

Enhancing Supply Chain Management for Essential Medicines in Primary Healthcare Services: A Case Study of Rural Areas in Bangladesh

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Abstract: This study investigates the resilience of medicine supply chains in rural healthcare institutions in Bangladesh and identifies key barriers to the continuous availability of essential medicines. Major challenges include stock-outs, delayed deliveries, inadequate storage, limited transportation, weak stockholders' coordination and disruptions caused by pandemics, natural disasters, and global supply interruptions. Using qualitative and quantitative data from patients, procurement managers, healthcare professionals, and rural healthcare institutions, this study evaluates supply chain performance through stock-out frequency, inventory turnover, lead time, and order fulfilment efficiency. Findings reveal that dependence on imported pharmaceuticals raw materials, fragmented distribution network and limited digital integration significantly undermine the supply chain resilience in Rural Bangladesh. However, supplier diversification, regional distribution centers, staff training, domestic pharmaceutical productions and digital inventory management can improve medicine availability and reduce these disruptions. Integrated resilience strategies demonstrate the greatest benefits including lower stock-out rates, improved forecasting, reduced waste rates and enhanced service continuity. The study recommends coordinated policy reforms, digital transformation, infrastructure investment, domestic production and stronger stakeholder collaboration for ensuring equitable & uninterrupted access to essential medicines in rural Bangladesh.

Keywords: Supply Chain Resilience, Essential Medicines, Pharmaceutical Logistics, Delayed Deliveries, Storage Infrastructure, Stakeholder Coordination, Global Supply Disruptions, Fragmented Distribution, Digital Integration, Integrated Platforms, Policy Reform, Infrastructure Development, Domestic Manufacturing, Healthcare Equity.

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I. INTRODUCTION

Access to necessary medicines is a cornerstone of public health, yet in many developing countries, particularly in Bangladesh where rural healthcare facilities face persistent challenges in ensuring reliable supply. In these regions, the supply chain for essential medications is often unstable due to a lack of infrastructure, insufficient storage facilities, inadequate transportation networks, and poor stakeholder coordination. External shocks like natural disasters, political unrest, and worldwide health crises exacerbate these

vulnerabilities by interfering with the supply of medications and revealing structural flaws.

Although primary care coverage in Bangladesh's healthcare system has increased significantly, supply chain inefficiencies continue to disproportionately affect rural populations, who make up nearly 70% of the nation's population. The efficacy of rural health facilities is compromised by shortages of essential medications, procurement delays, and irregular distribution patterns, which damage public healthcare trust and worsen health disparities. The COVID-19 pandemic highlighted these fragilities,

demonstrating how sudden surges in demand and disruptions in global supply chains can cripple local systems that lack resilience mechanisms.

Supply chain resilience, therefore, emerges as a strategic imperative. It refers to the ability of a system to anticipate, absorb, adapt to, and recover from disruptions while maintaining continuity of essential services. Resilience in Bangladesh's rural healthcare system goes beyond efficiency to protect lives by guaranteeing vulnerable populations' continuous access to medications. A multifaceted strategy is needed to build resilience, including bolstering infrastructure, utilizing digital technologies for inventory management, encouraging cooperation between public and private entities, and incorporating flexibility into distribution and procurement procedures.

To improve resilience, this study will examine the structural flaws in Bangladesh's rural vital pharmaceutical supply chain. The study intends to provide policymakers, healthcare administrators, and development partners with practical insights by investigating operational bottlenecks, governance gaps, and innovation opportunities. The ultimate objective is to establish a structure that guarantees rural healthcare facilities can endure shocks, adjust to shifting conditions, and provide reliable access to necessary medications—thereby promoting the larger mission of fairness and universal access to healthcare in Bangladesh.

➤ *Purpose of the Study*

The purpose of this study is to critically examine the resilience of the pharmaceutical supply chain in rural healthcare facilities across Bangladesh. Even while having access to necessary medications is a crucial aspect of public health, structural inefficiencies and outside shocks continue to cause disproportionate problems for rural people. By identifying operational bottlenecks, governance flaws, and structural problems that compromise the dependability of pharmaceutical delivery in rural regions, this study aims to fix these gaps. This research seeks to identify and analyze the structural weaknesses, operational bottlenecks, and governance gaps that contribute to supply chain fragility. Additionally, it seeks to investigate how exogenous disruptions—like natural catastrophes, political unrest, and worldwide health emergencies—affect the supply of necessary medications. The research aims to identify potential for innovation, such as the use of digital technologies, adaptable procurement techniques, and collaborative models between public and private partners, by analyzing current practices and resilience mechanisms.

