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ROLE OF LOGISTIC IN SUPPLY CHAIN CHALLENGES OF PHARMACEUTICALS

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ABSTRACT

In the contemporary competitive marketplace, pharmaceutical firms have recognized that enhancing supply chain efficiency is essential for sustaining competitive advantage. Key managerial decisions involve forecasting, planning, procurement, financing, inventory management, and marketing strategies, all of which must be coordinated and balanced to achieve organizational objectives. This study is grounded in a comprehensive literature review, expert opinion elicitation, and qualitative system dynamics modeling; therefore, a triangulation research approach has been adopted.

The primary objective of this research is to investigate the challenges within the pharmaceutical supply chain (PSC) and to analyze the dynamic behavior of critical variables influencing its performance. Additionally, the study proposes strategic interventions to address these challenges. Initially, a series of semi-structured interviews with experienced supply chain professionals were conducted to identify major issues. The findings reveal that demand forecasting inaccuracies, extended lead times, suboptimal inventory levels, and elevated supply chain costs are among the most significant concerns.

Subsequently, a qualitative system dynamics approach is employed to illustrate the interdependencies among variables affecting these challenges. Finally, three strategic recommendations are proposed: fostering collaborative partnerships with suppliers, investing in advanced technologies, and implementing robust information technology (IT) systems. Overall, the findings provide supply chain managers with a holistic perspective for informed decision-making, emphasizing the importance of feedback mechanisms and their long-term impact on organizational performance and strategic goals.

KEYWORDS: Pharmaceutical supply chain, System dynamics, Performance, SCOR model, Iran.

INTRODUCTION

In recent years, organizations have increasingly focused on effective supply chain management (SCM) due to intensifying market competition. This trend is driven by shrinking product life cycles, fluctuating customer preferences, and rising production and distribution costs (1). Consequently, many firms have acknowledged the strategic importance of SCM in achieving organizational objectives by accelerating innovation and product introduction, enhancing customer value, optimizing resource utilization, reducing operational costs such as production, inventory, and transportation, and ultimately improving profitability (2).

A supply chain can be defined as a dynamic system involving the forward movement of materials and the reverse flow of information and financial resources across multiple operational entities, both within and across organizations (3). With rapid technological advancements, traditional supply chain structures have evolved into complex networks characterized by greater interconnectivity and collaboration among various stakeholders. These supply chain networks highlight organizational interactions and facilitate the flow of materials and information across entities. Typically, such networks encompass five primary components: inbound logistics (suppliers), internal operations (manufacturing), outbound logistics (distribution), demand markets, and transportation infrastructure (4).

Within the generic pharmaceutical sector, supply chains generally include raw material suppliers, pharmaceutical manufacturers, distribution centers, retail pharmacies or hospitals, and ultimately patients (5). Due to ongoing economic transformations, pharmaceutical companies have been compelled to redesign and optimize their supply chain structures. The pharmaceutical industry is inherently complex, involving multiple stakeholders with conflicting objectives and operating under stringent regulatory frameworks. The critical nature of pharmaceutical products further adds to the complexity, making the industry uniquely challenging (6). As highlighted by Wang, the fundamental objective of SCM in the pharmaceutical sector is to ensure the delivery of the right product, to the right customer, in the right quantity, and at the right time (7).

Industrial processes are often characterized by intricate activities due to the presence of numerous variables and their non-linear interactions. Developing comprehensive models to capture such dynamic behaviors is often challenging or impractical (8). Various modeling approaches have been proposed for supply chain analysis; however, many are based on static assumptions and fail to capture dynamic characteristics such as fluctuations, lead time delays, and demand variability. Therefore, system dynamics (SD) modeling emerges as a suitable methodology for representing the complex interactions among supply chain variables.

This study explores a broad range of challenges within the pharmaceutical supply chain and aims to identify internal issues as well as the interrelationships among variables that influence PSC performance. The Supply Chain Operations Reference (SCOR) model is utilized as a conceptual framework to categorize these challenges, while qualitative system dynamics modeling is applied to depict the complex interdependencies among key variables.

Literature Review

Pharmaceutical Supply Chain Challenges

In a rapidly evolving business environment, organizations are required to deliver high-quality products, respond swiftly to market demands, and continuously enhance their dynamic capabilities. The pharmaceutical industry, in particular, is encountering challenges similar to those experienced by other sectors in the past. Only organizations that are adaptable and proactive in refining their strategies are likely to achieve sustained long-term success (9).

