International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 10s, 2025
https://www.theaspd.com/ijes.php

Understanding Supply Chain Bottlenecks In Saudi Pharmaceutical Companies

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Accepted: 02.06.2025 Published: 15.06.2025

Abstract
This study analyzes supply chain bottlenecks in Saudi pharmaceutical manufacturing companies through a comprehensive systems approach. Drawing on the Supply Chain Operations Reference (SCOR) model framework, the research identifies critical constraints affecting supply chain performance across reliability, responsiveness, flexibility, cost, and asset management dimensions. The analysis reveals complex interconnections between various bottlenecks, including forecast inaccuracies, dependence on imported raw materials, long lead times, limited production flexibility, high inventory costs, and inefficient asset utilization. These challenges create reinforcing patterns that amplify negative effects throughout the pharmaceutical supply chain. Based on this systems analysis, three strategic interventions are proposed: developing collaborative supplier relationships, investing in advanced manufacturing technologies, and implementing integrated information systems. These strategies work synergistically to address multiple bottlenecks simultaneously, enhancing overall supply chain performance. The findings provide valuable insights for pharmaceutical executives and policymakers in Saudi Arabia as they work to strengthen the sector's competitiveness and resilience in alignment with Vision 2030 objectives of pharmaceutical manufacturing localization and enhanced drug security.

INTRODUCTION

The pharmaceutical industry plays a crucial role in healthcare systems globally, with supply chain management being fundamental to ensuring continuous availability of medications. In Saudi Arabia, the pharmaceutical sector has been experiencing significant growth alongside the country's Vision 2030 initiative, which aims to diversify the economy away from oil dependency. However, despite this growth, Saudi pharmaceutical companies face numerous supply chain challenges that impact their performance, competitiveness, and ability to meet market demands efficiently. Supply chain bottlenecks in pharmaceutical companies represent critical constraints that limit overall performance and effectiveness. These bottlenecks manifest as delays, inefficiencies, or capacity limitations at various points in the supply chain network. Using system dynamics methodology offers a valuable approach to understanding these complex, interconnected challenges within pharmaceutical supply chains.

Supply Chain Structure in Saudi Pharmaceutical Companies

The Saudi pharmaceutical supply chain typically consists of several interconnected entities: raw material suppliers (both local and international), manufacturing facilities, distribution centers, hospitals, retail pharmacies, and ultimately patients. This chain is characterized by both forward

flows of materials and backward flows of information and funds, creating a complex network of interdependencies.

Saudi pharmaceutical manufacturers operate within a highly regulated environment overseen by the Saudi Food and Drug Authority (SFDA), which enforces strict quality standards and compliance requirements. The regulatory landscape significantly influences supply chain decisions and operational flexibility, creating unique challenges compared to other industries (Tawfik et al., 2022).

Market-oriented pharmaceutical supply chains in Saudi Arabia begin with product development and marketing activities that identify unmet healthcare needs. These activities then drive forecasting, planning, procurement, manufacturing, and distribution processes to deliver medications to end users. However, unlike the Iranian context described by Moosivand et al., Saudi pharmaceutical companies operate within a different economic and regulatory framework, facing region-specific challenges that require tailored analysis and solutions.

According to Alshehri et al. (2023), the pharmaceutical manufacturing sector in Saudi Arabia has been undergoing significant transformation as part of Vision 2030, with increased emphasis on localizing production to reduce import dependency. This transition presents both opportunities and challenges for supply chain management in the sector.

Supply Chain Bottlenecks in Saudi Pharmaceutical Companies

Reliability Challenges

Saudi pharmaceutical manufacturers face significant challenges in maintaining supply chain reliability. Forecast inaccuracy represents a major bottleneck, with deviations between predicted and actual demand leading to inventory imbalances. This is exacerbated by limited information sharing between supply chain partners, creating the bullwhip effect where small variations in consumer demand produce increasingly larger fluctuations in orders at upstream stages (Srivastava, 2017).

The reliability of imported raw materials represents another critical bottleneck. AlRuthia et al. (2023) identified that heavy dependence on imported active pharmaceutical ingredients (APIs) was among the primary causes of medicine shortages in Saudi Arabia. Their study revealed that 62% of supply chain professionals considered dependency on international suppliers as a major factor contributing to drug shortages. This dependency creates vulnerability to global supply disruptions, as evidenced during global health crises when border restrictions and logistics constraints severely impact material availability (Jaberidoost et al., 2013).