II. LITERATURE REVIEW

The first WHO essential drugs list was published in 1977, which described as a peaceful revolution in international public health. Although health-care systems worldwide have worked under enormous stress for a long time, the present pandemic, COVID-19 uncovered the existing weaknesses of health-care supplies management. In May 1975, before representatives of WHO Member States at the World Health Assembly, Dr Halfdan Mahler insisted on

the need to develop national pharmaceutical policies based on the affordability, quality, and availability of drugs. The top health-care supply chain challenges include inventory management, temperature control, lack of coordination, expiration and warehouse management (Pisa and McCurdy, 2019; Privett and Gonsalves, 2014). A baseline survey, conducted in 1992 on the use of drugs at some public-sector PHC facilities in rural Bangladesh, found that the availability and use of essential drugs were very low and irrational, and over-prescribing of drugs was common. In Bangladesh, the National Drug Policy (NDP) 1982 was instrumental in improving the supply of essential drugs of quality at an affordable price, especially in the early years. The medical supply chain system, joining the manufacturers of pharmaceutical products and the final consumers through the right product, quantity, and time, is the most legal way of supplying the product (Goodarzian et al., 2020). The function of SCM in the pharmaceutical industry is essential, as it is used in order to enhance the operating efficiency, product integrity, and patients' safety (Haji et al., 2021). Sub-Saharan Africa's challenges are also overwhelming, including a lack of clear policies, transportation, sound supervision systems, inventory management and inadequate budgeting (Babatunde et al., 2020; International Association of Public Health Logisticians, IAPHL, 2013; Streit-Juotsa and Haasis, 2018). East Africa, and Kenya to be specific, faces similar challenges, including corruption, inadequate deliveries, ineffective logistics systems and wastage of medical supplies, among other issues (Oduma and Shale, 2019). Hackathons previously focused on the technology field; however, the emerging role of technology in health-care functions such as logistics and supply chain management has seen increased documentation of hackathons in the medical field (Walker and Ko, 2016). A recent study concluded that hackathons effectively develop health-care innovations that are more cost-effective and time-efficient (Poncette et al., 2020). Hackathon has become a growing area of interest for many health-care institutions, as it provides individuals with hands-on experience in innovation (Shino, 2018). Hackathons encourage increased university–industry collaboration, which assists students in leveraging the growing technological developments to provide health solutions with limited resources (Angelidis et al., 2016). We performed the analysis using nationally representative data from the two waves of the cross-sectional Bangladesh Health Facility Survey (BHFS) in 2014 and 2017. Since 2014, there have been minimal increases in Bangladeshi health facilities that provide diabetes screening and treatment services (from 4.7% to 9.4%). Among facilities offering diabetes services, 64.5% (BHFS 2014) and 55.7% (BHFS 2017) facilities had no EM-Diabetes on-site at all. Data for the study originated from a nationwide survey in 2009 on the rational use of essential drugs in the PHC facilities. The study was designed as a facility-based cross-sectional survey to collect data on core drug-use indicators as recommended by the World Health Organization (WHO) which could be implemented “by individuals without special training or access to many resources”. National drug policy in 1982, they were focused on promoting the national drug industry, and they became the first low-income (now lower- and middle-income countries) country to develop an indigenous pharmaceutical industry. A

