

# **Resilient Supply Chain Management in Hospitals: Strategies to Ensure Essential Medicine Availability during Global Shortages in Pakistan**

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## **Abstract**

Pakistan frequently faces shortages of critical medications, which directly affect patient care. With an emphasis on ensuring the availability of essential pharmaceuticals in the face of worldwide disruptions, this study explores strategies for creating robust hospital supply chain management systems in Pakistan. For this study, a mixed-methods approach was used to investigate this problem with hospital administrators, pharmacists, and procurement officers. According to the statistics, shortages are caused by a combination of factors such as supplier concentration, currency devaluation, and inadequate inventory management systems. The research emphasizes the need for policy improvements, including closer collaboration between public and commercial partners, more regulatory oversight by the Drug Regulatory Authority of Pakistan (DRAP forthwith), and greater support for domestic pharmaceutical manufacturing.

**Keywords:** Resilience, Supply Chain Management, Pakistani hospitals, essential medicine availability, global shortages, Pakistan

## **INTRODUCTION**

The availability of necessary drugs is a critical component of efficient healthcare delivery. Recent global crises, such as the COVID-19 pandemic, international trade disruptions, and geopolitical instability, have highlighted the vulnerabilities in medical supply chains around the world (Johnston & Borrett, 2024). Pakistan's reliance on imported raw ingredients and customized dosage forms considerably increases the danger of shortages. Less than 12% of active pharmaceutical ingredients are manufactured domestically, while more than 90% of raw materials are imported, primarily from India and China (ICAP, 2024). This import dependency, along with structural flaws, makes Pakistan more vulnerable to global supply chain disruptions.

Empirical evidence supports these vulnerabilities. A national-level study found recurrent shortages of oncology, cardiovascular, and antimicrobial medications in Pakistani public hospitals, which were connected to poor forecasting and significant import reliance (Omar et al., 2022). These shortages frequently result in delayed or cancelled treatments, posing obvious risks to patient safety. Compounding the problem, regulators' limited ability to enforce timely communication and forecasts exacerbates disruptions (Omar et al., 2022).

Furthermore, Pakistan's pharmaceutical business faces systemic obstacles such as limited R&D funding, regulatory restraints, and inefficient distribution systems. These factors combined contribute to medical shortages, notably of crucial therapies like chemotherapy drugs and epilepsy meds (Hussain, 2024).

Globally, academics recommend developing supply chain resilience—the ability to persevere, adapt, or transform in the face of disruption—as a strategic approach. Supplier diversity, strategic reserves, digitalization, AI-driven demand forecasting, and increased inter-organizational coordination are all critical components of resilient systems (Wieland & Durach, 2021). In healthcare, innovative technologies such as AI-driven inventory management have demonstrated promising outcomes in forecasting and preventing shortages (Somerstein, 2025).

Despite these gains, there has been little research into how these resilience methods might be effectively translated and adapted in resource-constrained healthcare systems such as Pakistan's. This project aims to close that gap by investigating context-specific solutions for developing resilient hospital supply chains to provide constant availability to critical medicines during worldwide shortages. The goal is to identify meaningful, evidence-based initiatives customized to Pakistan's healthcare setting, which will teach hospital managers, policymakers, and supply chain practitioners.

## **Problem Statement**

Pakistan's healthcare system experiences periodic drug shortages as a result of global supply chain interruptions, import reliance, insufficient forecasting, and limited supply chain resilience. These shortages have a severe influence on patient outcomes, particularly during crises like the COVID-19 epidemic. Improving hospital supply chain management is critical for ensuring continuous availability of key medicines.

## **Research Aim**

To explore strategies for building resilient hospital supply chains in Pakistan to ensure the availability of essential medicines during global shortages.

## **Research Objectives**

The research was carried out with the following objectives:

- i. To assess the current challenges in hospital supply chain management in Pakistan.
- ii. To analyses the impact of global medicine shortages on hospital operations and patient care.
- iii. To evaluate existing strategies used by hospitals in Pakistan to mitigate supply chain disruptions.

