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Review Article

Risk Management Frameworks in Healthcare Supply Chains: A Comprehensive Review

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Abstract - *This comprehensive review examines risk management frameworks—structured methodologies designed to identify, assess, mitigate, and monitor potential disruptions—within healthcare supply chains, which are networks responsible for the acquisition and distribution of essential medical supplies and services crucial to patient care. The review emphasizes the critical role of these frameworks in maintaining the resilience and efficiency of healthcare operations amidst growing global complexities. It begins with an overview of the inherent risks in healthcare supply chains, which have been exacerbated by factors such as globalization and the recent COVID-19 pandemic. Highlighting the complexity of these supply chains, which involve diverse stakeholders and vital supplies, the paper delves into internal and external risk factors, including operational inefficiencies, inventory mismanagement, regulatory changes, market volatility, and natural disasters. Additionally, it explores the SCRM network, focusing on processes like risk identification, analysis, mitigation, and monitoring. The review contrasts risk management practices in developed and developing countries, illustrating disparities in capabilities and outcomes due to infrastructural and resource limitations. Concluding with an analysis of key risk factors and their implications, the paper calls for a strategic, technology-enhanced approach to risk management, underscoring the importance of collaboration and technological advancements to safeguard healthcare supply chain resilience.*

Keywords *- SCRM, Risk Control, Risk Analysis, HCRM, HCSCM.*

1. Introduction

In today's interconnected and globalized society, risks have grown into an unavoidable part of our everyday lives. Every action we take, and every decision we make has some level of risk. This is especially evident in the realm of supply chain management, where globalization has significantly amplified the complexity and scope of risks. As a result, risk assessment and management have become critical components of supply chain operations across various sectors. This trend is particularly pronounced in the healthcare sector, where the stakes are immeasurably high. SCRM primarily arose as a concept in the early 2000s, aiming to identify, assess, and mitigate risks within supply chain networks to guarantee their resilience and continuity. Healthcare supply chains are unusually complicated since their primary goal is to save lives rather than make a profit. Healthcare providers, such as clinics and hospitals, are at the forefront of patient care and drive demand across the HSC [1]. Risk management in supply chains involves continuous evaluation of potential risks and the implementation of strategies to minimize vulnerabilities. Although the risks encountered by different supply chains can vary, certain risks are common across industries [2]. Supply chains are dynamic and evolve in response to economic changes. Companies that fail to anticipate or respond to disruptions risk slipping behind their competitors. The COVID-19 pandemic underlined the critical importance of robust risk management in supply chain networks. By August 1, 2020, the pandemic had resulted in over 17 million cases and 675,000 deaths globally [3]. This unprecedented interruption underscored the need for practical risk assesment and management to mitigate the impacts of such crises. Risk in supply chain management is inherently tied to uncertainty, as it is impossible to predict future events with absolute certainty. The SCRM literature offers various definitions of risk, often blurring the line between risk and uncertainty. Risk can be seen as unreliable and uncertain resources causing supply chain interruptions, while uncertainty involves mismatches between supply and demand. Risks can originate from numerous sources; some can be mitigated, while others cannot. It is crucial to study and analyze these uncertainties to develop effective risk management strategies. Effective risk management includes identifying operations prone to risk, preventing failures before they occur, addressing issues when they arise, minimizing negative consequences, and ensuring the recovery of planned operations. In healthcare, risk handling refers to medical and administrative systems, procedures, and reports that identify, monitor, analyze, mitigate, and avoid hazards. By proactively

managing risks, healthcare organizations can safeguard patient safety, protect organizational assets, maintain market share, ensure accreditation, secure reimbursement levels, preserve brand value, and uphold their community standing. This paper reviews the existing literature on healthcare supply chain risk evaluation and management, highlighting critical gaps and proposing directions for future research. It emphasizes the urgent need for an innovative DSS tailored to the healthcare sector, incorporating advanced analytics, real-time data monitoring, and predictive modeling to evaluate and manage risks effectively.

1.1. Research Gap and Identification of Problem

The complexity of supply chain management has increased significantly in recent years due to globalization and interconnectivity, making effective risk management a crucial component across various sectors. In the healthcare sector, where supply chain disruptions can directly impact patient safety and care quality, these risks are particularly consequential. Despite the development of SCRM as a discipline, many frameworks are tailored for commercial sectors and do not fully address the unique demands and life-saving focus of healthcare supply chains.A noticeable research gap exists in tailored risk management approaches for healthcare supply chains, especially regarding the integration of advanced analytics and real-time data to predict and mitigate disruptions.

This gap has been highlighted by recent global crises like the COVID-19 pandemic, which exposed vulnerabilities and underscored the need for specialized risk management frameworks to sustain healthcare delivery in times of crisis. This paper examines existing literature on HSRM to uncover these gaps and address the urgent need for an innovative, decision-support system that can enhance resilience in healthcare logistics through advanced analytics, predictive modeling, and real-time monitoring. This focus on specialized frameworks aims to bridge current research gaps and provide healthcare organizations with a robust toolkit to ensure continuous and safe patient care.

