An Integrated SCOR-MCDM Approach for Performance Evaluation in Pharmaceutical Distribution Network

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ARTICLE INFO	ABSTRACT
Article type: Research Article **Article History:** Received 09 February 2025 Revised 31 June 2025 Accepted 14 October 2025 Published Online 20 February 2026 **Keywords:** Pharmaceutical distribution network, SCOR model, MCDM, Performance evaluation.	The pharmaceutical supply chain plays a critical role in ensuring the timely and safe delivery of medicines to pharmacies, hospitals, and patients. However, the increasing complexity caused by diverse demand, stringent transportation and storage requirements, and the need for precise logistics pose significant challenges. This study aims to improve performance evaluation by providing an integrated SCOR-MCDM framework, combining the supply chain operations reference model (SCOR) with multi-criteria decision-making (MCDM) techniques. The novelty of this research lies in integrating the Decision Evaluation and Testing Laboratory (DEMATEL) method to identify causal relationships among performance criteria, with the Best-Worst Method (BWM) to prioritize them based on expert judgment in the pharmaceutical industry. The proposed approach provides a structured mechanism for evaluating the pharmaceutical distribution network, especially when real-time operational data is limited. The findings show that according to DEMATEL, "Supply stability," "Facility cost," and "Information systems cost," "Number of vehicles for distribution," "Delivery time," and "Flexibility in product volume" have the greatest impact on the efficiency of the pharmaceutical distribution network. In addition, the results of the BWM also show that "Delivery time" is the most important from the expert's point of view, which indicates that if decision makers want to improve the most important factor, namely "Delivery time," they need to pay special attention to the factors affecting this factor to create an overall improvement. These insights provide practical implications for improving the efficiency and responsiveness of pharmaceutical supply chains. In addition, by addressing global challenges in pharmaceutical distribution network, the proposed model is also relevant beyond the Iranian context and can be effective in decision making in similar healthcare systems around the world.

1. Introduction

The drug supply chain is one of the most complex infrastructures within the healthcare system, as it must ensure timely delivery of medicines under appropriate storage conditions, to the correct recipients at a reasonable cost, whether pharmacies, healthcare facilities, or directly to patient (Abu Zwaida et al., 2021). This complexity stems form various challenges, including fluctuating demand, strict storage and transportation requirements, and the critical nature of timely and error-free logistics. Even minor mistakes in supply operations can have severe consequences for public health (Goodarzian et al., 2021). An inefficient pharmaceutical distribution network may lead to inflated costs, reduced operational efficiency, longer waiting times, compromised drug safety, excessive inventory levels, patient dissatisfaction, and, in extreme cases, loss of life (Birhanu et al., 2022). Moreover, incorrect or delayed deliveries can damage the reputation of pharmaceutical companies and erode patients' trust in receiving safe and timely healthcare services (Rouhani-Tazangi et al., 2023).

Effectively addressing these issues calls for rapid responsiveness, operational flexibility, and robust logistics and transportation management. To support this, a comprehensive performance evaluation system is required , one that can accurately assess critical indicators and guide actionable improvements. In this study, we propose an integrated evaluation framework that combines the SCOR model with a MCDM approach. The SCOR model offers a systematic structure for identifying inefficiencies and applying best practices to enhance supply chain performance (Lima-Junior & Carpinetti, 2020). Its implementation in pharmaceutical supply chains is especially vital in developing countries, which often encounter both domestic and international barriers to ensuring equitable access to medicines. Regular performance assessment of pharmaceutical distribution networks is, therefore, crucial for strengthening the broader healthcare system. Accordingly, this study investigates the application of the SCOR model within the pharmaceutical sector of developing economies

Moreover, MCDM methods offer a systematic and transparent approach for analyzing complex problems involving numerous, and often conflicting, criteria. These methods break down problems into smaller, manageable components, establish the relationships among them, quantify each factor, and integrate the results to guide effective decision-making (Taherdoost & Madanchian, 2023). In this study, we apply MCDM techniques to identify and evaluate performance criteria within a pharmaceutical distribution network, an inherently complex system with interdependent elements. The DEMATEL method is employed to uncover cause-and-effect relationships among the criteria (Si et al., 2018). Following this, the BWM is used to determine the relative importance of each factor. BWM enhances judgment consistency and reduces the cognitive burden on experts by minimizing the number of pairwise comparisons required (Rezaei, 2015). By combining DEMATEL and BWM, this study establishes a coherent and efficient framework: DEMATEL elucidates the structural interdependencies among criteria, while BWM assigns accurate and stable weights to the most influential factors. Based on the designed framework, this study pursues four main research objectives (RO):