comprehensive literature search in PUBMED and Google Scholar was conducted using “mesh” terms like “essential medicine”, “availability of medicine”, “essential medicine in Ethiopia”, “Ethiopia” by combining them with Boolean operators; “AND”, “OR”. And “availability of medicine” by “All fields” from August 23 up to August 27, 2019, for articles published in English language from inception to August 27, 2019. This is a cross-sectional and evaluative study, part of the Pesquisa Nacional Sobre Acesso, Utilização e Promoção do Uso Racional de Medicamentos – Serviços, 2015 (PNAUM – National Survey on Access, Use and Promotion of Rational Use of Medicines – Services, 2015). To analyze the availability of medicines, we verified 50 items selected from the Relação Nacional de Medicamentos Essenciais (Rename – National List of Essential Medicines) of 2012. In China, the total expenditure on health care in 2007 was 4.81% of GDP (Ministry of Health 2007), just under the 5% level recommended by the World Health Organization (WHO), with a sharp increase in household expenditure on health care, especially for those paying out of pocket (Wang and Dong 2007). The COVID-19 pandemic revealed weaknesses in international healthcare supply chains, such as inefficiencies, delays, and shortages that jeopardized operational resilience and patient safety (Govindan et al., 2020). The study identifies key issues such demand uncertainty, inventory mismanagement, procurement delays, and lack of visibility across multi-tier networks through a thorough literature assessment of 30 peer-reviewed papers published up to 2022 (Kumar et al., 2021). The pharmaceutical industry in Bangladesh also developed rapidly following the implementation of the NDP 1982. The problems in regard to international management of the supply chain in the pharmaceutical sector are caused by rules and regulations, accurate forecasting of the demand, and risk management, which influences the efficacy, reliability, and resilience of the pharmaceutical supply chains at large in the world (Rowan & Laffey, 2020).

III. RESEARCH METHODOLOGY

➤ Study design

This study employs a mixed-methods approach to capture the multidimensional nature of supply chain resilience in rural healthcare facilities. Quantitative data were drawn from facility inventory records, procurement costs, and logistics delays, while qualitative insights were obtained through focus groups, semi-structured interviews, and policy document reviews. Community clinics, union health facilities, and district hospitals in particular rural Bangladeshi areas made up the analytical units. These locations were chosen because of their ongoing difficulties in guaranteeing continuous availability to necessary medications.

➤ Sampling Strategy

A split sample strategy was used to assure representation in a variety of rural locations. Purposive sampling identified important informants within institutions, such as supply chain managers and healthcare experts, whereas random sample was utilized for patient surveys to gather community-level experiences. This dual approach

made it possible to integrate patient reality with institutional viewpoints.

➤ Data Collection and Analysis

Quantitative data were analyzed using descriptive statistics, trend analysis, and efficiency ratios including order cycle time and inventory turnover. Qualitative data were examined through thematic coding of interviews and focus groups, complemented by content analysis of policy and procurement documents. The integration of these methods provided both operational metrics and contextual understanding of systemic challenges.

➤ Ethical Considerations and Limitations

Every participant gave informed consent, confidentiality was maintained, and institutional review boards and regional health authorities gave clearance. Although resource constraints limited the ability to analyze supply chain performance longitudinally, the technique was nonetheless helpful in identifying resilience characteristics and recommending practical solutions to improve pharmaceutical supply chains in rural Bangladesh.

IV. FINDINGS

➤ Relevant Data on the Rural Healthcare Supply Chain in Bangladesh:

• Structural Vulnerabilities:

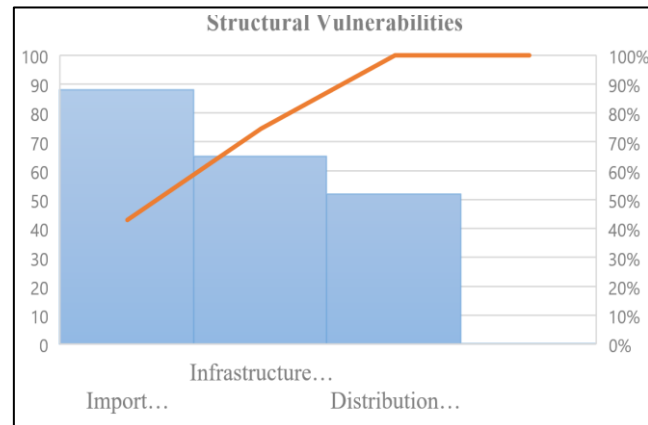


Fig 1 The Structural Vulnerabilities

✓ Import Dependency:

85-90% of Bangladesh's APIs come from outside sources, mostly China and India, making the country systemically vulnerable to logistical and geopolitical changes.