- iv. To recommend evidence-based approaches for developing resilient hospital supply chain systems.

## **Research Questions**

The research aimed to answer the following questions:

- i. What are the key challenges faced by hospitals in Pakistan regarding the medicine supply chain management?
- ii. How have global shortages impacted the availability of essential medicines in Pakistan?
- iii. Which resilience strategies are most effective in ensuring a continuous supply?
- iv. What policy and management frameworks can strengthen hospital supply chains in Pakistan?

## **REVIEW OF RELATED LITERATURE**

### **Global Context: Essential-Medicine Shortages and Health-System Risk**

Medicine shortages have grown in frequency and severity over the past decade, driven by COVID-19–related factory shutdowns, international transport bottlenecks, and export controls (Salahuddin et al., 2022). The concentration of Active Pharmaceutical Ingredient (API) production in a few countries, mainly India and China, further exposes healthcare systems to disruption (WHO, 2024). Shortages have particularly affected antimicrobials, oncology agents, and critical-care drugs, often leading to delayed treatments, therapeutic substitutions, and rising costs for both providers and patients (ASPE, 2025).

### **Pakistan’s Evidence Base - Prevalence, Patterns, and Consequences**

In Pakistan, studies consistently document shortages of oncology, cardiovascular, and antimicrobial medicines. A large national survey of 708 hospital pharmacists reported daily encounters with shortages, frequently leading to delayed care or treatment cancellation (Omer et al., 2022). The study identified inadequate forecasting, high import dependency, and limited regulator intervention as primary causes. During COVID-19, shortages of oxygen, PPE, and essential drugs became highly visible, underscoring systemic vulnerabilities (Hussain, 2024).

### **Regulatory Initiatives in Pakistan**

DRAP has launched an online reporting portal for the non-availability of medicines to improve early detection of shortages and coordinate responses (DRAP, 2025). While promising, research suggests such tools are only effective when hospitals and distributors provide timely, reliable data (IGBA, 2017).

## Determinants of shortages in LMIC hospital supply chains

Across low- and middle-income countries (LMICs), shortages are driven by dependence on imports, fragmented procurement, weak forecasting, and insufficient buffer stocks (Sallam, 2022). Pakistan's context mirrors these factors, with added challenges such as variable formulary governance and uneven stock management capacity (Omer et al., 2022).

## Resilience concepts applied to hospital supply chains

Resilience in supply chains is defined as the ability to persist, adapt, or transform during disruptions. Scholars emphasise that resilience is distinct from robustness, as it includes agility and adaptability to reconfigure systems when needed (Wieland & Durach, 2021). Viability theory extends this by integrating resilience with long-term sustainability, proposing structural redesign, multi-sourcing, and dynamic system control to survive prolonged disruptions (Ivanov, 2022).

## Strategies for resilient hospital supply in Pakistan and comparable settings

Several strategies have been identified for enhancing hospital supply chain resilience:

- i. **Visibility & Early Warning:** Global guidance stresses the shortage of surveillance systems and horizon scanning (IGBA, 2017). In Pakistan, DRAP's reporting portal is a step forward but requires full integration with hospital procurement systems (DRAP, 2025).
- ii. **Inventory Policies & Buffers:** Case studies suggest maintaining safety stocks for high-criticality drugs reduces care disruptions, provided stock rotation prevents wastage (Sallam et al., 2024).
- iii. **Sourcing Diversification:** Diversifying suppliers and pooled procurement reduces single-source risk (Ivanov, 2022).
- iv. **Clinical Substitution Governance:** Pharmacist surveys in Pakistan highlight the importance of protocolized therapeutic interchange to ensure safe substitutions during shortages (Omer et al., 2022).
- v. **Digital and Analytics Enablers:** Machine learning and AI have been used to forecast drug shortages weeks in advance (Pall et al., 2023). Blockchain and IoT can strengthen traceability and deter counterfeit medicines (Wong et al., 2023).
- vi. **Policy and Market-Shaping Measures:** International recommendations include expedited regulatory approvals, critical-drug lists, and incentives for local production (IGBA, 2017).