- **RO_1**: Identifying factors that affect the efficiency of pharmaceutical distribution networks. An effective performance evaluation system, grounded in the SCOR model, can assist organizations in implementing successful strategies, making informed decisions, and achieving continuous progress.
- **RO_2**: Understanding the cause-and-effect relationships between criteria, which provides deeper insights into the interconnections within different aspects of the pharmaceutical distribution network.
- **RO_3**: Weighting and prioritizing criteria to highlight the most important ones, allowing for focused efforts to enhance distribution network performance.
- **RO_4**: Offering practical solutions aimed at improving the performance of pharmaceutical distribution networks.

The format of the paper is as follows. Section 2 contains an overview of the literature and proposes a framework of criteria based on the SCOR model that can impact the performance of pharmaceutical distribution network. Section 3 outlines the integrated performance evaluation approach utilized in this study. Section 4 highlights the outcomes of interrelationships and the weighting of criteria. Finally, Section 5 presents conclusions and recommendations for enhancing the performance of pharmaceutical distribution network.

2. Literature Review

This section is organized into three main parts. The first part provides a brief review of the existing literature on performance evaluation within pharmaceutical supply chains. The second part outlines the theoretical underpinnings of the SCOR model and the MCDM methods referenced in previous studies. The third part highlights the research gaps that this study aims to address.

2.1. Performance Assessment

Performance evaluation has always been a key issue in management and organizational decision-making, playing an important role in guiding strategies, supporting informed decisions, and enhancing efficiency. In fact, an effective performance evaluation system is essential for implementing appropriate strategies, improving decision making, and achieving organizational development and excellence. Performance measurement is defined as a process used to assess the effectiveness of decisions and their related criteria. In recent years, the importance of such systems has increased, particularly in healthcare supply chains, and especially in the pharmaceutical distribution sector. For instance, George and Elrashid (2023) examined the impact of inventory management and demand forecasting on the performance of the pharmaceutical supply chain at the pharmacies. Using structural equation modeling (SEM), this study showed that efficient inventory management and accurate forecasting can help increase drug availability and reduce financial losses. The combined effects of supply chain management (SCM) and total quality management (TQM) on efficiency in operation were also investigated by Sharma and Modgil (2020). Their research, also employing SEM, demonstrated that integrating TQM practices with SCM strategies can have a strong positive impact on operational performance by creating synergies.

The impact of important achievement elements in supply chain quality management on the efficiency of the supply chain in the pharmaceutical industry was examined by Tayyab et al. (2020). Their study emphasized that employing quality management practices in distribution facilities could address challenges such as increasing drug demand, poor inventory control, and forecasting inaccuracies. Taking into account the opinions of different stakeholders, Dixit et al. (2020b) assessed the effectiveness and flexibility of the generic medication delivery system in India. Their research offered an assessment of the quality of the medication delivery system, assessing elements such as sourcing, ordering, procurement, logistics, warehousing, inventory management, and information systems, providing insightful information about the present situation of generic delivery of medicines. Mezouar et al. (2016) used the SCOR model and Business Process Modelling Notation (BPMN) to identify key performance factors in the pharmaceutical supply chain of hospitals. The results of this study emphasized that monitoring the flow of materials and information can improve productivity. The link between social responsibility, total quality management (TQM), and organizational efficiency, as determined by the balanced scorecard (BSC) in Iranian pharmaceutical businesses, was examined by Mehralian et al. (2016). Their findings, based on SEM, suggested that incorporating social responsibility into operational processes strengthens stakeholder relationships and ultimately boosts organizational performance. In a study conducted in Jordanian private hospitals, Al-Saa'da et al. (2013) examined the quality of health services, focusing on the role of supply chain management in improving it. In addition, Stankevičienė and Sviderskė (2010) employed the balanced scorecard (BSC) and AHP methods to provide a framework for implementing value-based management (VBM) in a pharmaceutical company. The results showed that the company's ability to monitor the progress of strategies in real time improves overall performance and creates long-term value. Overall, these studies show that evaluating efficiency in the pharmaceutical supply chain is of great importance and various methods, such as SEM, BSC, AHP, and SCOR have been used to overcome challenges and improve operational performance.