Responsiveness Bottlenecks

Long lead times across various supply chain processes significantly constrain responsiveness in Saudi pharmaceutical companies. Manufacturing cycle times in many pharmaceutical plants can be lengthy, reducing companies' ability to respond quickly to market changes or unexpected demand fluctuations.

Regulatory approval processes represent another responsiveness bottleneck. Despite recent improvements, review timelines for new medications and manufacturing changes remain lengthy compared to leading regulatory authorities. These regulatory delays compound with operational delays to further extend time-to-market for new products (Shah, 2004).

Alajmi et al. (2021) highlighted how the COVID-19 pandemic exposed significant responsiveness limitations in Saudi medical supply chains, including pharmaceutical products. Their study found that while some organizations demonstrated resilience in responding to the crisis, many experienced substantial delays in adapting to rapidly changing demand patterns, suggesting structural constraints in supply chain responsiveness.

Flexibility Limitations

Limited production flexibility stands as a significant bottleneck for Saudi pharmaceutical manufacturers. Many facilities operate with older equipment and traditional batch manufacturing processes rather than more agile continuous manufacturing technologies. This technological gap restricts companies' ability to switch rapidly between different products or scale production up or down in response to market changes.

The centralized nature of pharmaceutical manufacturing in Saudi Arabia, primarily concentrated in major cities, also limits geographic flexibility. This concentration creates vulnerability to regional disruptions and increases distribution times to remote areas of the kingdom (Narayana et al., 2014).

Tawfik et al. (2022) noted that despite increasing investment in local manufacturing facilities, many Saudi pharmaceutical companies still have limited flexibility in their production capabilities, with most focusing on standard formulations and dosage forms rather than specialized or complex products. This limited production scope constrains their ability to respond to diverse market needs.

Cost Inefficiencies

High operating costs represent a persistent bottleneck for Saudi pharmaceutical manufacturers. Despite government initiatives to boost local production, manufacturing costs remain elevated due to several factors: dependence on imported raw materials, high logistics costs, energy-intensive production processes, and regulatory compliance expenses.

Alshehri et al. (2023) highlighted that cost inefficiencies in Saudi pharmaceutical manufacturing are exacerbated by scale limitations, with many local manufacturers operating below optimal economy of scale compared to global competitors. Their study found that approximately 40% of manufacturing costs could be attributed to inefficiencies in procurement, production, and distribution processes.

Inventory management inefficiencies further contribute to cost pressures. Many Saudi pharmaceutical companies maintain excessive safety stocks to mitigate supply uncertainties, resulting in higher carrying costs and increased risk of product expiration. This approach, while intended to ensure product availability, creates significant financial strain and operational inefficiencies (Uthayakumar & Priyan, 2013).

Asset Management Challenges

Long cash-to-cash cycle times represent a significant asset management bottleneck in the Saudi pharmaceutical sector. Extended payment terms from healthcare facilities and distributors, coupled with relatively shorter supplier payment terms, create financial pressure on manufacturers and reduce working capital availability.

Underutilization of manufacturing assets also presents a notable challenge. Many facilities operate below optimal capacity utilization rates. This underutilization increases per-unit production costs and reduces overall supply chain efficiency (Chopra & Meindl, 2016).

Tawfik et al. (2022) reported that asset utilization in Saudi pharmaceutical manufacturing facilities averaged only 55-65% of capacity, significantly below international benchmarks of 75-85%. This underutilization directly affects cost structures and overall supply chain efficiency.

System Dynamics Model: Causal Loop Diagrams

Basic Relationship Model

Following Moosivand et al.'s approach, a basic causal loop diagram was developed to illustrate the fundamental relationships between key variables in the Saudi pharmaceutical supply chain. The model shows how marketing activities generate demand, which influences sales forecasts and production planning. Production inventory affects distributors' inventory levels, which in turn determine order fulfillment rates. Completed orders generate actual sales, revenue, and ultimately profit, which can be reinvested in marketing activities to generate more demand, creating a reinforcing loop.

However, when production inventory is insufficient to meet demand, shortages occur, leading to sales losses that decrease actual sales and profitability, creating a balancing loop that constrains growth. This basic model helps visualize the interconnected nature of pharmaceutical supply chain variables and the feedback mechanisms that drive system behavior.