1.2. Novelty of this Work

This review paper, titled "Risk Management Frameworks in Healthcare Supply Chains: A Comprehensive Review," stands out by providing an integrative analysis of risk management frameworks specifically designed for healthcare, addressing unique challenges such as patient safety, regulatory compliance, and complex supplier relationships that general supply chain frameworks do not fully cover. Unlike existing research that often isolates risk factors, this review proposes a holistic framework tailored for healthcare supply chains, advocating for a Decision Support System (DSS) that leverages advanced technologies like AI and ML.

This novel approach of integrating predictive analytics and real-time monitoring into risk management frameworks specifically for healthcare is a significant advancement over current models. Furthermore, this work introduces a comprehensive comparative analysis between developed and developing countries and a perspective rarely explored in HSCRM, which provides new insights into regional disparities and highlights strategies that can be adapted to various healthcare settings worldwide. This inclusive and technologically advanced framework positions this review as a valuable foundation for future research, aiming to elevate resilience and adaptability within global healthcare supply chains.

2. The Complexity and Importance of HSC

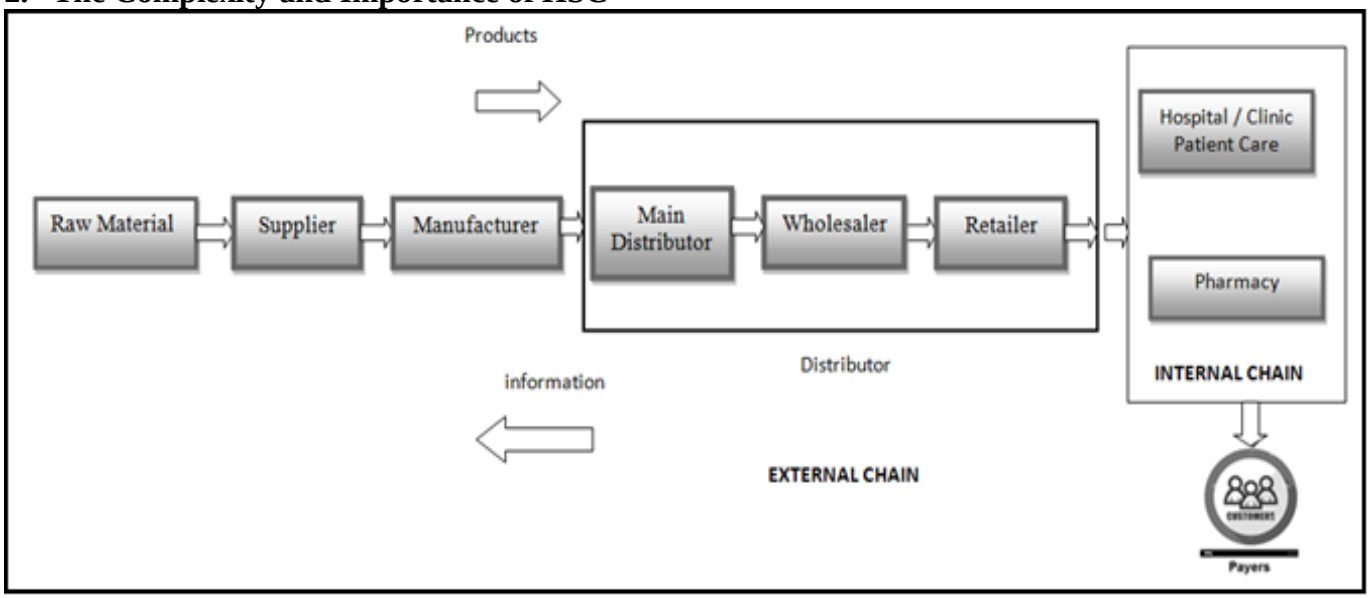

Fig. 1 Healthcare supply chain

The HSC is one of the most critical industries, and high levels of built-in complexity characterize it. Also, due to its level of importance, a lot more risk management strategies have been incorporated into this sector [4]. Supply chain risks are pervasive across industries and regions, emphasizing the universal need for effective management practices. Healthcare Supply Chain Management (HCSCM) uniquely involves managing a diverse array of items—medicines, equipment, food—across stakeholders such as hospitals, suppliers, and transport providers. Unlike traditional supply chains, HCSCM faces distinct challenges due to the diverse diagnoses and treatments, necessitating specific and often high-value supplies that must be carefully managed to prevent spoilage or obsolescence [5].

Healthcare supply selections are heavily influenced by physician preferences, shaped by medical training, experience, and patient-specific needs, rather than production forecasts typical in other industries. This diversity in supply requirements underscores the need for a flexible and responsive supply chain framework capable of meeting dynamic clinical demands while maintaining high standards of quality and efficiency.The HSC encompasses both external and internal components (Figure 1). Internally, it involves patient care units and hospital pharmacies, where the timely availability of supplies directly impacts patient care outcomes. Externally, it encompasses producers, purchasers, distributors, and payers, all playing crucial roles in ensuring the efficient flow of supplies from manufacturers to end-users. Integrating these components is essential for achieving Total Quality Management (TQM) and optimizing resource utilization in healthcare settings.