2.2. SCOR Model and MCDM Methods

In contemporary supply chain management, particularly within the pharmaceutical and healthcare sectors, performance evaluation systems increasingly rely on multi-criteria and multi-level decision-making methods to improve operational efficiency. A number of studies have applied such approaches to assess the performance and effectiveness of pharmaceutical supply chains. For instance, Kumar et al. (2024) have combined Fuzzy-DEMATEL and BWM methods to identify key factors in the sustainability

of vaccine supply chains in developing countries. Aytekin et al. (2023) assessed logistics service providers (distribution companies) by developing a comprehensive evaluation model. Fuzzy entropy and the WASPAS methodologies were used to rank the distribution firms and assess the significance of the 10 criteria to assess these businesses. Kumar and Das (2023) introduced a performance evaluation framework for the public health sector in India, focusing on the timely delivery of essential medicines. In their study, performance criteria were evaluated using the AHP method, and distribution companies were evaluated based on cost and service quality, with expert input drived from the companies themselves. Ziaee et al. (2023) tackled issues related to drug shortages and inventory optimization by using big data analysis (BDA) within the drug supply chain. They applied the SCOR model to assess the benefits of BDA adoption and showed that it positively impacts the general efficiency of the pharmaceutical supply chain. In critical situations, such as the COVID-19 pandemic, the performance of hospital emergency departments has been evaluated using fuzzy data-based hybrid MCDM approach and areas for improvement have been identified by Ortíz-Barrios et al. (2023). Khan et al. (2023) presented a hybrid MCDM approach with the aim of evaluating the key factors affecting the pharmaceutical supply chain performance. Thus, after identifying the indicators, using a combination of the two DEMATEL and ANP methods, the cause-and-effect relationships between these factors and their importance on the entire supply chain performance were analyzed. In another study, Dolatabad et al. (2022) used a combination of Fuzzy Cognitive Mapping (FCM) and Fuzzy-DEMATEL to identify key performance indicators (KPIs) in the circular hospital supply chain. The results indicated that the availability of inventory, information, and technology are among the most important performance indicators. In a study, using a combination of Fuzzy-AHP and Fuzzy-DEMATEL methods, Hossain and Thakur (2021) identified and prioritized key factors affecting performance in implementing Industry 4.0 in the healthcare supply chain. Using a combination of Delphi-based Fuzzy DEMATEL and System Dynamics (SD) methods, Karmaker and Ahmed (2020) modeled performance indicators in a resilient pharmaceutical supply chain. The results identified 12 KPIs for pharmaceutical supply chain resilience. Divsalar et al. (2020) used the SCOR model to evaluate performance in the medical equipment and pharmaceutical industries. Their study, which incorporated frameworks such as agility, flexibility, lean, and green employed the ANP, DEMATEL, and VIKOR methods for performance evaluation. To assess the general efficacy of companies in the pharmaceutical supply chain, Sahu and Sahu (2019) created a decision support system. Their research considered factors such as green, flexible, agile, lean, and resilient strategies, calculating overall performance based on 22 criteria using a fuzzy model. In a study by Supeekit et al. (2016), the healthcare supply chain's performance was evaluated based on the interdependence of functional aspects and their impact on process efficiency and patient safety. They employed a combined DEMATEL-ANP method for their analysis. Similarly, Achuora et al. (2013) investigated the factors affecting pharmaceutical product distribution performance in Kenya. Using descriptive statistics and correlation analysis, the study identified the importance of information technology, government communication, and transportation outsourcing for optimizing pharmaceutical distribution systems. Ghatari et al. (2013) studied the essential variables for choosing agile suppliers in the pharmaceutical business, utilizing the SCOR model. They applied the TOPSIS method to prioritize these factors, revealing the speed of delivery, order planning, re-distribution, and trust development as keys for fostering agility in the supply chain. Agami et al. (2012) utilized a fuzzy-based method to manage supply chain performance in the healthcare sector. By applying Fuzzy AHP, they prioritized the performance dimensions of healthcare services and concluded that customer needs and competitor actions are crucial in adopting a lean supply chain management strategy. In Table 1, a summary of the most important relevant studies is presented, briefly outlining their methods/approaches and research areas.