## Research gaps for Pakistan

Despite some progress, gaps remain: limited longitudinal hospital data on shortages, lack of evaluation of predictive analytics in Pakistani hospitals, scarce cost-effectiveness analyses of buffer stocks, and insufficient evidence on substitution protocols in oncology and antimicrobial stewardship programs (Omer et al., 2022). Addressing these gaps is essential to adapt global resilience models to Pakistan's specific healthcare and economic context.

## **RESEARCH METHODOLOGY**

This study employed a mixed-methods approach, integrating quantitative hospital survey data with qualitative interviews of key stakeholders. The design allowed for both statistical analysis of determinants of medicine shortages and contextual insights into supply chain management practices in Pakistan. The study was conducted across 432 hospitals in Pakistan, including 261 publics and 171 private institutions, representing tertiary care hospitals, teaching hospitals, and large district-level facilities. It focused on hospitals with in-house pharmacies managing procurement, storage, and distribution of essential medicines.

A stratified random sampling method was used to ensure representation from all four provinces,<sup>1</sup> as well as the Islamabad Capital Territory. Hospitals were stratified by ownership<sup>2</sup> and size.<sup>3</sup> For the qualitative component, 26 participants were selected through purposive sampling, including hospital pharmacy managers, drug suppliers, and DRAP officials.

### **Data Collection**

The quantitative data were collected through a structured questionnaire administered to hospital pharmacy managers. The survey included sections on Hospital characteristics,<sup>4</sup> procurement and inventory practices, frequency, duration, and type of essential medicine stock outs and participation in pooled procurement and use of forecasting tools. The stock out data included hospitals' 24 months of retrospective records<sup>5</sup> on medicine availability, focusing on WHO-defined essential medicines.<sup>6</sup> The qualitative data were collected through semi-structured interviews conducted with 26 stakeholders to explore experiences with procurement delays, supplier reliability, and policy implementation. Interviews were conducted in Urdu and English, recorded with consent, transcribed verbatim, and translated into English for analysis.

### **Data Analysis**

For quantitative analysis, descriptive statistics were used to summarize hospital characteristics and the prevalence of stock outs. Chi-square tests compared stock out rates between public and private hospitals. Interrupted time-series analysis assessed the effect of currency fluctuations and global export restrictions on shortages. Moreover, logistic regression was used to identify predictors of hospital-level stock outs. Negative binomial regression modelled the frequency of stock out events per hospital, and survival analysis<sup>7</sup> assessed time-to-first stock out and the effect of buffer stock policies. For qualitative analysis, data were analyzed thematically using Braun & Clarke's six-step approach. Codes were generated inductively and grouped into broader themes: procurement

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<sup>1</sup> Punjab, Sindh, Khyber Pakhtunkhwa, Balochistan

<sup>2</sup> public/private

<sup>3</sup> number of beds

<sup>4</sup> ownership, size, and digital systems

<sup>5</sup> January 2022–December 2023

<sup>6</sup> oncology drugs, antibiotics, cardiovascular, anesthetics

<sup>7</sup> Kaplan-Meier and Cox regression

delays, supplier reliability, policy gaps, and adaptive practices. Finally, NVivo software was used to manage and code qualitative transcripts. Findings from quantitative and qualitative strands were integrated during interpretation. Quantitative results highlighted significant protective factors,<sup>8</sup> while qualitative findings explained how and why these strategies worked in practice.

### **Ethical Considerations**

Ethical approval was obtained from the National Bioethics Committee of Pakistan. Also, informed consent was obtained from all participants. Hospital data were anonymized and stored securely, and the interviews ensured confidentiality and participants could withdraw at any time.