The challenges faced by pharmaceutical companies are multifaceted, encompassing political, economic, social, technological, and legal dimensions. The industry comprises a network of organizations, processes, and activities involved in the discovery, development, and commercialization of pharmaceutical products. The pharmaceutical supply chain plays a critical role in ensuring the availability and timely delivery of medicines, which directly impacts customer satisfaction (10).

Key challenges in the pharmaceutical sector include inefficiencies in research and development (R&D), shortening product life cycles, reduced patent exclusivity periods, intensifying competition from generic drugs, compliance with regulatory standards, and escalating operational costs (9, 11). According to a study by Oliver Eitelwein, pharmaceutical firms must improve critical supply chain components such as customer satisfaction, forecasting precision, inventory optimization, and overall cost efficiency. Additionally, the inherent complexity of pharmaceutical products and processes arises from factors such as a broad product portfolio, diverse raw material requirements, extensive distribution networks, high investment in product development, capacity limitations, and stringent regulatory constraints (12).

Supply Chain Challenges Based on SCOR Framework

Similar to other industries, the pharmaceutical supply chain begins with the procurement of raw materials required for production. Active pharmaceutical ingredients (APIs), along with excipients, are processed into standardized dosage forms and packaged using primary and secondary packaging systems. The finished products are then distributed from manufacturers' warehouses to distributors, retail pharmacies, hospital pharmacies, and ultimately to end-users. Conversely, the flow of information and financial transactions moves upstream from consumers to manufacturers through multiple channels (13).

Given the multitude of factors influencing supply chain performance, this study does not attempt to address all variables. Instead, the Supply Chain Operations Reference (SCOR) model is employed as a conceptual framework to focus on critical determinants. Developed by the Supply Chain Council, the SCOR model provides a standardized structure for evaluating supply chain performance and offers universally accepted metrics applicable across industries (2, 14).

Numerous analytical models have been developed in business and engineering disciplines to address supply chain design and operational challenges (15). However, there remains a scarcity of comprehensive models suitable for strategic decision-making. According to Huan's survey, the SCOR model is considered one of the most effective frameworks for strategic supply chain management (16). It facilitates performance assessment and improvement by providing a cross-industry standard for supply chain processes (17).

Within the SCOR framework, supply chain management is analyzed from an operational perspective. Recent research has explored the application of the SCOR model in evaluating organizational performance and its impact on supply chain efficiency (16, 18–20). Furthermore, a study conducted by Zhue demonstrated the interrelationships among various supply chain processes defined within the SCOR model (21).

Accordingly, this well-established model, validated by numerous scholars and industry professionals across both academic and corporate domains, was selected as the conceptual framework for this study to analyze supply chain issues in pharmaceutical manufacturing firms.

Within the SCOR model, supply chain operations are represented as a sequence of interconnected inter-organizational processes comprising five primary stages: plan, source, make, deliver, and return. Each stage encompasses distinct intra-organizational activities that are assessed using five key performance attributes: supply chain reliability, responsiveness, flexibility, cost efficiency, and asset management. The first three attributes correspond to customer-focused performance indicators (effectiveness), such as delivery reliability, whereas the latter two reflect internal operational efficiency, including metrics like cash-to-cash cycle time (22).

Customer-Oriented Perspective

From a customer-centric viewpoint, critical supply chain capabilities include reliability, responsiveness, and flexibility. Reliability refers to the ability to consistently deliver the correct product, in the appropriate quantity, with suitable packaging and documentation, to the right customer, at the designated location, and within the specified timeframe.

Responsiveness denotes the speed at which the supply chain can react to customer requirements. Flexibility, on the other hand, reflects the capacity of the supply chain to adjust production volumes or rapidly switch between products in response to fluctuations in demand, thereby sustaining or enhancing competitive advantage. This adaptability minimizes the risk of stockouts caused by sudden demand surges and reduces the necessity for maintaining excessive inventory levels (23).

In the current competitive landscape, time-based competition has emerged as a dominant strategic approach. Supply chains must minimize the time required for product development, manufacturing, marketing, and distribution in order to respond effectively to customer needs within the shortest possible lead time. In this context, responsiveness to market demand serves as a fundamental prerequisite for achieving reliability. It can be further interpreted as the ability of a supply chain to respond efficiently and within an appropriate timeframe to customer requests or market fluctuations—often referred to as agility (24).

The concept of agility is particularly significant in the pharmaceutical sector due to factors such as shortened product life cycles, increased mergers and acquisitions, evolving customer expectations, and intensified competitive pressures, all of which compel organizations to enhance their responsiveness (12).