2.3. Research Gaps
This study distinguishes itself from previous research in several important ways. While numerous healthcare studies have used quantitative and qualitative methods, the direct focus on the performance of pharmaceutical distribution network, which plays a key role in the timely delivery of drugs and maintaining the quality of drugs to patients, has remained very limited. However, most previous studies have examined in detail the various dimensions of the supply chain, while the analysis of the cause-and-effect relationships between key factors remains limited. Moreover, in developing

Table 1. Summary of Literature

Raw	Author (s)	Methodology/Approach	Research area
1	Kumar et al. (2024)	Fuzzy-DEMATEL, BWM	Investigating factors affecting the sustainable performance of the vaccine supply chain in low-income countries
2	Aytekin et al. (2023)	Fuzzy Entropy, WASPAS	Ranking of pharmaceutical distribution companies
3	Kumar & Das (2023)	AHP	Evaluating the performance of distribution companies in delivering essential medicines
4	Ziaee et al. (2023)	SCOR, Big Data	Using big data analytics to improve pharmaceutical supply chain efficiency
5	Ortíz-Barrios et al. (2023)	Intuitive Fuzzy-AHP, Intuitive Fuzzy-DEMATEL	Evaluating the performance of hospital emergency departments during the Covid-19 crisis
6	George & Elrashid (2023)	SEM	Analyzing the role of inventory control and demand forecasting on pharmacy performance
7	Khan et al. (2023)	DEMATEL, ANP	Identifying key performance factors and analyzing causal relationships in the pharmaceutical supply chain
8	Dolatabad et al. (2022)	FCM, Fuzzy-DEMATEL	Analysis of performance indicators in the hospital circular supply chain
9	Hossain & Thakur (2021)	Fuzzy-AHP, DEMATEL	Prioritizing performance factors in implementing Industry 4.0 in the health chain
10	Karmaker & Ahmed (2020)	Delphi, DEMATEL, SD	Modeling resilience indicators in the pharmaceutical supply chain
11	Divsalar et al. (2020)	SCOR, ANP, DEMATEL, VIKOR	Evaluating the performance of the medical equipment and pharmaceutical supply chain
12	Sharma & Modgil (2020)	SEM	Investigating the combined effects of TQM and SCM on improving operational efficiency
13	Tayyab et al. (2020)	Qualitative method	Investigating the impact of quality management in pharmaceutical distribution centers and reducing challenges
14	Dixit et al. (2020b)	Qualitative method	Evaluating the quality and flexibility of the generic drug delivery system
15	Sahu & Sahu (2019)	Fuzzy Performance Index	Analyzing the macro performance of pharmaceutical supply chain companies
16	Supeekit et al. (2016)	DEMATEL, ANP	Investigating the functional relationship between health chain components with a focus on patient safety
17	Mezouar et al. (2016)	SCOR, BPMN	Designing key performance indicators for hospital pharmaceutical supply chains
18	Mehralian et al. (2016)	SEM, BSC	Investigating the impact of social responsibility and TQM on the performance of Iranian pharmaceutical companies
19	Achuora et al. (2013)	Descriptive statistics-Correlative	Pharmaceutical distribution performance analysis
20	Ghatari et al. (2013)	SCOR-TOPSIS	Identifying factors affecting the selection of agile suppliers in the pharmaceutical industry
21	Al-Saa'da et al. (2013)	Hypotheses testing	The role of SCM in improving the quality of hospital services in Jordan
22	Agami et al. (2012)	Fuzzy-AHP	Prioritizing functional dimensions of health services
23	Stankevičienė & Sviderskė (2010)	BSC, AHP	Creating a Value-Based Management (VBM) framework in a pharmaceutical company

countries, such as Iran, which face economic challenges, restrictions on drug supply, sanctions, and logistical challenges, the pharmaceutical distribution network, as an intermediary link between the manufacturer and the final consumer, faces significant concerns in effectively and efficiently meeting customer demand. In order to improve the assessment of efficiency, the present study attempts to address these issues by integrating quantitative and qualitative methods. In fact, by integrating and utilizing the SCOR-DEMATEL-BWM hybrid approach, this research improves computational efficiency and supports better decision-making practices. By analyzing the interactions between

factors and calculating their relative importance, this study provides practical solutions for industry stakeholders and helps them better meet the pharmaceutical needs of society.

