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Determining the relationships and ranking of desirable risk control factors in the medical laboratory supply chain using an interpretive structural approach

Masoumeh Pashapour[1], Mehdi Zakipour[2], Reza Mohamadi[3], Amir Mohammadzadeh[4]

1- Department of Business Management, Qa.C., Islamic Azad University, Qazvin, Iran.
2- Department of Business Management, Qa.C., Islamic Azad University, Qazvin, Iran.
3- Department of Clinical Biochemistry, TeMS.C., Islamic Azad University, Tehran, Iran.
4- Department of Accounting and Financial Department, Qa.C., Islamic Azad University, Qazvin, Iran.

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Abstract

The aim of this study is to determine the relationships and hierarchical levels of optimal risk control factors in the medical laboratory supply chain using an Interpretive Structural Modeling (ISM) approach. In terms of implementation, this research adopts a mixed-methods design (qualitative–quantitative); and in terms of purpose, it is an exploratory study conducted through a descriptive–survey method. The statistical population of the study consisted of 15 senior managers and experts working in medical laboratories across the supply chain, selected by the snowball sampling method. Data were collected through semi-structured interviews. For data analysis, the Fuzzy Delphi method, Interpretive Structural Modeling (ISM), and MICMAC software were employed.

The results of the interpretive structural analysis using the exploratory model indicated that the proposed model consists of four main factors and thirteen sub-factors identified across four levels. The fourth level involves supply chain risk identification, including the dimensions of financial and legal risks, quality risks, and supplier and logistics risks. The third level includes failure mode and effects analysis, encompassing the identification of weaknesses, analysis of failure effects, and risk prioritization. The second level involves risk response and management strategies, including supplier diversification, emergency planning, and quality control supported by information technology. Finally, the factors and dimensions identified in the previous three levels lead, at the first level, to achieving optimal risk control, which includes risk and failure reduction, increased supply chain efficiency, continuous improvement, and performance monitoring.

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Corresponding Author: Mehdi Zakipour | **Email:** m.zakipour@iau.ac.ir

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Extended Abstract

Introduction

The extensive use of medical and laboratory technologies requires a significant number of resources for the procurement of equipment and materials; an issue that must be given considerable attention in these organizations. It is evident that if the procurement of equipment and materials is carried out without a precise and structured mechanism, the quality of purchases will not align with the actual needs of healthcare centers. Therefore, the procurement process in medical centers is of great importance and must be continuously monitored. Risk assessment is a systematic process for measuring quantitative and qualitative hazards associated with materials, processes, activities, personnel, equipment, and the environment (Rahmanifar, 2014).

Utilizing the findings of this research on the supplier side can lead to the development of structures that ensure timely procurement and provide an understanding of risks and potential failure points in the laboratory supply process. As a result, suppliers can devise various methods to meet laboratory needs. Considering that the researcher is also active in the laboratory supply sector, if the findings are validated, they can be presented to the laboratory community through multiple sessions, thus contributing to the dissemination and expansion of the research results. Given that multiple methods and individuals are involved in the procurement of laboratory necessities, this analytical approach can also be applied in this study, representing one of its innovative aspects.

Failure Mode and Effects Analysis (FMEA) is one of the most widely used tools for enhancing the reliability and safety of products or processes (Radpour & Karbasian, 2011). This tool is particularly used in the design and development of new products (Fattahi, 2009). Various techniques exist for risk identification, and no single method serves as the best approach; instead, an appropriate combination of techniques should be utilized. Moreover, evaluating risks solely based on their probability of occurrence and severity of impact is insufficient, as these two criteria do not fully capture all influential aspects of risk. FMEA is an analytical technique that combines technology and expertise to prevent the procurement of substandard products and protect the reputation of the organization (Radpour & Karbasian, 2011).

Therefore, aligned with this objective, the main research question of the present study is: *What are the relationships and hierarchical levels of optimal risk control factors in the medical laboratory supply chain using an Interpretive Structural Modeling approach?*

Theoretical Framework

Risk Management

Supply chain risk management focuses on controlling risks that affect the efficient flow of information, materials, and products across different segments of the supply chain. Risk management is a key component of supply chain management; and given the diverse objectives within supply chains, it can be utilized when risk is considered a multidimensional phenomenon. Factors such as uncertainty in supply and demand, market globalization, shorter technology and product life cycles, and the increasing use of outsourcing have been identified as major reasons for the importance of supply chain risk management (De Oliveira et al., 2024).