Internal Perspective

From an internal operational standpoint, supply chain efficiency is evaluated primarily in terms of cost optimization and asset utilization. Effective supply chain management contributes to reductions in production, inventory, and transportation costs, while simultaneously improving service levels. All operational expenses—including costs associated with planning, sourcing, manufacturing, delivering, and returning products, as well as cost of goods sold, direct costs (labor and materials), and indirect costs (overheads)—are considered in assessing overall productivity.

Operational costs have a direct impact on profitability and, consequently, on overall organizational performance, making cost efficiency a critical performance indicator. The greater the degree of cost optimization, the higher the operational efficiency achieved (25). Leading organizations pursue cost reduction by strengthening collaborative relationships with supply chain partners, minimizing internal lead times and work-in-progress inventory, enhancing forecasting accuracy and consistency, and implementing just-in-time (JIT) delivery systems for high-value raw materials. These initiatives significantly reduce indirect costs (26).

Supply chain asset management is assessed using three primary indicators: cash-to-cash cycle time, return on supply chain fixed assets, and return on working capital. The cash-to-cash cycle time represents the duration between the outflow of cash for raw material procurement and the inflow of cash from product sales. This metric is crucial for determining the financial requirements for both current and future operations (14).

Experimental Section

System Dynamics Methodology

Supply chain systems exhibit dynamic behavior due to uncertainties in demand, supply conditions, and logistics operations. With the increasing complexity of supply chain networks, system dynamics (SD) modeling has gained prominence as an effective analytical tool (27). Since SD models are grounded in feedback structures, causal loop diagrams (CLDs) are utilized to represent the inherent feedback mechanisms within the system. A feedback loop occurs when a change in a variable ultimately influences itself through a chain of interactions (28).

Qualitative System Dynamics Using Causal Loop Diagrams

Numerous researchers have proposed that causal loop diagrams serve as valuable conceptual tools for structuring and addressing managerial challenges (29–31). Over time, two parallel approaches have emerged. The first, known as qualitative system dynamics, focuses on applying all stages of system dynamics except quantitative simulation. This approach emphasizes defining system boundaries and enables managers to anticipate how different processes interact. Additionally, it can be integrated into various simulation platforms (32).

The second approach considers CLDs as a fundamental component of organizational learning, commonly referred to as systems thinking. This perspective enhances managerial understanding of system behavior through logical inference rather than numerical computation (28). The visualization of dynamic systems through CLDs effectively highlights decision points and performance indicators, thereby supporting managerial decision-making (33).

System Dynamics Modeling Process

According to Sterman, the standard system dynamics methodology consists of a sequence of steps used to analyze complex problems (30). These include problem identification, formulation of dynamic hypotheses, model development, validation and testing, policy design, and evaluation. In this study, the SD approach is applied to examine variable interactions and flows from both a systemic and managerial perspective.

The present research focuses on identifying challenges within the pharmaceutical manufacturing supply chain in Iran and analyzing the relationships among influencing variables using the initial stages of the SD methodology—problem definition and causal loop diagram development. The proposed model is qualitative in nature and is based on an extensive literature review combined with semi-structured interviews with industry experts.

Key Challenges Identified

The findings indicate several critical challenges affecting the Iranian pharmaceutical industry, impacting competitiveness, profitability, and overall supply chain performance at both internal and external levels. External (macro-environmental) challenges include economic instability, political factors such as sanctions, exchange rate volatility, financial constraints, inadequate infrastructure, the prevalence of counterfeit drugs, lack of transparency, unpredictability in government policies, and the highly regulated nature of the industry.

Internally, major challenges include insufficient integration and coordination among supply chain stakeholders, limited information visibility and data sharing, outdated machinery, high costs and extended timelines associated with research and development, restrictive pricing policies affecting product competitiveness and quality, uncertainty in sourcing high-quality raw materials in required quantities and timelines, and ineffective supplier relationship management.

Problem Definition (Boundary Identification)

In any modeling exercise, it is essential to clearly define the scope and boundaries of the system. Without explicit boundary delineation, model development can become excessively complex and unmanageable.

Accordingly, the initial phase of this research involved conducting semi-structured, face-to-face interviews with 25 experienced managers from various pharmaceutical manufacturing organizations. These participants possessed a minimum of five years of experience across different supply chain functions, including marketing, planning, commercial operations, manufacturing, sales, and finance. The purpose of these interviews was to define the structure and boundaries of the pharmaceutical supply chain and to identify key challenges associated with supply chain management.