Based on the literature review, a set of criteria for evaluating the pharmaceutical distribution network was identified. These criteria were classified using the SCOR model. Thanks to its standardized and process-oriented framework, the SCOR model strengthens the link between performance indicators and organizational strategies, enabling the identification and correction of weaknesses across the entire supply chain. The SCOR model places all important criteria in performance evaluation into five main categories: "Reliability," "Responsiveness," "Flexibility," "Costs," and "Asset management" (Nguyen, 2024). Therefore, the identified criteria, based on the SCOR model, were divided to these five main categories. The indicators along with their definitions are presented in Table 2.

Table 2. Identified Criteria Based on SCOR Model

Dimension	Criteria	Definition	References
Reliability	Return ability	Refers to the capability return of unsold, expired, or recalled drugs to maintain safety and reduce waste.	(Kumar & Das, 2023; Prabhuram et al., 2020)
	Supply stability	It ensures that medications are continuously available to meet demand without interruption.	(Lee et al., 2018)
	Delivery performance	Ensures that medications reach pharmacies, hospitals, and patients without delay or damage.	(El Mokrini et al., 2018; Kumar & Das, 2023; Leblebicioğlu & Keskin, 2021; Prabhuram et al., 2020; Sahu & Sahu, 2019)
	Drug availability	It represents product accessibility and implies the possibility that the product is accessible to meet the requirements of the entire order.	(Dixit et al., 2020a; El Mokrini et al., 2018; Hosseini et al., 2017; Kumar & Das, 2023; Prabhuram et al., 2020)
	Order visibility	Refers to the ability to track and monitor the status of drug orders throughout the supply chain in real time.	(Kumar & Das, 2023; Leblebicioğlu & Keskin, 2021; Prabhuram et al., 2020)
	Smart supply	Refers to the use of advanced technologies and data analytics to optimize the drug supply chain.	(Lee et al., 2018)
Costs	Inventory cost	Inventory cost includes all costs associated with maintaining, storing, and managing inventory in the pharmaceutical supply chain.	(El Mokrini et al., 2018; Kumar & Das, 2023; Prabhuram et al., 2020)
	Transportation cost	Transportation costs include all costs associated with moving medicines from suppliers to distribution centers and from there to pharmacies or healthcare facilities.	(El Mokrini et al., 2018; Hosseini et al., 2017; Kumar & Das, 2023; Prabhuram et al., 2020)
	Facilities costs	This include costs associated with setting up, maintaining, and operating the physical infrastructure required for pharmaceutical distribution.	(El Mokrini et al., 2018; Kumar & Das, 2023; Prabhuram et al., 2020)
	Information systems cost	This criterion includes costs for inventory management software, order tracking and control systems, communication infrastructure, cybersecurity, and employee training to use these technologies.	(El Mokrini et al., 2018; Kumar & Das, 2023; Prabhuram et al., 2020)
Asset management	Number of refrigerated vehicles	It measures the capacity of pharmaceutical distribution companies to transport temperature-sensitive drugs, such as vaccines and biologics, under controlled conditions.	(Aytekin et al., 2023)
	Number of Warehouses	It refers to the number of warehouses operated by the firms.	(Aytekin et al., 2023)
	Number of vehicles for distribution	It alludes to the quantity of vans and trucks used in distribution activities.	(Aytekin et al., 2023)
Responsiveness	Delivery time	This criterion measures the time it takes to ship a drug from a warehouse or distribution center to its final destination.	(Dixit et al., 2020a; Feibert et al., 2016; Hosseini et al., 2017; Leblebicioğlu & Keskin, 2021; Sahu & Sahu, 2019)
	Reaction to demand change in Time	It demonstrates the ability of pharmaceutical distribution companies to quickly adjust inventory, transportation, and supply processes based on fluctuations in demand.	(Leblebicioğlu & Keskin, 2021; Sahu & Sahu, 2019)
Flexibility	Flexibility in volume of product	It indicates the ability of pharmaceutical distribution companies to adjust supply levels based on changes in demand, production capacity, and supply chain constraints.	(Sahu & Sahu, 2019)
	Product variety	It indicates the breadth and the number drugs types that a pharmaceutical distribution company offers. This indicator determines the extent to which the various needs of patients and healthcare centers are covered.	(Aytekin et al., 2023; Prabhuram et al., 2020)