Wang et al. (2025), in their study on *Strategic Behavior in Multi-Criteria Sorting with a Trust-Relationship-Based Consensus Mechanism: Application to Supply Chain Risk Management*, examined strategic behavior using a cost-based consensus mechanism within a social trust network. First, a piecewise cost function dependent on trust relationships was

formally defined and formulated, taking into account the influence of trust on preference adjustments required to achieve consensus sorting. Based on this trust-dependent cost structure, a strategic preference manipulation model was proposed to enable strategic behavior in consensus sorting by minimizing the adjustment costs incurred by decision-makers. Considering that the social trust network affects strategic manipulation, an extended collaborative strategic manipulation model was introduced to guide decision-makers in adjusting both their preferences and their social trust networks. Furthermore, the practical applicability of the proposed strategic manipulation models was demonstrated through a supply chain risk management case study, and their performance was validated through simulation analysis.

Mobo et al. (2025) investigated *Supply Chain Risk Management in the Trade Sector: A Modern Perspective*. Their findings indicate that studying supply chain sustainability strategies is crucial, especially when the risks faced by commercial farms within the supply chain are increasingly complex, diverse, and sudden—making prediction and probability assessment more difficult than ever. This underscores the significance of supply chain management. It was found that in order to gain competitive advantages within the market, the trade sector must improve supply chain management practices, which leads to reduced costs from production to delivery, optimized timing, and enhanced customer satisfaction. Their study also concludes that an effective risk assessment mechanism in the supply chain for the trade sector must serve as an appropriate tool for evaluating the effectiveness of risk management from the perspective of all business segments involved in the supply chain.

Research Methodology

This study was conducted using a mixed-methods approach (qualitative–quantitative) and, in terms of purpose, followed an exploratory and descriptive–survey design. The statistical population consisted of 15 senior managers and experts working in medical laboratories across different stages of the supply chain, selected through the snowball sampling method. Data were collected by semi-structured interviews.

Research Findings

For data analysis, the Fuzzy Delphi method, Interpretive Structural Modeling (ISM), and MICMAC software were used. The results of the interpretive structural analysis using the exploratory model revealed that the model includes four main factors and thirteen sub-factors distributed across four hierarchical levels.

The fourth level involves supply chain risk identification, including financial and legal risks, quality risks, and supplier and logistics risks. The third level consists of failure mode and effects analysis, including identifying weaknesses, analyzing failure impacts, and prioritizing risks. The second level encompasses risk response and management strategies, including supplier diversification, emergency planning, and quality control supported by information technology.

Finally, the factors and dimensions identified in the previous three levels lead, at the first level, to achieving optimal risk control, characterized by risk and failure reduction, increased supply chain efficiency, continuous improvement, and performance monitoring.

Conclusion

The present study aimed to determine the relationships and hierarchical levels of optimal risk control factors in the medical laboratory supply chain using an Interpretive Structural Modeling approach. The results of this research are consistent with the findings of Wang et al.

(2025), Mobo et al. (2025), Shishehgarkhaneh et al. (2024), Choudhary et al. (2023), Ganesh & Kalpana (2022), Qaraghanabadi & Sarkardeh (2024), Arab Cham Khalifa & Alavi (2023), and Fokerdi & Talavari (2021). Mobo et al. (2025) demonstrated that an effective risk assessment mechanism in the supply chain for the commercial sector must serve as an appropriate tool for evaluating the effectiveness of risk management from the perspective of all business units involved in the supply chain. Based on the findings of the study, the following recommendations are proposed:
Organizations should prioritize reducing risks and preventing failures in order to achieve optimal risk control. Implementing preventive processes, continuously analyzing risks, and executing proactive programs can help reduce the likelihood of failure causes and, in turn, ensure the efficiency and continuity of the supply chain.

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Conflicts of Interest
The authors declare that they have no financial or non-financial, personal, professional, or institutional conflicts of interest relevant to this work.

Conflicts of Interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement
The data supporting the findings of this study are available from the corresponding author upon reasonable request.

AI Use Statement
The authors declare that no generative artificial intelligence (AI) or AI-assisted technologies were used in the preparation, writing, or editing of this manuscript.

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Ethics Approval
All procedures performed in this study were conducted in accordance with the ethical standards of the responsible institutional and national research committee.