To achieve these objectives, the interview framework was developed based on an extensive review of existing literature and aligned with the five primary SCOR performance attributes and their corresponding Level 1 metrics (34, 35). Table 1 presents these five performance attributes along with thirteen associated Level 1 performance indicators.

Table 1.

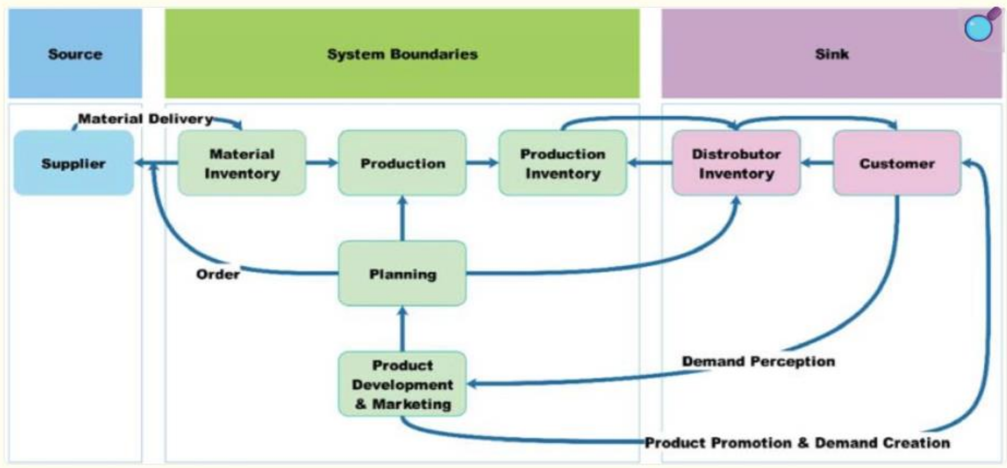
The SCOR performance attributes with the associated level 1 metrics

SC Performance	SCOR Perspectives	Metrics
Supply Chain Capabilities	Reliability	Delivery performance Fill rate Perfect order fulfillment
	Responsiveness	Order fulfillment lead time
	Flexibility	SC response time Production flexibility
Supply Chain Efficiency	Cost	Total SC cost Cost of goods sold Value added productivity Return processing costs
	Asset Management	Cash to cash cycle time Inventory day of supply Asset turns

The respondents were requested to describe the structure and operational processes of the supply chain within their respective organizations and to identify the key challenges that hinder the achievement of supply chain objectives, in alignment with SCOR performance attributes. Furthermore, participants were encouraged to highlight any additional issues they considered significant to their specific operational context. All interviews were digitally recorded, and detailed notes were documented concurrently during the sessions.

The determination of model boundaries and the identification of variables incorporated within each segment of the causal loop diagrams (CLDs) were derived from the recorded data and interview transcripts. Figure 1 illustrates the market-oriented pharmaceutical supply chain along with the defined system boundaries of the model.

Figure 1.



General model boundaries for market oriented pharmaceutical supply chain

In summary, within the pharmaceutical industry, supply chain (SC) processes are initiated through product development and marketing functions, which serve as strategic drivers. The sales and marketing departments identify market needs and translate them into actual demand. This is primarily achieved through interaction with physicians who are authorized to prescribe pharmaceutical products to end users. Simultaneously, these departments engage with distribution firms and pharmacies to facilitate product sales. Through such downstream interactions, they are able to monitor market trends and generate demand forecasts.

The marketing division subsequently provides forecasting data to the planning department, which utilizes this information to coordinate and schedule internal operations, including procurement of raw materials, product formulation, manufacturing of finished goods, and distribution activities, all aligned with anticipated market demand.

Pharmaceutical manufacturing companies, particularly those producing branded generics, also rely on upstream suppliers operating at both domestic and international levels for the provision of active pharmaceutical ingredients (APIs) and excipients. Consequently, supplier selection and relationship management represent critical functions. Manufacturers must evaluate suppliers using both qualitative and quantitative criteria, including material quality, delivery reliability, industry reputation, bargaining strength, production capacity, technical expertise, geographical location, order fulfillment lead time, pricing, and total logistics costs (36).

Based on these considerations, the scope of this research is defined to include all challenges associated with the internal processes of pharmaceutical manufacturing companies that can influence performance and can be improved through strategic decisions and policy interventions. Issues related to upstream and downstream entities beyond the manufacturer's direct control are considered outside the boundaries of this study.

Dynamic Hypothesis

Drawing upon the insights obtained from the interviews, key supply chain challenges faced by pharmaceutical manufacturing firms have been identified and systematically categorized according to the SCOR model performance attributes, as presented in Table 2.