The importance of risk management for SCM has become increasingly evident over the years and cannot be overstated. Effective risk management practices are essential to mitigate disruptions and ensure continued accessibility to essential medical supplies. In healthcare, where patient health and safety hinge on the availability of timely and accurate supplies, any disruption can have profound consequences. Research indicates that adopting SCM practices in healthcare can yield significant benefits, including cost reduction, enhanced operational efficiency, and improved service quality. By implementing SCM principles, healthcare organizations can streamline processes, optimize inventory management, and proactively mitigate supply chain risks. In conclusion, the complexity and critical nature of HSC necessitate a strategic approach to risk management and supply chain optimization. As healthcare systems evolve to meet the increasing demands of patient care, adopting innovative SCM practices tailored to the unique challenges of the healthcare sector becomes imperative. Future research should focus on addressing these challenges, leveraging technological advancements, and fostering collaboration among stakeholders to achieve sustainable improvements in HSC performance.

3. Risk Factors in HSCs and SCRM Network

3.1. Risk Factors in Healthcare Supply Chains

Unlike commercial industries, the risks in the HSC stem from both external and internal sources. Internal risks include operational inefficiencies, inventory mismanagement, and supply chain disruptions. External risks are often associated with the broader environment, such as regulatory changes, market volatility, and natural disasters. These risks can lead to severe consequences, including supply shortages, increased costs, compromised patient care, and even loss of life.

3.1.1. Internal Risks

1. Operational Inefficiencies: Inefficiencies in HSC operations can result in delays, increased prices, and wastage of resources. These inefficiencies often arise from inadequate inventory management, lack of coordination among stakeholders, and outdated information systems.
2. Supply Chain Disruptions: Transportation delays or supplier breakdowns can have an adverse impact on healthcare delivery. Such disruptions can cause shortages of key medical supplies, compromising the health of patients.
3. Inventory Mismanagement: Proper inventory management is crucial to ensure the availability of medical supplies. Overstocking or understocking can lead to increased costs and potential stockouts of essential items.

3.1.2. External Risks

1. Regulatory Changes: Healthcare is a heavily regulated industry. Changes in regulations can impact the supply chain, necessitating adjustments in procurement, storage, and distribution practices.
2. Market Volatility: Fluctuations in market conditions, such as changes in demand and supply dynamics, can affect the availability and cost of medical supplies.
3. Natural Disasters: Natural disasters, such as earthquakes, floods, and pandemics, can disrupt the supply chain, causing shortages and delays in the delivery of medical supplies.

3.2. Supply Chain Risk Management Network

The risk management process is an organized framework for taking the steps necessary to manage risks successfully. It begins with risk identification, followed by risk analysis, prioritization, solution implementation, and risk monitoring. This approach is critical for organizations of all sizes. The goal of the risk evaluation process is to provide evidence-based information and analysis so that stakeholders can make educated decisions about how to manage specific risks. The desired outcome of risk identification is to find out which circumstances are likely to occur and have an influence on organizational objectives, as well as to identify the origins and sources of risks and their possible consequences [6, 7]. Risk management should be a constant, evolving process that is

incorporated into an organization's strategy and implementation.

3.2.1. Risk Management Process (RMP)

There is general agreement on the stages of the RMP, which typically include:

Risk Analysis: The estimation of the risk associated with identified hazards consists of the following three stages:

1. Risk identification refers to identifying all potential project risks.
2. Risk estimation involves determining the likelihood and magnitude of the most critical risks.
3. Risk evaluation involves establishing the best management response for each detected risk or combination of risks, as well as the right party to manage them.

Risk Control: The actions for executing risk management decisions include the following stages:

1. Risk Mitigation is an approach for preparing for and mitigating the consequences of risks to a firm. Risk mitigation, like reducing risk, aims to lessen the adverse effects of risks and emergencies on company operations.
2. Risk monitoring is the process of measuring and analyzing an organization's risk levels, including the efficacy of risk management measures.