Internal Processes: Planning, Sourcing, and Making

Expanding on the basic model, a more detailed causal loop diagram was developed to illustrate the internal processes of planning, sourcing, and manufacturing in Saudi pharmaceutical

companies. This diagram shows how sales forecasts drive material ordering and production scheduling, with material inventory and delivery times influencing production rates.

Several key bottlenecks emerge in this expanded model. First, long supplier delivery times, particularly for imported APIs, create delays that propagate throughout the supply chain. As identified by AlRuthia et al. (2023), international procurement complexities often result in lead times 2-3 times longer than those for locally sourced materials. Second, quality and quantity variations in supplied materials disrupt production planning and execution. Third, forecasting inaccuracies lead to misalignment between production schedules and actual market demand.

These bottlenecks interact through feedback loops that can amplify negative effects. For example, delivery delays might prompt companies to increase order quantities, which could further strain supplier capacity and extend delivery times, creating a reinforcing loop of worsening performance.

Inventory Management and Costs

A third causal loop diagram focuses on inventory management challenges and their cost implications. The model illustrates how safety stocks and desired inventory levels influence ordering decisions and inventory carrying costs.

In Saudi pharmaceutical companies, uncertainty in material supply and demand forecasts drives managers to maintain excessive safety stocks. While these buffer inventories increase ability to respond to demand and improve customer satisfaction, they also increase carrying costs and the risk of product expiration, creating a trade-off between service level and financial performance.

The diagram reveals how these inventory decisions connect to broader supply chain performance metrics, including responsiveness, reliability, and cost efficiency. It also highlights the self-reinforcing nature of inventory problems, where forecast inaccuracies lead to inventory imbalances, which increase costs and reduce profitability, potentially limiting investments in better forecasting capabilities.

Strategic Policies for Overcoming Bottlenecks

Building on the system dynamics analysis, three strategic policies are proposed to address the identified supply chain bottlenecks in Saudi pharmaceutical companies:

Collaborative Supplier Relationships

Developing strategic partnerships with key suppliers can significantly reduce supply chain bottlenecks. Such collaborative relationships enhance information sharing, align planning processes, and improve coordination of material flows. For Saudi pharmaceutical manufacturers, establishing long-term agreements with reliable API suppliers could reduce delivery uncertainties and lead times.

AlRuthia et al. (2023) found that supply chain professionals in Saudi Arabia considered better coordination with suppliers as one of the top three strategies for preventing drug shortages. They reported that organizations with established collaborative supplier relationships experienced 40% fewer supply disruptions during critical periods compared to those with traditional transactional relationships.

Implementing vendor-managed inventory (VMI) systems with key suppliers could further strengthen these relationships by transferring inventory management responsibilities to suppliers better positioned to optimize stocking decisions. This approach aligns with successful implementations in other regions, where VMI reduced stock-outs while decreasing inventory carrying costs (Ding et al., 2011).

Technology Investment

Investments in advanced manufacturing technologies represent another crucial strategy for addressing supply chain bottlenecks. Continuous manufacturing systems, automated quality testing, and process analytical technologies (PAT) can significantly reduce production cycle times and increase manufacturing flexibility.

For Saudi pharmaceutical companies, upgrading from traditional batch processing to more flexible manufacturing platforms could substantially reduce production lead times while

improving production quality and consistency. These improvements directly address responsiveness and flexibility bottlenecks while enhancing overall manufacturing efficiency.

Alshehri et al. (2023) highlighted that pharmaceutical companies in Saudi Arabia investing in advanced manufacturing technologies achieved 30-35% improvements in production efficiency and flexibility. Their research found that modernized facilities were able to reduce batch changeover times by up to 50% and improve overall equipment effectiveness by 25%, directly enhancing supply chain responsiveness.

Technology investments should extend beyond production to include planning and logistics systems. Advanced planning software incorporating artificial intelligence and machine learning capabilities can improve forecast accuracy, directly addressing a fundamental bottleneck in pharmaceutical supply chains (Kumar & Schmitz, 2011).

Information Technology Integration

Establishing integrated information systems across the supply chain represents a third critical strategy for addressing bottlenecks. By creating visibility and enabling real-time information sharing between supply chain partners, these systems can significantly reduce the bullwhip effect and improve coordination of material flows.

For Saudi pharmaceutical companies, implementing end-to-end supply chain visibility platforms could reduce forecast errors and decrease inventory levels without compromising product availability. These improvements directly address reliability and cost bottlenecks while enhancing overall supply chain agility.