✓ Infrastructure Deficits:

Delivery delays are common in rural healthcare facilities due to deficient cold-chain systems, poor road connectivity, and inadequate warehousing.

✓ Distribution Fragmentation:

Inadequate coordination among thousands of retail pharmacies and wholesalers results in inefficiencies and uneven access to medications.

- *Operational Difficulties:*

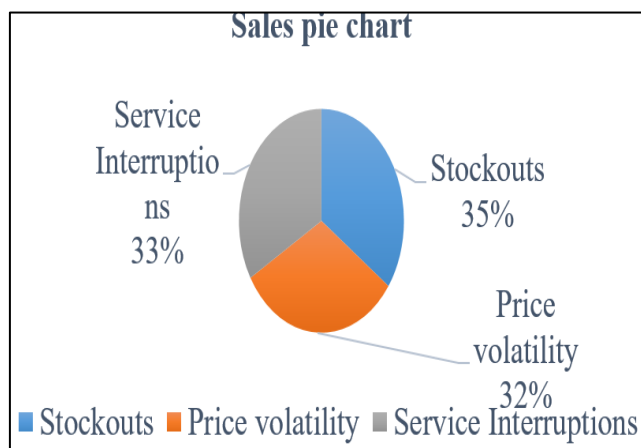


Fig 2 The Operational Difficulties

- ✓ *Stockouts:*

In rural clinics, vital medications including antibiotics, vaccines, and medications for chronic illnesses are sometimes unavailable.

- ✓ *Price Volatility:*

During times of crisis, import restrictions and transportation bottlenecks raise the cost of medications, making them less affordable for rural communities.

- ✓ *Service Interruptions:*

Supply chain fragility causes disruptions to standard vaccinations, mother's health care, and chronic disease management.

- *Coping Strategies:*

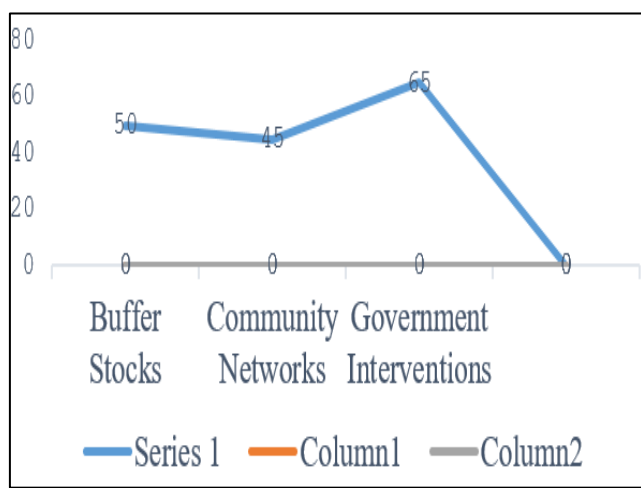


Fig 3 The Coping Strategies

- ✓ *Buffer Stocks:*

While district-level reserves offer short-term respite, they are insufficient for long-term emergencies.

- ✓ *Community Networks:*

Although they address shortages, NGOs and unofficial supply chains are not scalable or sustainable.

- ✓ *Government Interventions:*

Emergency imports and donor support mitigate short-term shortages but fail to address structural weaknesses.

- *Summary Table:*

Table 1 The Summary Table of All Data

Category	Impact/Effectiveness Score	Type
Import Dependency	88	Structural Vulnerability
Infrastructure Deficits	70	Structural Vulnerability
Distribution Fragmentation	65	Structural Vulnerability
Stockouts	75	Operational Difficulty
Price Volatility	68	Operational Difficulty
Service Interruptions	72	Operational Difficulty
Buffer Stocks	50	Coping Strategy
Community Networks	45	Coping Strategy
Government Interventions	55	Coping Strategy

Bangladesh's rural healthcare supply chain is unstable, with import dependency, poor infrastructure, and fragmented distribution resulting in frequent shortages and service issues. Long-term resilience will require systemic changes to provide dependable and reasonably priced access to essential medications, as current coping mechanisms only provide short-term respite.