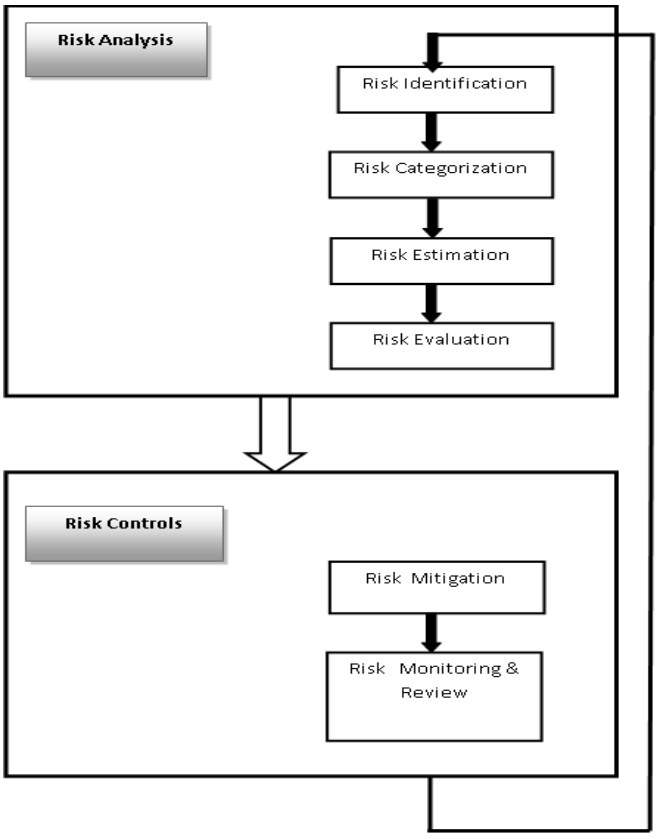

Fig. 2 SCRM network

4. Literature Review

4.1. Overview of the Literature Review Process

The literature review for this research was conducted systematically and comprehensively to identify, evaluate, and synthesize studies related to healthcare supply chain risk management. We aimed to generate new knowledge mainly by reviewing insights from existing literature. We received an overview of the current state of knowledge as well as potential research gaps in communication studies. The following steps were undertaken in the review process:

4.2. Review Methodology

4.2.1. Defining the Scope and Objectives

The first part required for a literature review is to set the scope, e.g., objectives with which to search articles according to it. These included identifying key themes after the scoping review, such as risk identification in the HSC and the assessment of those risks, as well as how to mitigate these risks.

4.2.2. Selecting Databases and Sources

Selected databases and sources were identified to locate a broader scope of literature:

- PubMed for health-related research
- IEEE Xplore for technology and systems studies
- Scopus and Web of Science for Interdisciplinary Studies
- Google Scholar for additional gray literature and reports

4.2.3. Search Strategy and Keywords

A combination of keywords and terms was used:

- "Healthcare supply chain risk"
- "Risk management in healthcare logistics"
- "Supply chain disruptions in healthcare"
- "Decision support systems in healthcare supply chains"
- "Technological innovations in healthcare SCM"

Boolean operators (AND, OR, NOT) were used for searching, and Boolean relationships were constructed using the mentioned terms.

4.2.4. Inclusion/Exclusion Criteria

Specific inclusion and exclusion criteria were established to help ensure the quality and relevance of research included in this review:

Inclusions:

- Peer-reviewed articles, conference papers, and industry reports
- Publications from within the last 10 years
- Research on HSC risk management

Exclusions

- Non-English sources
- Studies not directly related to healthcare or supply chain management
- Duplicates or non-peer-reviewed materials

4.2.5. Screening and Selection

The initial search results, after entering keywords into the literature review sourcing tool, were first filtered to remove irrelevant studies through a scan-through assessment using titles and abstracts. The manuscripts were then brought as full-text articles and subjected to further review.

4.2.6. Data Extraction and Synthesis

Data from the selected studies were extracted using a standardized form. Key information included:

- Study objectives and research questions
- Methodologies used
- Main findings and conclusions
- Identified risks and mitigation strategies

The extracted data were synthesized to present a snapshot reflecting existing knowledge with respect to HSCRM.

5. HSCRM: Developed & Developing Countries Status

The status of HSCRM significantly differs in developed countries as opposed to developing ones, depending on the country's prerequisites based on infrastructure, technology advancement, and regulatory frameworks.

5.1. Developed Countries

Healthcare supply chains in developed countries enjoy greater infrastructure, innovation, and technology. Effective risk management often involves systems robust enough to support these information flows, real-time data analytics, and sophisticated logistics networks. For example, some countries like the U.S. and Germany have enforced supply chain management systems that provide end-to-end visibility and traceability of product lifecycle across a consignment right from its origin to the delivery point; this results in making it easier to gear up smart manufacturing initiatives with IoT-enabled production lines, etc.

Key Characteristics:

1. Advanced Technology: Consistent uses of technologies like IoT, AI, Blockchain, etc., help enable real-time monitoring and control operations across the supply chain. [8-13].
2. Regulatory Frameworks: Strict regulations to maintain a high level of compliance and quality control. Such regulations enforce best practices in supply chain management, which would lead to more consistent continuity of operations and a greater availability of critical medical supplies. [14-16].
3. Strong Infrastructure: Developed countries typically have a well-established infrastructure that supports efficient logistics and distribution networks. This infrastructure involves sophisticated transportation systems, warehousing facilities, and communication networks. [17-19].

5.2. Developing Countries

In comparison, the challenges for developing countries when it comes to managing HSC risks are enormous. Higher susceptibility to supply chain interruptions is negatively affected due to limited resources, inadequate infrastructure, and less stringent regulatory environments. Nations like India and Nigeria have major issues with regard to mismanagement in the inventory system, inexpediency of real-time data processing, and logistical execution.

5.2.1. Key Challenges

1. Resource Constraints: Limited financial and technological resources hinder the implementation of advanced supply chain management systems. This leads to reliance on manual processes and outdated information systems [17, 20, 21].
2. Infrastructure Deficiencies: Inadequate infrastructure, such as poor transportation networks and insufficient warehousing facilities, exacerbates supply chain inefficiencies and delays [22-24].
3. Regulatory Gaps: Developing countries often have less stringent regulatory frameworks, resulting in lower compliance with international standards and best practices. This increases the risk of substandard products and supply chain disruptions [25-27].

