification), blockchain, the Internet of Things (IoT), and automated equipment play an increasingly important role in improving the hospital pharmaceutical supply chain.

4.1 Barcode Technology

Barcode technology is one of the most widely used technologies in hospitals for the identification of medications and ensuring their safe distribution. It enables precise traceability, reduces human errors, and improves inventory management.

According to Poon et al. (2006) and Maviglia et al. (2007), the implementation of barcode reading systems at the time of medication administration significantly reduces the error rate in distribution. Koppel et al. (2008) also highlighted improved staff satisfaction and a reduction in workload.

1D and 2D barcodes are used, respectively, for identifying simple products or storing more complex data (batch, expiration date, patient, etc.). Torres (2012) emphasizes that this mature and low-cost technology remains the dominant solution for ensuring traceability throughout the care process.

4.2 RFID (Radio Frequency Identification)

RFID enables automatic, contactless identification, with remote and bulk reading capabilities. It provides real-time visibility of stock, improves the management of expired items, reduces errors, and allows for the tracking of medications all the way to the patient's bed.

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Fathollahi-Fard et al. (2025) highlight the integration of RFID in hospital environments as a strategic advancement, particularly for sensitive or costly products. Torres (2012) points out that RFID bracelets can identify patients even if they are unconscious, and that RFID tags on medication doses enhance the security and responsiveness of the logistical process.

However, despite its advantages, RFID remains costly and raises concerns about privacy (e.g., unauthorized access to patient data) and reliability for certain materials (e.g., liquids, metals).

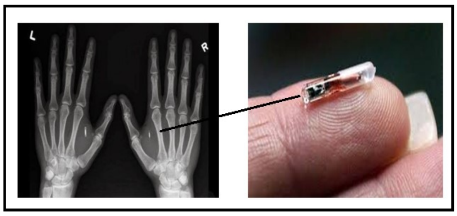

Figure : Subcutaneous chip

4.3 Blockchain

Blockchain technology is revolutionizing supply chain management by providing an immutable and transparent transaction ledger. It offers numerous benefits in SCM, including the reduction of fraud and errors through immutable transaction tracking, enhanced transparency between different actors in the supply chain.

4.4 Internet of Things (IoT)

The Internet of Things (IoT) is transforming logistics by enabling real-time tracking, predictive maintenance, and waste reduction. By combining sensors, tags, and trackers for shipments, pallets, or containers, companies gather precise real-time data on the location and condition of goods.

This visibility helps to identify potential issues, coordinate supply chain processes, and optimize inventory levels before disruptions occur. The impact of IoT on logistics is substantial, with increasing adoption in the sector.

4.5 Automated Equipment

Automated Dispensing Machines (ADMs), secure pharmacy cabinets (APS), and robotic storage systems are increasingly being implemented in modern hospitals.

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According to Franklin et al. (2008), their use helps reduce preparation time, enhance medication safety, improve traceability, and free up time for healthcare providers. Piccinini et al. (2013) report a significant reduction in medication errors with the use of APS, as well as gains in space and efficiency.

French hospitals, such as the CHU of Lille, have implemented innovative solutions like the use of augmented reality glasses for chemotherapy preparation, guiding the preparer step by step and allowing the reading of barcodes or data matrices to identify preparations and verify products.

4.6 Hybrid Technologies and Perspectives

An increasing number of healthcare facilities are adopting hybrid solutions that combine RFID and barcodes to benefit from the advantages of both. For example, the Pittsburgh Hospital (United States) uses a mixed solution to identify both patients and medications during administration (Swedberg, 2005).

Finally, the WHO recommends, through its 2023-2024 guidelines, the adoption of digital technologies to ensure compliance with good distribution practices (GDP), improve the quality of care, and strengthen the resilience of hospital supply chains (WHO, 2024).

5 Synthesis and Discussion

The analysis of recent and classic works on the hospital pharmaceutical supply chain reveals a convergence of objectives around three main areas: securing the flows, improving operational performance, and integrating innovative technologies. While logistical fundamentals – such as inventory management and internal distribution – remain essential, the rapid evolution of technologies and healthcare constraints (e.g., crises, shortages) requires continuous adaptation of practices.

5.1 Complementarity of Logistical Tools

Restocking policies (periodic, continuous, hybrid) and classification methods (ABC, VED, MASTA) help prioritize resources and streamline inventory management. However, their effectiveness heavily depends on the hospital context (size, specialization, budgetary constraints) and the available information tools. It appears that combined methods, contextualized and supported by digital tools (ERP, CMMS, etc.), provide the most robust results.

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5.2 Importance of Internal Distribution

Distribution methods (full-empty system, requisition, level approach, DIN) directly influence the flow efficiency and satisfaction of medical staff. Recent studies (Mahfoudh et al., 2023; Akhdari et al., 2023) highlight that distribution failures can weaken the entire supply chain, emphasizing the importance of coordinated management between central pharmacy, clinical services, and logistics management.

5.3 Technologies: Drivers of Transformation

Technologies such as barcode systems and RFID provide significant benefits in terms of traceability, security, and automation. The emergence of hybrid solutions, as well as new technologies like blockchain or IoT, pave the way for a smarter, more resilient, and predictive hospital logistics. However, their adoption must be accompanied by a strategy of gradual integration, appropriate staff training, and a rigorous cost-benefit analysis.

5.4 Limitations of the Literature and Research Perspectives

Most studies focus on specific contexts (developed countries, university hospitals, targeted hospital services), which limits the generalizability of the results. Additionally, few studies simultaneously integrate all dimensions of the supply chain: inventory, distribution, and technologies. There is a need to develop integrated models that take into account ethical, environmental, and social constraints, particularly in resource-limited countries.

Moreover, approaches based on artificial intelligence (such as machine learning for demand forecasting or deep reinforcement learning for inventory optimization) offer strong potential but remain underexplored in real hospital contexts.

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