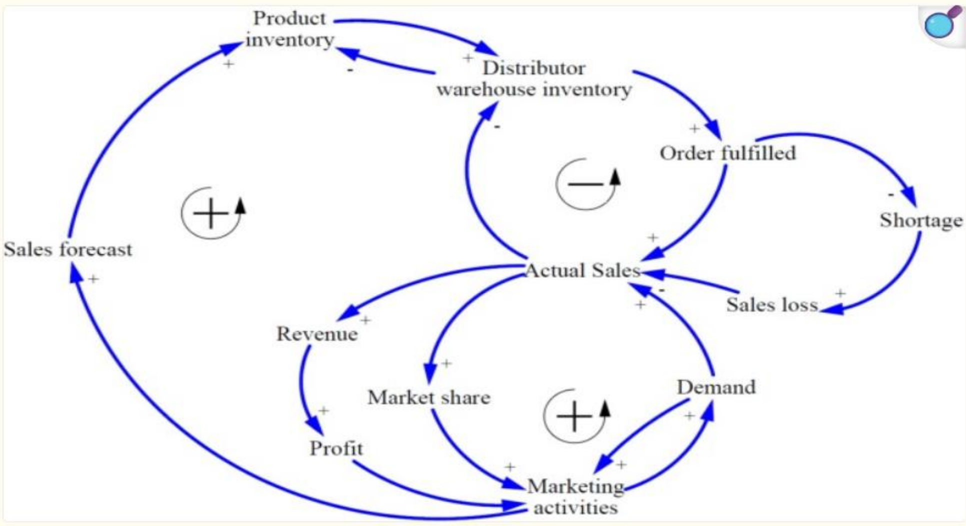
Table 2.

Supply Chain challenges in pharmaceutical manufacturing company

SC Performance	SCOR Perspectives	Problems related this metrics
Supply Chain Capabilities	Reliability	High backorders value (Sales loss) Destocking episodes and inventory oscillation Forecast inaccuracy Delay in supply orders
	Responsiveness	High average manufacturing cycle time
	Flexibility	Lack of on time delivery percentage Lack of response to unpredictable changes Time consuming R and D process
Supply Chain Efficiency	Cost	High inventory cost
	Asset Management	Long cash to cash cycle time Inactive inventory percentage

The fundamental causal loop diagrams (CLDs) for the market-oriented pharmaceutical supply chain (PSC) were developed based on an extensive review of existing literature and insights obtained from domain experts. Figure 2 illustrates the primary interrelationships among the key variables influencing the performance and behavior of the pharmaceutical supply chain system.

Figure 2.



In general, the primary objective of profit-oriented organizations is to maximize shareholder value, which can be broadly categorized into three key sub-goals: profitability, long-term survival and sustainability, and organizational growth. Achieving these objectives requires improvements in both financial performance indicators—such as revenue generation, return on investment (ROI), and cash flow—and non-financial metrics, including market share, customer satisfaction, new product development, and workforce expansion.

In market-driven pharmaceutical manufacturing firms, all operational activities originate from product development and marketing functions. These activities are guided by market research and analysis aimed at identifying unmet healthcare needs and generating demand through promotional strategies targeted at healthcare professionals. Simultaneously, marketing departments monitor market conditions to estimate sales forecasts, which are then communicated to the planning division. This information is used to design production schedules and determine appropriate finished goods inventory levels in alignment with anticipated demand.

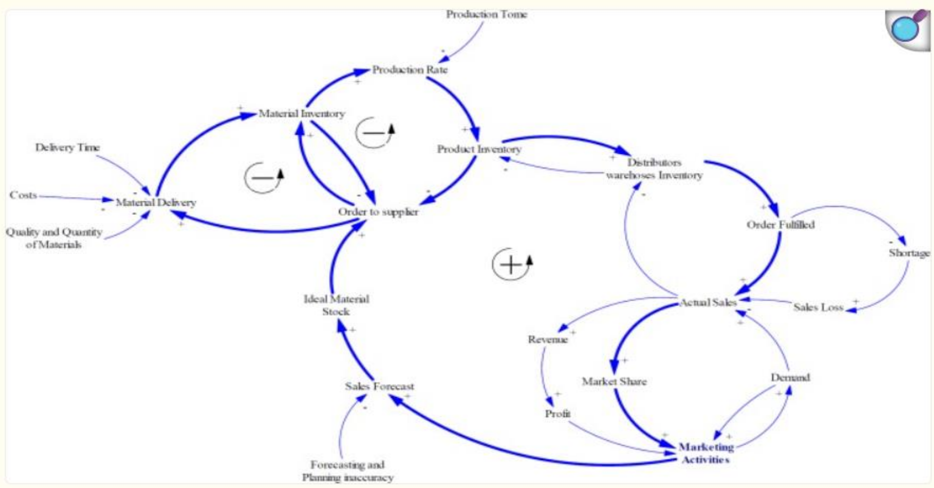
Maintaining optimal production inventory ensures adequate stock levels in distributors' warehouses, thereby enabling complete order fulfillment. At this stage, actual sales are recorded by manufacturing firms; however, payments are typically received after a delayed period of several months. An increase in actual sales contributes directly to higher revenues and profitability, while also enhancing market share. In turn, improved financial performance allows marketing departments to intensify promotional activities, further stimulating demand.