5.3. Efforts and Initiatives

Despite these challenges, numerous actions are being taken to enhance the management of HSC risks in developing countries. For example, the WHO and a range of Non-Governmental Organizations (NGOs) are working across borders to improve supply chain confidence in developing countries through training initiatives, investments in existing programs, and the introduction of innovative technologies.

5.4. Comparative Analysis

The comparative analysis of HSCRM between developing and developed countries reflects a major disparity in two ends with respect to ability and results. On the one hand, advanced technologies and structural mitigations help them overcome risks with ease in developed countries. However, due to resource risk and lack of resources, developing economies still struggle, hindering infrastructural capabilities. However, the global emphasis on improving healthcare systems and the increasing availability of affordable technologies offer promising prospects for developing countries to enhance their supply chain risk management capabilities. Collaborative efforts, knowledge sharing, and investment in infrastructure are critical to bridging the gap between developed and developing countries in this crucial area.

6. Factors Responsible for Risk Assessment

In the risk assessment, factors affecting healthcare supply chains are to be analyzed. Types of these risks differ, each with its implications:

1. Supply Risks: These are those that have a bearing on the availability and quality of supplies. Key factors include:
- Counterfeiting: The production and distribution of substandard medicines that harm patients and disrupt the supply chain.
- Unavailability of Raw Material: Difficulties in obtaining raw materials due to supply chain disruptions or commercial reasons.
- Supplier Failure: Shortfalls on the side of your supplying partner.

2. Demand Risks: These risks relate to variations or inaccuracies in the demand for healthcare services and products. They include:
- Unexpected Increase in Demand: Sudden surges that outstrip supply, often due to new approvals or unforeseeable events.
- Wrong Demand Forecasting: Incorrect forecasted future requirements of materials to furnish products, resulting in understocking or overstocking.
- Fluctuation in Customer Demands: Variability in patient demand that can impact inventory and supply planning.

3. Process Risks: These are risks related to the procedures and operations within the supply chain. Key risks include:
- Lack of Visibility of Stock: Inability to monitor and track inventory levels effectively.
- Inadequate Buffer Stock: Not enough raw materials to handle variations in demand or supply chain disruptions.
- Transportation Issues: Suppose you are unable to embark upon the plane because of faults at best/over some other time, like running out of gas, airport bottlenecking, or late departures due to weather/logistics constraints.
- Human Error: The potential for errors in medication dispensing, packaging, or inventory control with implications on patient safety.

4. Control Risks: These risks are around managing and controlling the supply chain. They include:
- Contract Problems: Issues arising from poorly managed contracts, including disputes and compliance failures.
- Lack of Data Standardization: This is due to the data being stored in a variety of formats and codes across different systems and entities.

5. Environmental Risks: These risks derive from the outside landscape and can affect all parts of a supply chain. They include:
- Regulatory Issues: Changes in laws and standards that affect manufacturing and distribution.
- Geopolitical Factors: International political events that can disrupt the supply chain, such as trade restrictions or conflicts.
- Environmental Conditions: Natural disasters or any other environmental offenders that may affect supply chain operations.

6.1. Classification of HSC Risk Factors Identified by Researchers

L. Breen [28]

1. Supply Risks
- Counterfeiting: The risk of fake products infiltrating the supply chain.
- Competitive Tactics: Strategies to eliminate competitors from the market.
- Manufacturer Strategies: Defensive measures to maintain market share.
- Manufacturing Diversion: Shifting production priorities away from certain products.
- Raw Material Shortages: Both genuine and artificially induced unavailability of materials.
- Financial Instability: Cash flow issues affecting small pharmaceutical companies and hospitals.

2. Demand Risks
- Sudden Demand Surges: Unexpected increases in demand.
- Capacity Constraints: Balancing production capacity with fluctuating demand.
- Poor Forecasting: Inaccurate demand predictions from customers.
- Economic Limitations: Financial constraints hinder the ability to meet demand.
- Approval-Driven Demand: Increases in demand following approvals from bodies like NICE.
- Healthcare Provider-Driven Demand: Demand initiated by nurses rather than patients.

3. Process Risks
- Inventory Visibility: Challenges in tracking stock levels.
- Insufficient Buffer Stock: Inadequate safety stock due to lean practices.
- Transportation Challenges: Issues such as fuel shortages, congestion, weather, and illness affecting transport.
- Dispensing Errors: Mistakes in medication or packaging during dispensing.
- Storage Issues: Problems maintaining proper storage conditions, including cold chain requirements.
- Procurement Complexity: Added complexity from centralized procurement hubs.
- Information Flow Problems: Issues with the flow of demand information and data overload.
- Supply Chain Fragmentation: Disjointed operations within the supply chain.
- Short-Term Planning: Lack of long-term strategic planning in the supply chain.
- Prioritization Conflicts: Balancing patient needs with profit motives.

4. Control Risks
- Data Inconsistency: Lack of standardized data and coding practices.

- Supplier Contract Issues: Problems with supplier agreements.
- High-Risk Contracting: Large contracts pose significant risks.