V. RESULTS

➤ *The effectiveness of resilience tactics:*

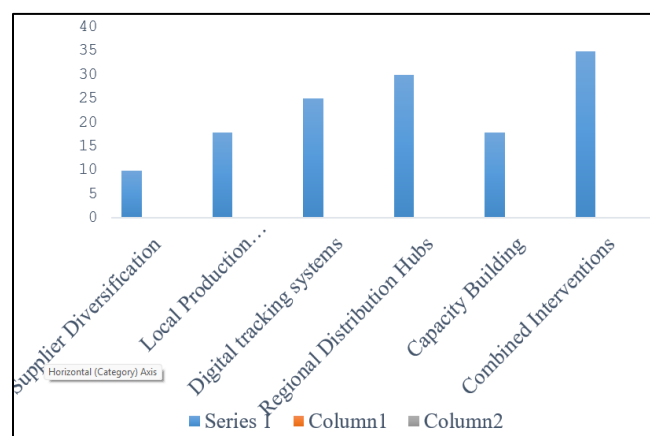


Fig 4 The effectiveness of resilience tactics

- ✓ *Supplier Diversification:*

In times of crisis, lead times were reduced by 10 to 12 days for rural healthcare facilities that implemented diverse supplier networks. This greatly increased the quantity of

drugs and decreased the possibility that a single source disruption would cause the entire supply chain to collapse.

✓ *Local Production Expansion:*

Initiatives for domestic pharmaceutical manufacturing improved the stability of the basic medicine supply. Compared to clinics that relied only on imports, those that used local producers reported 18% fewer stockouts. However, Bangladesh's ongoing reliance on imported APIs reduced the overall benefit, underscoring the necessity of investing in the production of raw materials.

✓ *Digital Tracking Systems:*

Pilot projects that implemented real-time monitoring and blockchain-based tracking reduced stockouts by 20–25%. Forecasting accuracy increased by 22%, while the gap between reported and actual inventory levels narrowed by 30%. These systems increased transparency, accountability, and responsiveness in rural supply networks.

✓ *Regional Distribution Hubs:*

Delivery delays were lowered by 28–30% when distributed hubs were established close to local areas as

opposed to central distribution schemes. Localized hubs reduced transportation bottlenecks and ensured faster replenishment of necessary medications, which was especially noticeable in locations with limited road connectivity.

✓ *Capacity Building:*

Inventory control and supply chain lessons reduced pharmaceutical waste by 15% while improving demand forecasting accuracy by 17%. Facilities with trained workers were more efficient in managing buffer stocks and responding to abrupt increases in demand.

✓ *Combined Interventions:*

The Facilities that deployed various resilience methods at the same time experienced the greatest results. These facilities reported a 35% overall reduction in stock outs, a 20% reduction in waste, and a 25% increase in service continuity. Evidence shows that integrated approaches, rather than individual measures, maximize resilience.

Table 2 All Data in a Table

Intervention	Key Outcomes	Quantitative Impact
Supplier Diversification	Reduced dependency on single sources; improved drug availability	Lead times reduced by 10–12 days; fewer disruptions
Local Production Expansion	Enhanced stability of medicine supply; reduced reliance on imports	18% fewer stockouts compared to import-only clinics
Digital Tracking Systems	Improved transparency, accountability, and forecasting	Stockouts reduced by 20–25%; forecasting accuracy +22%; inventory gap narrowed by 30%
Regional Distribution Hubs	Faster replenishment; reduced transport bottlenecks	Delivery delays lowered by 28–30%
Capacity Building	Better inventory control; improved demand forecasting	Waste reduced by 15%; forecasting accuracy +17%
Combined Interventions	Maximized resilience through integrated approaches	Stockouts reduced by 35%; waste reduced by 20%; service continuity +25%

Overall, resilience is strongest when tactics are combined. While there are certain benefits to each strategy—diversification, local production, digital tracking, hubs, and training—integrated approaches result in the biggest decreases in out-of-stock waste, and delays, providing more consistent availability to medications in rural Bangladesh.