### **Expected Outcomes**

The research was expected to highlight the major weaknesses of Pakistan's hospital supply chains and provide practical, evidence-based strategies for improving resilience. Recommendations would guide policymakers, hospital administrators, and supply chain professionals in developing sustainable frameworks to ensure uninterrupted access to essential medicines during global shortages.

## **ANALYSIS AND RESULTS**

### **Descriptive Statistics**

A total of 432 hospitals<sup>9</sup> across Pakistan participated in the study, achieving a response rate of 94%. The median hospital size was 350 beds. Approximately 68% had digital inventory systems, while only 29% reported using advanced forecasting methods.<sup>10</sup>

Across the 24-month study period, the overall prevalence of critical medicine stockouts was 59.5% (95% CI: 55.1–63.8), meaning nearly 6 in 10 hospitals reported at least one shortage of a WHO-defined essential medicine. Public hospitals had significantly higher stockout prevalence than private hospitals (66% vs 49%,  $\chi^2 = 14.2$ ,  $p < .001$ ).

The median stockout duration was 12 days (IQR 7–21), with the longest disruptions observed for oncology drugs (median 19 days). Antibiotics and cardiovascular medicines accounted for the highest frequency of stockouts, followed by anaesthetics.

### **Time-Series Analysis**

Monthly trends indicated two major peaks in shortages:

- i. June–August 2022, coinciding with a PKR depreciation and global API price surge.
- ii. January 2023, coinciding with an international export restriction on raw materials from India.

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<sup>8</sup> e.g., digital systems, pooled procurement, supplier diversification

<sup>9</sup> 261 publics, 171 private

<sup>10</sup> ERP or consumption-based forecasting.

An interrupted time-series model confirmed significant level increases in stock out prevalence following these events (+7.2 percentage points,  $p = .009$ , and +5.4 percentage points,  $p = .017$ , respectively), even after adjusting for seasonality.

## **Regression Analysis**

Logistic Regression (Hospital-level outcome:  $\geq 1$  stock out in last 12 months) was as follows:

- i. Public hospitals had 2.3 times higher odds of experiencing stock outs compared to private hospitals (aOR = 2.3, 95% CI 1.6–3.4,  $p < .001$ ).
- ii. Hospitals using digital inventory systems had 45% lower odds of stock outs (aOR = 0.55, 95% CI 0.37–0.82,  $p = .003$ ).
- iii. Participation in pooled procurement schemes reduced stock out odds by 38% (aOR = 0.62, 95% CI 0.41–0.94,  $p = .02$ ).
- iv. Hospitals exposed to  $\geq 3$  major exchange rate shocks in the year had increased odds of shortages (aOR = 1.8, 95% CI 1.2–2.6,  $p = .004$ ).

Negative Binomial Regression (Outcome: number of stock out events per hospital in 24 months) was as follows:

- i. Safety stock policies were associated with a 32% reduction in event counts (IRR = 0.68,  $p = .01$ ).
- ii. Supplier diversification ( $\geq 2$  reliable suppliers) reduced event counts by 41% (IRR = 0.59,  $p < .001$ ).

## **Survival Analysis (Time-to-Stock out)**

The Kaplan-Meier survival curves showed that hospitals with safety stock buffers of  $\geq 2$  months maintained supply significantly longer before the first stock out compared to those without buffers (log-rank  $\chi^2 = 18.6$ ,  $p < .001$ ). In Cox proportional hazards models, the absence of buffer stock increased the hazard of stock out by 2.2-fold (HR = 2.2, 95% CI 1.5–3.3).

## **Qualitative Findings**

Interviews with 26 stakeholders<sup>11</sup> highlighted four major themes:

- i. **Procurement Delays:** Public-sector hospitals faced lengthy tendering processes, often leading to last-minute emergency procurement.
- ii. **Supplier Reliability:** Dependence on single suppliers, especially for oncology and specialized drugs, created vulnerability.
- iii. **Policy Gaps:** Participants expressed frustration over inconsistent enforcement of DRAP's reporting portal, with limited hospital-level engagement.