3. Methodology

This study is grounded in a comprehensive literature review and the application of MCDM techniques. The SCOR model is especially valuable for organizations seeking to enhance their performance, as it provides a structured framework to identify inefficiencies. By evaluating operational performance from multiple perspectives, the SCOR model enables organizations to objectively pinpoint their weaknesses (Lima-Junior & Carpinetti, 2020). DEMATEL effectively addresses complex problems by clarifying interdependencies among factors and mapping their internal relationships. This method is particularly useful for assessing both direct and indirect connections and assists decision-makers through the use of an influence-relation map (IRM). While DEMATEL can assess the weight of evaluation criteria, it bases these weights solely on collective interconnections without considering other criteria (Khan et al., 2023). Therefore, integrating DEMATEL with complementary MCDM approaches can improve decision-making outcomes. In this study, DEMATEL is combined with the BWM to enhance the robustness of the analysis. Compared to other MCDM methods, BWM offers more reliable pairwise comparisons and reduces bias during the weighting process (Kheybari et al., 2019). Accordingly, this research employs a hybrid approach integrating the SCOR model, DEMATEL, and BWM to evaluate the performance of pharmaceutical distribution networks. The overall research process is illustrated in Figure 1.
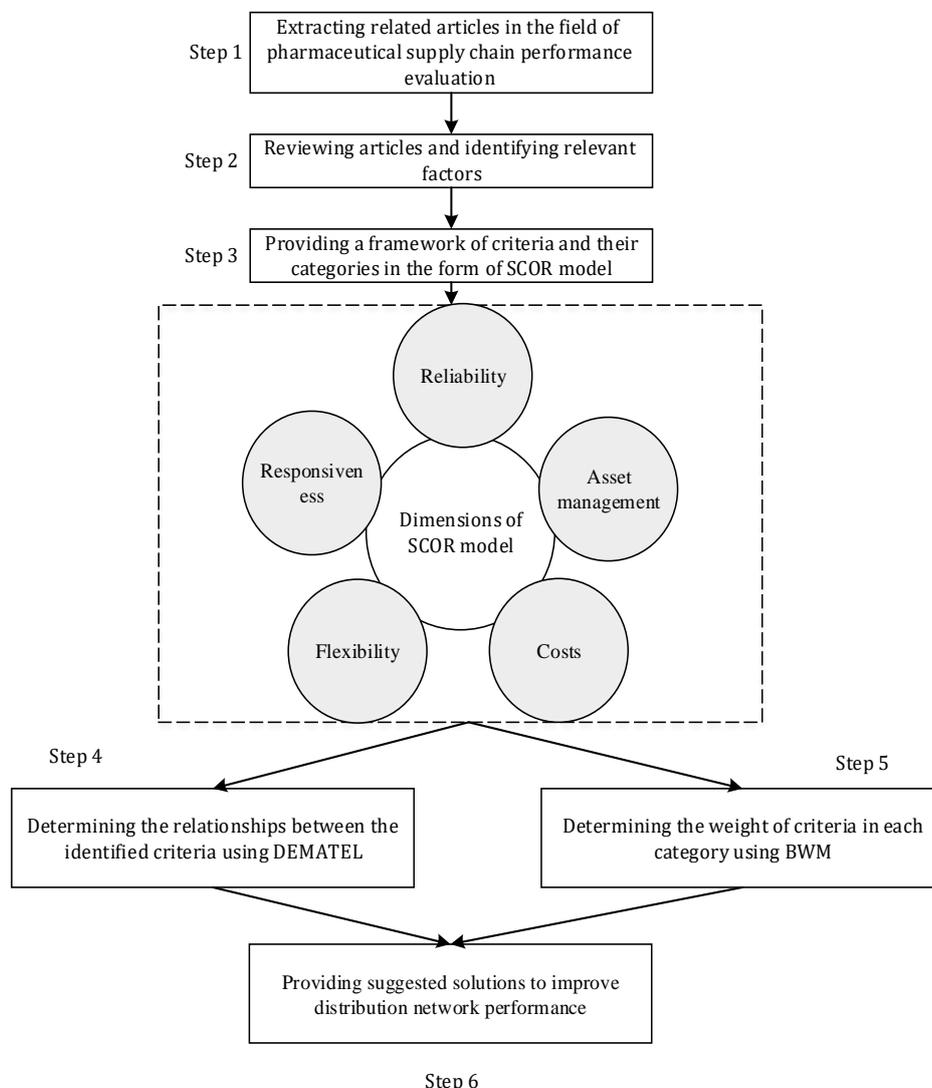