5. Environmental Risks
- Environmental Compliance: There is a need to adhere to environmental protection regulations.
- Regulatory Challenges: Issues with manufacturing licenses, changes in standards, and drug recalls.
- Disaster Recovery: The impact of external disasters and recovery efforts.
- Legal Risks: The risk of litigation affecting market dynamics.

Kamath et al. [29]
1. Supply Risks:
- Counterfeit risk: Risk of fake drugs.
- Unavailability of supplier: Supplier shortages.

2. Demand Risks:
- Wrong demand forecasting: Incorrect demand predictions.

3. Process Risks:
- Insufficient inventory at CMS: Not enough stock at central storage.
- Delays by procurement staff: Slow purchasing processes.
- Poor inventory management by pharmacies: Inefficient stock handling.

4. Control Risks:
- Withholding of funds by donors: Donors stopping funds.
- Lack of funds at the hospital: Financial shortages.
- Rigorous government intervention: Strict regulations.
- Unexpected disease outbreaks: Sudden health crises.

5. Environmental Risks:
- Financial risk: Economic instability.
- Regulatory risk: Compliance challenges.

Kanyoma et al. [4]
1. Supply Risks:
- Unavailability of supplier: Supplier shortages.

2. Demand Risks:
- Wrong demand forecasting: Incorrect demand predictions.

3. Process Risks:
- Insufficient inventory at CMS: Not enough stock at central storage.
- Delays by procurement staff: Slow purchasing processes.
- Poor inventory management by pharmacies: Inefficient stock handling.

4. Control Risks:
- Withholding of funds by donors: Donors stopping funds.
- Lack of funds at the hospital: Financial shortages.
- Rigorous government intervention: Strict regulations.
- Unexpected disease outbreaks: Sudden health crises.

5. Environmental Risks:
- None were specifically mentioned.

Ilie & Popa [30]
1. Supply Risks:
- Domestic drug shortages: Shortages of local drugs.
- Location of manufacture/supplier: Dependence on foreign suppliers.

2. Demand Risks:
- Clinician's preference: Doctors' preferences affecting demand.
- Slow information transmission: Delays in information flow.

3. Process Risks:
- Regulation risks (EU): Compliance with EU regulations.

4. Control Risks and Environmental Risks:
- None were specifically mentioned.

Maryland [31]
1. Supply Risks:
- Grey-market activity: Involves unauthorized channels selling drugs outside regulated systems.
- Counterfeiting: Refers to the distribution of fake or substandard drugs.
- Diversion of drugs: Drugs being rerouted from their intended distribution channels.
- Drug shortages: Insufficient availability of necessary drugs within the supply chain.

2. Demand Risks:
- Fragmentation of the drug distribution processes: Involves inefficiencies caused by disconnected or poorly coordinated distribution networks.
- Restricted drug distribution systems: Occurs when drug distribution is limited to a few channels, causing supply bottlenecks.

3. Process Risks:
- Lack of incentive mechanisms: Absence of motivating factors for enhancing process efficiency.
4. Control Risks and Environmental Risks:
- No specific issues were highlighted.

Aguas et al. [32]

1. Supply Risks:
- Medicine availability in the market: Refers to the challenge of ensuring that sufficient quantities of drugs are available for consumers.

2. Demand Risks:
- Capacities of logistics systems: Pertains to the limitations within the logistics network that can hinder drug distribution.

3. Process Risks:
- Asymmetries of the information: Indicates disparities in access to crucial information among different stakeholders.

4. Control Risks and Environmental Risks:
- No specific risks were identified.

Elleuch et al. [33]

1. Supply Risks:
- Poor quality in purchased drugs from suppliers: Describes the risk of receiving subpar drugs from suppliers.
- Shortage of drugs (without substitutes): Refers to a lack of essential drugs, with no alternatives available.

2. Demand Risks:
- Fluctuation in customer demands: Involves unpredictable changes in the demand for drugs.

3. Process Risks:
- Lack of personnel: Points to a shortage of staff necessary to maintain operations.
- Human error: Mistakes made by staff during drug handling and distribution.

4. Control Risks:
- No specific risks were mentioned.

5. Environmental Risks:
- Time limit of drugs: Concerns the expiration dates of drugs, limiting their shelf life.

Enyinda et al. [34]

1. Supply Risks:
- Supplier failure: Occurs when suppliers are unable to meet their delivery commitments.
- Counterfeiting: Involves the presence of fake drugs within the supply chain.

2. Demand Risks:
- None were highlighted.

3. Process Risks:
- Transportation logistics: Refers to challenges in moving drugs efficiently across different locations.
- Electricity: Addresses issues related to inconsistent power supply affecting operations.
- Technology: Involves the difficulties associated with outdated or inadequate technological infrastructure.
- Strikes: Labor actions that disrupt the supply chain's normal functioning.
- Lack of key talents: Highlights a shortage of skilled professionals in critical areas.

4. Control Risks:
- Geopolitical issues: Refers to political instability that may affect the supply chain.
- Public opinion: The influence of public perception on supply chain decisions.
- Regulations and laws: Concerns the challenges of staying compliant with changing regulations.