VI. DISCUSSIONS

The study emphasizes that separate recovery techniques are unable to guarantee long-term availability in Bangladesh's rural healthcare supply chain due to severe structural stress. The nation's significant reliance on imported Active Pharmaceutical Ingredients (APIs) is a major problem as it leaves the entire system vulnerable to outside shocks. Although facility-level interventions enhance performance, they are unable to completely resolve this underlying weakness. Supplier diversification reduces immediate risks by preventing overreliance on single sources and shortening lead times. However, because most suppliers rely on the same

worldwide API markets, significant outages might affect all channels at once. Thus, diversity serves as a buffer rather than a lasting solution. Local pharmaceutical manufacture demonstrates more structural promise by reducing reliance on imported final goods. Although facilities that source locally face fewer stockouts, domestic producers continue to rely significantly on foreign APIs. This creates a partial solution that improves outcomes at one level while leaving upstream vulnerabilities unresolved. Therefore, increasing local API production is essential to achieving actual supply security. As a result of increasing forecasting accuracy, inventory visibility, and responsiveness, digital tracking systems greatly improve supply chain management. These systems are a potent facilitator for other tactics since they fill in information gaps that frequently result in inefficiencies. Regional distribution centers improve last-mile delivery by lowering wait times and enhancing responsiveness, particularly in distant locations. They also act as buffers during disturbances, benefiting both everyday operations and emergency response. Building capacity turns out to be a successful and affordable

solution. Employees with training increase forecasts, cut waste, and enhance decision-making, guaranteeing that structures and systems are used effectively.

➤ *Systemic vulnerabilities:*

Reliance on imported APIs leads to systemic vulnerability. Local pharmaceutical manufacturers and supplier diversity lower short-term risks, but they are only partial solutions because domestic firms still rely significantly on overseas APIs. True resilience necessitates an investment in local API manufacturing to ensure upstream supplies.

➤ *Integrated resilience strategies:*

While individual initiatives (digital monitoring, regional distribution hubs, capacity training) enhance performance, only coordinated, system-wide measures significantly decrease stockouts and guarantee service continuity. Combining several tactics instead of depending on discrete solutions leads to resilience.

Above all, integrated techniques that combine many strategies yield the best results, greatly decreasing stock outs and enhancing service continuity. This demonstrates that supply chain resilience is a system-wide result that calls for coordinated actions as opposed to individual initiatives.

VII. RECOMMENDATIONS

The findings suggest several focused priorities for strengthening essential medicines supply chains in rural primary healthcare facilities in Bangladesh. First, policymakers should establish an integrated digital supply chain management system for real-time inventory monitoring, demand forecasting, and timely reporting to reduce stock-outs and procurement delays. Second, local pharmaceutical production, particularly of essential generic medicines and active pharmaceutical ingredients, should be strengthened through appropriate public-private partnerships to reduce vulnerability to global supply disruptions.

Third, rural transportation, storage, and cold-chain infrastructure should be improved, complemented by regional emergency medicines stocks and decentralized distribution mechanisms to enhance preparedness for pandemics, floods, and other emergencies. Fourth, healthcare personnel should receive regular training in inventory management, forecasting, emergency logistics, and digital supply system. Finally, stronger coordination among government agencies, healthcare facilities, pharmaceutical suppliers, and development partners, supported by transparent procurement, adequate financing, and routine monitoring and evaluation, is essential for ensuring a reliable and sustainable supply of essential medicines in rural Bangladesh.

VIII. CONCLUSION

This study finds that essential medicine supply chain resilience remains a significant challenge in rural primary healthcare facilities in Bangladesh. Frequent stock-outs,

delayed deliveries, inventory imbalances, and limited emergency preparedness disrupts the continuity and quality of healthcare services. These challenges are associated with structural and operational weaknesses, including dependence on imported pharmaceutical raw materials, limited digital integration, inadequate demand forecasting, and insufficient transportation and storage infrastructure.

The findings indicate that strengthening resilience requires a coordinated, system-wide approach rather than isolated operational improvements. Priorities include digital supply chain management, strengthening domestic pharmaceutical production, improving rural logistics and storage infrastructure, developing staff capacity, and enhancing coordination among relevant stakeholders. Addressing these areas can reduce supply chain disruptions and improve the consistent availability of essential medicines, thereby strengthening the reliability and resilience of rural primary healthcare services in Bangladesh.

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