Within this system, two reinforcing feedback loops drive growth, while one balancing (negative) loop regulates system stability. When production inventory is insufficient to meet market demand, distributors are unable to fulfill orders completely. This leads to reduced order fulfillment rates, product shortages, and lost sales opportunities, ultimately resulting in a decline in actual sales. Based on expert insights and supporting literature, inaccuracies in demand forecasting and limitations in production capacity are identified as key contributors to inadequate inventory levels.

Additionally, two balancing feedback loops can be incorporated to explain the mechanisms governing inventory creation. As previously discussed, both procurement planning and production scheduling are driven by demand forecasts. Procurement units are responsible for sourcing raw materials from multiple suppliers, and supplier performance is influenced by several factors, including their ability to meet quantity and quality requirements, material and transportation costs, and delivery lead times.

Furthermore, both raw material inventory and finished goods inventory exert a regulatory (moderating) effect on ordering rates, thereby stabilizing the overall supply chain system, as illustrated in Figure 3.

Figure 3.



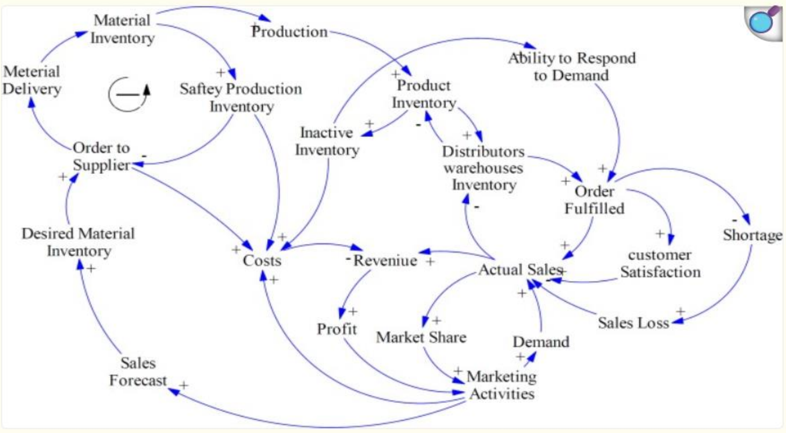
According to expert insights from the Iranian pharmaceutical sector, financial constraints and political factors impose significant barriers to the procurement of active pharmaceutical ingredients (APIs), particularly those sourced through imports. Furthermore, the absence of effective collaborative partnerships with suppliers exacerbates these challenges, leading to issues such as demand forecast deviations, severe inventory fluctuations, and frequent stock-out occurrences.

In response to these uncertainties, pharmaceutical manufacturing firms often adopt a buffering strategy by maintaining high levels of raw material and finished goods inventory.

While this approach improves supply chain responsiveness, enhances customer satisfaction, and reduces the likelihood of lost sales, it simultaneously introduces several operational drawbacks. These include increased requirements for warehouse capacity and management, higher inventory holding costs, and an elevated risk of product or material obsolescence and expiration.

These dynamic interactions and trade-offs are illustrated in Figure 4.

Figure 4.



A further critical challenge in the pharmaceutical sector is the presence of extended lead times across multiple stages, including new product development, capacity expansion, procurement, manufacturing, distribution, regulatory approval processes, and the cash-to-cash cycle. Prolonged lead times significantly constrain the ability of the pharmaceutical supply chain (PSC) to achieve reliability and responsiveness. This limitation not only diminishes supply chain agility and reduces market share but also contributes to increased overall operational costs. However, to sustain competitiveness, firms must simultaneously pursue cost reduction while continuously enhancing responsiveness.

Following the identification of PSC-related issues, dynamic hypotheses were formulated. The primary challenges affecting both the effectiveness and efficiency of the pharmaceutical supply chain can be summarized as: forecasting inaccuracies, extended lead times, suboptimal inventory levels, and elevated supply chain costs.