5. Environmental Risks:
- No specific risks were mentioned.

Kim et al. [35]

1. Supply Risks:
- Unexpected changes in environmental conditions: Refers to sudden changes in the environment that could disrupt the supply chain.

2. Demand Risks and Process Risks:
- No specific risks were highlighted.

3. Control Risks and Environmental Risks:
- No specific risks were mentioned.

Zepeda et al. [36]

1. Supply Risks:
- Demand uncertainty for clinical requirements: Refers to the unpredictability of clinical needs that complicates supply planning.

2. Demand Risks:
- None were specified.

3. Process Risks:
- Weak logistics services infrastructure: Refers to inadequate logistics capabilities that hinder efficient drug distribution.

4. Control Risks and Environmental Risks:
- No specific risks were identified.

Lord Carter [37]

1. Supply Risks:
- High purchase price: Refers to the elevated cost of procuring drugs, which can strain resources.

2. Demand Risks:
- High product and supplier/brand variety: Refers to the complexity introduced by having a wide range of products and suppliers, complicating supply chain management.

3. Process Risks, Control Risks, and Environmental Risks:
- No specific risks were highlighted.

7. Exploring Research Techniques and Addressing Gaps in HSCRM

HSCRM is a critical area of study that has been explored through various research methodologies.

However, despite the significant contributions made, several research gaps remain that warrant further investigation.

7.1. Literature Review Methodologie

- Aarti Singh et al. [38] conducted a literature review that identified a gap in the optimization of risks within HSC, particularly in addressing shortages in healthcare staff, PPE, and critical supplies. The study emphasizes the importance of integrating lean practices with Industry 4.0 technologies for robust disaster planning.
- Abdulaziz Marzouq Almutairi et al. [39]: Utilized a review of the literature and multi-grade fuzzy logic to develop a conceptual model for measuring leanness in HSCs. The authors highlighted the need to validate their model across different industries and regions, particularly in developing countries.
- Alberto Regattieri et al. [40]: Focused on a literature review to assess risk management within healthcare supply chains, identifying the underutilization of AI and ML for risk evaluation. They recommend integrating these technologies to enhance supply chain management.
- Bhavana Mathur et al. [41] completed a review of the literature. They identified a gap in the research on the impact of supply chain practices on SCP and OP within the Indian healthcare industry.

7.2. Empirical Studies and Case Studies

- Anuj Dixit et al. [42]: Adopted a comprehensive methodology, including reviews and empirical data collection, to explore various aspects of supply chain management. The study found gaps in employee and customer training, tracking of medicines, and cold chain management.
- George A. Zsidisin et al. [43] Used case studies to examine risk management within purchasing and supply management, identifying a gap in understanding how risks are managed in these areas.
- Jia Yi Woong et al. [44] employed a case study approach to examine SCRM, particularly during crises, and identified a gap in the evaluation of recovery strategies.

7.3. Field Surveys and Mathematical Formulations

- Daniel Q. Chen et al. [45] Conducted a field survey to collect data from hospital supply chain executives, revealing a gap in the expansion of the nomological network to include additional factors that influence hospital-supplier integration.
- E. David Zepeda et al. [38] Used mathematical formulations to study supply chain risks, suggesting the need for more geographically diverse samples and the application of their ideas in industries beyond healthcare.

7.4. Systematic Literature Reviews and Conceptual Work

- Claire Muñoz Parry et al. [46] carried out a review that identified deep-rooted challenges in the healthcare sector, such as inadequate funding and weak regulation, which cannot be addressed by AI solutions alone.
- Bob Ritchie et al. [47] Combined conceptual and empirical work to explore risks in supply chains, identifying the need for further research on the identification, categorization, and evaluation of different risk sources.

7.5. Advanced Analytical Techniques

- George Baryannis et al. [48] used an AI-focused analysis of reviewed studies and identified a gap in the exploration of AI's potential in proactive and predictive SCRM.
- Hassan Younis et al. [49]: Conducted a systematic review to explore emerging technology such as AI, ML, big data, and blockchain, identifying a gap in understanding their impact on supply chain management.

7.6. Specific Methodologies like FMECA

- Hatem Elleuch et al. [35] employed Failure Mode, Effects, and Criticality Analysis (FMECA) to study pharmaceutical supply chain risks, noting a gap in understanding the interdependencies within the entire supply chain network.

7.7. Framework Development

- Karen Moons et al. [50] carried out a literature review that highlighted the absence of a broad framework for evaluating the accomplishments of internal logistics in hospitals, particularly regarding time and cost efficiency.

8. Suggested Research Gaps

8.1. Optimization of Risk Management

- Gap: Limited exploration of risk management optimization in HSCs, especially with the integration of lean practices and Industry 4.0 technologies.
- Future Research: Systematically integrate AI, ML, and IoT into healthcare supply chains to optimize risk management.

8.2. Validation of Leanness Models in Diverse Contexts

- Gap: Lack of validation of leanness models in diverse industries and geographic regions.

- Future Research: Empirical studies to validate leanness models across different contexts, particularly in developing countries.