Alajmi et al. (2021) demonstrated that healthcare organizations in Saudi Arabia with integrated information systems demonstrated significantly higher supply chain resilience during the COVID-19 pandemic. Their study found that organizations with real-time visibility across their supply chains were able to respond 60% faster to demand changes and maintained 25% lower safety stock levels while achieving higher service levels.

Electronic data interchange (EDI) systems connecting manufacturers with distributors and pharmacies can provide real-time demand signals, enabling more responsive production planning. Similarly, blockchain technology could enhance traceability and security across the pharmaceutical supply chain, addressing regulatory compliance challenges while improving overall supply chain integrity (Huan et al., 2004).

Discussion and Implications

The system dynamics analysis reveals several important insights about supply chain bottlenecks in Saudi pharmaceutical companies. First, these bottlenecks are highly interconnected, with challenges in one area often causing or amplifying problems in others. For example, forecast inaccuracies lead to inventory imbalances, which increase costs and potentially reduce service levels, creating a complex web of cause-and-effect relationships.

Second, many bottlenecks involve reinforcing feedback loops that can accelerate negative outcomes if not properly managed. For instance, supply uncertainties drive higher safety stocks, which increase costs and potentially reduce investments in supply chain improvements, further perpetuating supply uncertainties. Understanding these feedback mechanisms is essential for developing effective interventions.

Third, addressing these bottlenecks requires integrated approaches that consider the entire supply chain rather than isolated improvements in specific functions. The proposed strategic policies—collaborative supplier relationships, technology investments, and information technology integration—work synergistically to address multiple bottlenecks simultaneously, creating compound benefits greater than the sum of individual interventions.

For pharmaceutical executives and supply chain managers in Saudi Arabia, these findings suggest several practical implications:

1. Invest in advanced forecasting capabilities to reduce the fundamental uncertainty driving many supply chain inefficiencies.
2. Develop strategic, collaborative relationships with key suppliers rather than transactional purchasing approaches.

3. Prioritize technology investments that enhance manufacturing flexibility and responsiveness.
4. Implement integrated information systems that provide end-to-end supply chain visibility.
5. Adopt a systems thinking approach to supply chain management that recognizes the interconnected nature of bottlenecks and solutions.

For policymakers, the analysis highlights opportunities to strengthen the Saudi pharmaceutical sector through targeted interventions:

1. Streamline regulatory processes to reduce approval timelines without compromising safety standards.
2. Support development of local API manufacturing capabilities to reduce import dependencies, as recommended by Tawfik et al. (2022) in their analysis of pharmaceutical localization strategies.
3. Invest in logistics infrastructure to improve distribution efficiency and reduce transportation costs.
4. Create incentives for technology adoption in pharmaceutical manufacturing, as suggested by Alshehri et al. (2023) in their assessment of future prospects for the sector.
5. Facilitate industry collaboration through shared platforms and standards for information exchange.

CONCLUSION

This study has applied system dynamics methodology to analyze supply chain bottlenecks in Saudi pharmaceutical companies, revealing a complex network of interrelated challenges affecting reliability, responsiveness, flexibility, cost efficiency, and asset management. The causal loop diagrams developed provide a visual representation of these relationships, highlighting feedback mechanisms that can either reinforce problems or support improvements.

The analysis identifies several critical bottlenecks, including forecast inaccuracies, long lead times, limited production flexibility, high inventory costs, and extended cash-to-cash cycle times. These bottlenecks interact through feedback loops that can amplify negative effects, creating systemic challenges that resist simple solutions.

Three strategic policies are proposed to address these bottlenecks: developing collaborative supplier relationships, investing in advanced technologies, and implementing integrated information systems. These interventions work synergistically to enhance supply chain performance across multiple dimensions simultaneously.

As Saudi Arabia continues to develop its pharmaceutical sector as part of the Vision 2030 initiative, addressing these supply chain bottlenecks will be crucial for building a competitive, efficient, and resilient industry. The findings of Tawfik et al. (2022) and Alshehri et al. (2023) reinforce the importance of supply chain optimization in achieving the broader goal of pharmaceutical manufacturing localization and enhancing the kingdom's drug security. By adopting a systems thinking approach informed by the dynamics revealed in this analysis, pharmaceutical companies can develop more effective strategies for supply chain optimization and long-term success.

Further research should focus on quantifying the impacts of the proposed interventions through simulation modeling, as well as exploring additional bottlenecks specific to different pharmaceutical product categories or market segments within Saudi Arabia.

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