These constraints hinder the achievement of key organizational objectives, including profitability, customer satisfaction, and market share growth. Nevertheless, various corrective measures and strategic interventions—previously validated in other industries and supported by empirical research—can be adopted to mitigate these challenges. The subsequent section evaluates the impact of selected policy interventions using the causal loop modeling framework.

Given that system dynamics modeling is inherently an iterative and participatory process involving researchers and domain experts (such as managers, executives, and other stakeholders), the developed causal loop diagrams were validated through consultation with pharmaceutical supply chain experts who participated in the interviews. The relationships among variables were reviewed and confirmed, ensuring the model's conceptual validity. Subsequently, the proposed policy interventions were incorporated into the model and further verified by these experts (37, 38). The next phase involved analyzing the implications of these policy measures.

RESULTS AND DISCUSSION

Proposed Strategies to Address Supply Chain Challenges

Collaborative Supplier Relationships

Supply chain collaboration has been defined by Togar as a cooperative approach in which two or more supply chain partners work jointly to achieve competitive advantage through information sharing, coordinated decision-making, and equitable distribution of benefits, resulting in enhanced profitability and improved customer satisfaction compared to independent operations (39).

Through collaborative practices, organizations can mitigate adverse effects such as the bullwhip effect and enhance their responsiveness to market volatility (40). The positive influence of collaboration on organizational performance has also been validated by multiple empirical studies (41–43).

When the objective is to improve organizational performance through efficient supply chain management, the role of suppliers becomes increasingly critical in aligning supply with demand (44). Numerous studies have explored various dimensions of supplier-manufacturer relationships, including supplier selection, strategic alliances, long-term partnerships, and supplier management practices (45–50).

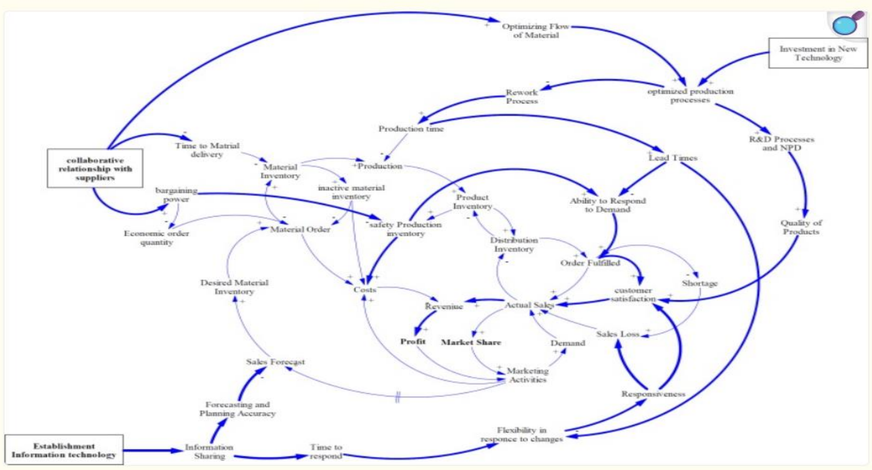
A long-term partnership between manufacturers and suppliers, often referred to as a strategic supplier relationship, enables firms to achieve significant operational advantages. Such relationships allow organizations to collaborate more effectively with a select group of key suppliers, thereby reducing complexity and improving efficiency. Strategic alignment between firms also minimizes time and resource expenditure (51–54).

Moreover, collaboration with strategic suppliers enhances responsiveness to market fluctuations by improving knowledge sharing, communication, and operational coordination (55, 56). These partnerships also support the adoption of flexible and lean manufacturing practices, particularly in pull-based production systems, by reducing cycle times and improving adaptability (57).

As illustrated in Figure 5, this study evaluates the impact of supplier collaboration on critical factors such as supply lead time, bargaining power, and order quantities. Establishing strategic partnerships and fostering trust among supply chain partners contributes to reductions in lead times, safety stock levels, economic order quantities, and overall costs. Simultaneously, it enhances demand responsiveness, customer satisfaction, market share, and profitability.

These findings are consistent with previous research across various industries, which demonstrates a positive relationship between supplier involvement in organizational processes and overall firm performance (58). Additionally, prior studies have confirmed the beneficial effects of collaboration on resource optimization, information accuracy, and cost efficiency (59, 60). Furthermore, research by Rajabzadeh et al. (61) highlights that effective supplier evaluation and prioritization are critical determinants of supply chain agility in pharmaceutical companies.