Fig.1. Research Steps

In this study, the DEMATEL and BWM methods were applied sequentially and in an analytically complementary manner to evaluate distribution performance. Initially, DEMATEL was used to identify and map the causal relationships among the relevant criteria, facilitating a better understanding of how various factors interact and influence one another within the system. Subsequently, BWM was independently conducted to determine the relative importance of these criteria based on expert judgments. Although the methods were implemented separately, integrating DEMATEL's structural insights into the interpretation of BWM results provides a more informed and system-aware decision-making framework. This approach enhances the robustness of the evaluation process and supports strategic planning in complex supply chain environments. While DEMATEL and BWM were applied independently at different stages, the DEMATEL findings later enriched the interpretation of BWM outcomes without affecting the weighting process itself.

3.1. SCOR Model

The SCOR model, established by the Supply Chain Council (SCC), presents operational performance measures aimed at enhancing the efficiency of supply chains (Huan et al., 2004). It offers practical guidelines for managing and analyzing various supply chain activities and processes. The SCOR model examines customer contacts, physical transactions, and market linkages to assess managing the supply chain from an operational perspective (H. Zhou et al., 2011). By implementing the SCOR model, companies can achieve benefits such as reduced cycle times, lower inventory levels, enhanced supply chain visibility, and real-time access to critical customer data. The performance attributes of SCOR metrics are outlined in Table 3.

Table 3. Performance Attributes of SCOR Model (Nguyen, 2024)

SCOR dimensions	Definition
Reliability	The ability of the supply chain to perform activities in a consistent and predictable manner, particularly by delivering orders on time and ensuring the correct quality and quantity.
Responsiveness	The speed with which the supply chain can respond to customer requests, including the time required to fulfill orders and deliver products.
Flexibility	The capacity of the supply chain to adapt rapidly and effectively to market changes or external disruptions, such as demand fluctuations or supply disruptions.
Costs	The total costs involved in operating supply chain processes, including the expenses related to materials, transportation, and management.
Asset management	The ability of the supply chain to support demand by optimally using assets, including minimizing inventory levels and optimizing capacity usage.

3.2. Decision-Making Trial and Evaluation Laboratory (DEMATEL)

The DEMATEL was developed to visualize complex connections through diagrams. This technique transforms dependencies into cause-and-effect groups utilizing matrices. It also connects key components within a complex system through the use of diagrams. Therefore, DEMATEL is an effective instrument for long-term strategic decision-making. The following actions are involved in the application of DEMATEL (Tsai & Shyr, 2022):

Step 1: Identify Important Factors and Design Measurement Scales

Factors that impact the effectiveness of pharmaceutical distribution network are first extracted from the literature and the SCOR model. To calculate the direct relationship matrix, the experts evaluate the implicit impact of each factor on others, using a scale from 0 to 4.