8.3. Comprehensive Risk Evaluation and AI/ML Integration

- Gap: Underutilization of AI and ML for risk evaluation and management in HSCs.
- Future Research: Explore the integration of AI and ML for proactive risk management.

8.4. Employee and Customer Training in SCM

- Gap: Insufficient focus on training programs in supply chain management.
- Future Research: Study the impact of training programs on SCP, particularly in tracking medicines and cold chain management.

8.5. Systemic Challenges beyond Technological Solutions

- Gap: Inadequate research on addressing deep-rooted systemic challenges in healthcare.
- Future Research: Investigate holistic approaches that combine technology with regulatory and socio-economic strategies.

8.6. Expansion of Nomological Networks in Supply Chain Integration

- Gap: Limited exploration of factors influencing hospital-supplier integration.
- Future Research: Expand research to include additional factors like tacit knowledge transfer and supplier perspectives.

8.7. Exploration of Recovery Strategies and Crisis Preparedness

- Gap: Lack of research on the effectiveness of recovery strategies during crises.
- Future Research: Evaluate recovery strategies used during recent crises to enhance future preparedness.

8.8. General Framework for Measuring Internal Logistics Performance

- Gap: Absence of a general framework for measuring internal logistics performance in hospitals.
- Future Research: Develop a comprehensive framework to evaluate logistics performance, focusing on efficiency and patient service levels.

8.9. Geographic Diversity in Risk Management Studies

- Gap: Geographically limited studies on risk management.
- Future Research: Extend research to include a more geographically diverse sample of healthcare organizations.

8.10. Interdependencies in Pharmaceutical Supply Chains

- Gap: Focused research on downstream aspects of pharmaceutical supply chains, neglecting interdependencies across the network.
- Future Research: Investigate interdependencies within the full pharmaceutical supply chain to develop a more holistic risk management approach.

9. Conclusion

This comprehensive review underscores the complex and multifaceted nature of HSCRM. Various risk factors—such as supply chain interruptions due to counterfeiting, shortages, demand forecasting inaccuracies, process inefficiencies, regulatory challenges, and environmental compliance issues—pose substantial threats to healthcare systems' stability and effectiveness. While research has provided valuable insights into these risks, several critical gaps remain that hinder a fully optimized approach to managing these challenges. One significant gap is the limited application of advanced technologies such as AI and ML in HSC risk assessment. Although AI and ML have shown promising results in other sectors by enabling accurate predictions and proactive responses to disruptions, their integration within healthcare supply chains is still in the nascent stages. Future research should explore the potential of AI and ML to develop predictive models tailored to healthcare-specific risk factors, such as demand variability and regulatory compliance. This approach could revolutionize risk mitigation strategies by providing real-time insights and automated decision support.Another key area requiring further research is the validation and contextualization of existing leanness models and risk management strategies across diverse geographical and industrial settings. Current studies predominantly focus on developed countries, creating a gap in understanding how these models perform in developing regions with unique infrastructural and regulatory constraints. Comparative studies across multiple countries, particularly in underrepresented regions, are essential to identify adaptable models that consider local challenges. Research in this area could provide frameworks that are both scalable and context-sensitive, facilitating the practical application of risk management strategies worldwide. Additionally, this review identifies the need for a broader nomological network to capture the factors influencing hospital-supplier integration. Many studies have overlooked elements such as tacit knowledge transfer, long-term supplier partnerships, and the integration of supplier feedback. Future research should incorporate these dimensions to deepen the understanding of how these factors impact SCP, especially in settings where resource limitations require strong supplier collaboration. Such research could aid in developing frameworks that strengthen hospital-supplier relationships, ensuring a more resilient supply chain.

The development of a standardized framework for measuring internal logistics performance in hospitals is also crucial. Existing studies rarely consider patient service levels as an indicator of supply chain performance. A systematic framework that evaluates not only logistics efficiency but also patient-centered outcomes could provide a more holistic

approach to healthcare logistics management. Research in this direction could help establish Key Performance Indicators (KPIs) that capture both operational and service-level outcomes, leading to more targeted improvements. Finally, the review highlights the need for geographic diversity in HSCRM studies. Concentrating research efforts in specific regions limits the applicability of findings and neglects the unique challenges faced by healthcare systems globally.

Expanding the scope to include a broader range of geographic contexts would offer a more comprehensive understanding of global HSCRM practices. Studies that involve diverse healthcare settings could also provide insights into best practices adaptable to different regions, creating a more universally applicable knowledge base. In summary, addressing these research gaps is critical for advancing the resilience and efficiency of HSCs. Future studies should focus on integrating advanced technologies, validating models across diverse contexts, expanding the nomological network, and developing comprehensive logistics frameworks. By adopting these holistic approaches, the healthcare industry can improve its risk management capabilities and, ultimately, enhance patient outcomes globally.

Abbreviation

AI	:	Artificial Intelligence
ML	:	Machine Learning
HSC	:	Healthcare Supply Chain
DSS	:	Decision Support System
SCM	:	Supply Chain Management
SCRM	:	Supply Chain Risk Management
HSCRM	:	Health Supply Chain Risk Management
SCP	:	Supply Chain Performance
OP	:	Organizational Performance

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