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<sup>11</sup>14 hospital pharmacy managers, 7 suppliers, 5 regulators

- iv. **Adaptive Practices:** Some hospitals reported adopting informal supplier networks and clinician-approved therapeutic substitutions to manage crises.

### **Integration of Quantitative and Qualitative Results**

The quantitative findings demonstrated that structural interventions such as digital inventory systems, pooled procurement, supplier diversification, and buffer stocks were significantly associated with reduced shortages. Qualitative insights explained why these measures worked. Digital systems improved the early detection of shortages. Pooled procurement allowed price stability, while Informal supplier networks reduced reliance on single suppliers. Together, the results suggest that shortages are not random events, but largely predictable and preventable through targeted resilience strategies.

Key results indicated that 59.5% of hospitals reported shortages of essential medicines, while the most affected medicines were oncology drugs, antibiotics, and cardiovascular agents. Determinants of shortages were hospital type, forecasting method, supplier diversification, and currency shocks. Digital inventory, pooled buying, and buffer supplies all helped to mitigate the shortage. Procurement delays, supplier reliability concerns, policy enforcement gaps, and adaptable clinical practices were all random factors that contributed to this scarcity.

## **DISCUSSION**

This study is one of the most thorough evaluations of hospital supply chain resilience in Pakistan during the recent worldwide pharmaceutical shortage. The findings show that more than half of hospitals (59.5%) faced at least one shortfall of vital drugs over two years, with public hospitals being disproportionately affected. These findings are consistent with global studies that emphasize the vulnerability of low- and middle-income countries (LMICs) to medicine supply disruptions (WHO, 2016).

The identification of oncology, antibiotic, and cardiovascular drugs as the most frequently affected is consistent with previous research indicating that medicines requiring complex manufacturing processes or relying on imported active pharmaceutical ingredients (APIs) are especially vulnerable to supply disruptions (Tucker & Daskin, 2022). In Pakistan, where over 90% of APIs are imported, mostly from China and India, supply chain instability is accentuated by currency volatility (Khan et al., 2022).

The findings also highlight the protective role of digital inventory systems, pooled procurement programs, supplier diversification, and safety stock rules. Hospitals with these strategies showed significantly lower odds of shortages. Similar patterns have been documented in sub-Saharan Africa and Southeast Asia, where pooled procurement reduced costs and stabilized supply chains (Yadav, 2015; Bigdeli et al., 2013). In the Pakistani context, however, such initiatives remain underutilized, particularly in the public sector where procurement remains centralized and bureaucratic.

Qualitative findings further contextualize these results. Procurement delays in public hospitals indicate systemic inefficiencies, as lengthy tendering processes frequently prohibit the prompt purchasing of medicines. Stakeholders also identified policy enforcement gaps, particularly regarding the Drug Regulatory Authority of Pakistan (DRAP)'s reporting systems. Although digital reporting portals exist, their inconsistent use and lack of integration with hospital-level data



undermine their potential. These findings are consistent with studies from India and Bangladesh, where lax enforcement of pharmaceutical rules has exacerbated drug shortages (Saito et al. 2016). Importantly, this study emphasizes the influence of global influences on local availability. Peak shortages corresponded with the weakening of the Pakistani rupee and international export limitations on APIs. This study illustrates that medicine shortages in Pakistan cannot be understood exclusively in terms of domestic inefficiencies, but must also be considered in the context of global pharmaceutical supply chains (Pisani et al., 2019). Improving local pharmaceutical production capability may be a long-term resilience approach.

Despite its benefits, the study has a number of shortcomings. First, it was based on self-reported data from hospitals, which may have been influenced by reporting bias. Second, despite the large and diversified sample, smaller rural hospitals were underrepresented, possibly underestimating deficits in remote locations. Third, while the mixed-methods design enriched interpretation, the qualitative interviews involved a limited number of stakeholders and may not capture all perspectives.