Figure 5.



Investment in Advanced Technologies

Another critical strategic intervention involves the adoption of advanced technologies to enhance research and development (R&D) capabilities, improve product quality, optimize existing manufacturing processes, and minimize rework and material wastage. Previous studies have indicated that the implementation of modern production technologies significantly strengthens organizational competitiveness (62). Moreover, empirical evidence suggests that innovative manufacturing technologies contribute to increased operational flexibility (63, 64). Since flexibility is a fundamental requirement for pull-based production systems, the integration of advanced technologies can substantially improve both efficiency and effectiveness.

In addition, technological advancements facilitate product innovation, particularly for complex products characterized by uncertain demand patterns (65).

Investment in cutting-edge technologies within pharmaceutical organizations leads to improvements in production flexibility, product quality, and overall customer satisfaction. Furthermore, by reducing production lead times, these technologies enhance supply chain responsiveness. Collectively, these improvements contribute to increased actual sales and expanded market share. Research also highlights that environmental uncertainty necessitates rapid adoption of new technologies to achieve higher levels of flexibility and responsiveness. Notably, logistics professionals consider technological advancement as a key driver in enhancing supply chain capabilities (66).

Information Technology (IT) Implementation

Information asymmetry is a common issue across upstream and downstream entities within the supply chain. Each participant often forecasts future demand based on incomplete or imperfect information received from other members of the supply chain. As a result, organizations tend to maintain excessive inventory levels to mitigate the risk of stockouts and ensure responsiveness to market fluctuations, ultimately increasing operational costs (67).

The implementation of robust information technology (IT) systems to enhance data visibility and facilitate information sharing among supply chain partners is therefore essential for improving supply chain effectiveness (68, 69). The utilization of IT systems enables more accurate demand forecasting, thereby reducing the need for safety stock and excess inventory, and lowering associated carrying costs. Enhanced visibility also mitigates the bullwhip effect and improves overall supply chain reliability (70).

Furthermore, collaborative practices enabled through IT integration provide significant advantages, including improved demand transparency and the development of realistic and coordinated response strategies (71). Researchers have emphasized the importance of IT infrastructure in enabling seamless information exchange and fostering collaboration across supply chain networks (72, 73). According to Mehralian's study, IT plays a pivotal role in enhancing coordination among supply chain entities (58). Additionally, the application of IT systems for improved information sharing has been shown to positively influence overall supply chain performance (74).

CONCLUSION

The ultimate objective of supply chain management is to create value for both end consumers and the entire supply chain network. Achieving this goal requires the integration of inter-organizational and intra-organizational processes. A firm's competitive advantage is closely linked to the degree of integration within its supply chain. Process integration involves effective coordination, resource sharing, and information exchange to manage operations collaboratively (70).

Chopra and Meindl have highlighted several benefits of supply chain integration, including reductions in safety stock and operational costs, as well as improvements in flexibility, responsiveness, product quality, and optimal resource utilization (15). However, achieving such integration presents significant challenges, including organizational resistance, infrastructural limitations, and the need for continuous learning and adaptation to change. Despite these challenges, the proposed model can serve as a foundational framework for configuring and improving supply chain systems.

The policies recommended in this study promote greater integration within the pharmaceutical supply chain. In particular, the implementation of Collaborative Planning, Forecasting, and Replenishment (CPFR) is suggested as an effective approach to enhance replenishment efficiency, reduce inventory levels and backorders, and minimize procurement and delivery lead times.

Limitations and Managerial Implications

This study represents an initial effort to systematically examine the key internal supply chain challenges faced by market-oriented pharmaceutical manufacturing companies. The findings demonstrate how qualitative system dynamics modeling can effectively support decision-makers in the formulation of strategic policies. The developed causal loop diagrams (CLDs) provide a visual representation of how organizational activities and decisions influence overall performance, thereby enabling managers to make more informed decisions and address operational challenges.

Furthermore, CLDs can serve as a conceptual foundation for more advanced system dynamics modeling, including the development of stock-and-flow diagrams and quantitative simulation models. Such frameworks enable organizations to collect and analyze data systematically based on identified variables, facilitating more detailed and data-driven decision-making.

However, this study has certain limitations. The data collection was restricted to supply chain managers within manufacturing firms. Future research could benefit from including a broader range of stakeholders across the supply chain, such as upstream suppliers and downstream customers, to provide a more comprehensive perspective. Additionally, since this research focuses solely on the pharmaceutical industry, the generalizability of the findings to other sectors may be limited.

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