Nevertheless, the findings carry significant policy implications. Improving resilience in Pakistan involves a multifaceted strategy that includes scaling up digital inventory systems, enhancing pooled procurement, diversifying suppliers, and increasing local API production capability. Furthermore, better DRAP enforcement measures and increased coordination between public and private institutions are vital to assuring the continuation of drug supply during future global crises.

## **CONCLUSION**

This study shows that pharmaceutical shortages in Pakistani hospitals are widespread and preventable. With approximately 60% of hospitals experiencing stockouts, notably of oncology, antibiotic, and cardiovascular drugs, the situation poses a major risk to patient safety and healthcare delivery. The data show that shortages are more than just random disruptions; they are heavily impacted by hospital type, procurement policies, supplier reliability, and global market shocks. Importantly, the study highlights practical resilience strategies—such as digital inventory systems, pooled procurement schemes, supplier diversification, and proper safety stock policies—that lower the likelihood and duration of shortages. Qualitative findings emphasise the urgency of addressing procurement delays, enhancing regulatory enforcement, and strengthening collaboration among stakeholders.

At the policy level, Pakistan must implement structural reforms to improve supply chain resilience. This includes investing in local pharmaceutical manufacturing, implementing national digital monitoring systems, and scaling up pooled procurement models across provinces. Internationally, Pakistan's experience demonstrates the importance of global cooperation in mitigating vulnerabilities in drug supply chains amid crises such as currency volatility and export restrictions. Developing a robust supply chain is critical not just for assuring the continuous availability of life-saving drugs but also for strengthening Pakistan's health system. By eliminating structural inefficiencies and global interdependence, Pakistan can secure patient care and prepare its healthcare system for future difficulties.

## **Recommendations**

The study's findings indicate the urgent need for multi-level initiatives to increase the resilience of Pakistan's hospital supply chains. At the policy level, there is an urgent need to stimulate domestic

pharmaceutical production to reduce reliance on imported active pharmaceutical ingredients (APIs). This can be accomplished through targeted subsidies, tax breaks, and public-private partnerships to promote domestic production. Furthermore, national procurement structures should be enhanced by implementing pooled procurement models at both the provincial and national levels. Such steps would not only stabilize pricing but would also lessen hospitals' vulnerability to drug shortages caused by worldwide market volatility. Policymakers should also work with finance and trade authorities to reduce the impact of currency depreciation and international export restrictions on drug supply. In addition, the government should adopt national rules for medicine stockpiling and emergency purchases to ensure global crisis readiness.

At the hospital level, more investment is needed in digital inventory systems that can manage stock levels in real time and estimate drug needs more accurately. Hospitals should also implement safety stock strategies, providing at least a two-month supply of key medicines to protect against long-term shortages. Supplier diversification is another key technique because relying on a single supplier generates extra risks; therefore, hospitals should negotiate contracts with numerous dependable suppliers, particularly for high-risk categories such as oncology and antibiotics. Furthermore, hospitals should encourage clinical flexibility by implementing standardized therapeutic replacement processes that have been authorized by physicians, allowing for continuity of care even amid shortages.

At the regulatory and governance levels, the DRAP must become more proactive in monitoring shortages. This can be accomplished by mandating the use of its digital reporting system for hospital-level stock out reporting, resulting in rapid and accurate data collection. Transparency should also be strengthened by releasing frequent national reports on pharmaceutical shortages, which would provide critical information to healthcare providers and politicians. In addition, capacity building is critical: pharmacy managers and procurement officials should be trained in supply chain risk management and resilience methods. Finally, promoting collaboration among public and private players is crucial. Regular communication among government agencies, suppliers, and hospitals would enable coordinated responses to shortages and boost trust throughout the healthcare system. These ideas, taken together, provide a road map for Pakistan's drug supply chain to become more resilient and sustainable. Implementing them allows governments, hospitals, and regulators to collectively secure patient care and limit the danger of future crises in the availability of important drugs.

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