Step 2: Create Direct Relationship Matrix

In the direct relation matrix, x_{ij} represents the influence of factor i on factor j. The diagonal elements of the matrix are set to zero, indicating that each factor does not influence itself. After the experts complete the questionnaire, the direct relation matrix is constructed on their assessments.

$$X = \begin{bmatrix} 0 & x_{12} & ... & x_{1n} \\ x_{21} & 0 & ... & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & ... & 0 \end{bmatrix} \tag{1}$$

Step 3: Produce Normalized Direct Relation Matrix

The largest row sum of the direct relation matrix is used as the basis for normalization. By multiplying the direct relation matrix X via a normalization coefficient λ (defined in Equation 2), the final normalized direct relation matrix N is obtained.

$$\lambda = \frac{1}{Max\left(\sum_{j=1}^{n} x_{ij}\right)_{1 \le i \le n}} \tag{2}$$

$$N = \lambda X$$

Step 4: Produce Total (Direct/Indirect) Relation Matrix

The following formula, in which *I* is an $N \times N$ identity matrix, is used to obtain the total impact matrix T after the calculation of the normalized relation matrix. The element t_{ij} represents the impact of factor *i* on component j. This matrix illustrates the overall influence that one element may have on another through both direct and indirect paths.

$$T = \lim_{k \to \infty} \left(N + N^2 + ... + N^k\right) = N\left(I - N\right)^{\wedge} -1 \tag{3}$$

Step 5: Calculating D_i and R_j Values and the Degree of Factor Influence

After obtaining the total relation matrix T, it becomes necessary to calculate how each factor influences and is influenced by others. The element t_{ij} in matrix T represents the impact of factor i on factor j, where i, j = 1, 2 …, n. D_i is calculated as the sum of row i, representing the total influence that factor i exerts on all other factors. R_j, calculated as the sum of column j, represents the total influence that j received from all other factors. Both D_i and R_j are derived from total relation matrix T, and they reflect both direct and indirect effects (J. Zhou et al., 2016).

$$D_i = \sum_{j=1}^{n} t_{ij} \left(i = 1, 2, ..., n\right) \tag{4}$$

$$R_j = \sum_{i=1}^{n} t_{ij} \left(j = 1, 2, ..., n\right) \tag{5}$$

Step 6: Calculating the Prominence (D+R) and Relation (D−R)

The prominence value, defined as (D+R), reflects the overall level of influence and interconnection of each factor within the system. It represents how significant and central a factor is by considering both the influence it exerts and the influence it receives. In contrast, the relation value, calculated as (D-R) indicates the degree of causality. It shows the extent to which a factor is a cause (driver) or an effect (receiver) within the system. A positive D-R value indicates that the criterion influences others more than it is influenced by them, classifying it as a causal factor. Conversely, a negative D-R value means the criterion is mainly influenced by others, and is therefore considered an effect factor. In general, the sign of D-R helps decision makers distinguish between the driving indicators of the system and those that are the outcomes (Su et al., 2016).

Step 7: Drawing the Cause-and-Effect Relationship Diagram

The intersection of the X and Y axes divides the diagram into four quadrants. The cause-and-effect diagram helps simplify complex interrelationships among variables and illustrates how each factor influences others. The horizontal axis (X) is the prominence (D+R), while the vertical axis (Y) is the relation (D−R). A higher (D+R) value indicates greater overall importance and the centrality of the

factor within the network. Factors located to the right of the vertical axis have higher prominence, indicating greater significance and priority. Each quadrant in the diagram represents a different role or implication for the factors based on their causality and centrality (Tsai & Shyr, 2022).

The first quadrant is referred to as the key component area. In this quadrant, factors exert a stronger influence on other factors than they are influenced by them, indicating a high level of interconnectedness. These factors are of the highest priority, as they serve as the primary influencers in the system. The second quadrant is known as the driving component area. Although the influence of these factors is weaker than those in the key component area, they still have a positive net effect (D-R>0); that is, they influence other factors more than they are influenced. These factors are relatively more independent and have a lower overall impact than those in the first quadrant. As a result, they are considered to hold the second-highest priority.

3.3. Best-Worst Method (BWM)

Best-Worst Method (BWM), vector-based weighting technique initially developed by Rezaei (2016), has been effectively applied in various research domains, such as manufacturing, energy, and supply chain sustainability. The BWM weighting procedure can be summed up in the following five steps (Rezaei, 2016).

Step 1: Identify a set of decision criteria. $C = \{c_1, c_2, ..., c_n\}$

Step 2: Determine the best (B) and the worst (W) criteria.

In this step, a panel of experts is asked to identify the most (best) and least (worst) important criteria, drawing on their domain knowledge and practical experience. The best criterion refers to the factor that, in the experts' view, plays the most critical role in achieving the study's objective (namely, improving pharmaceutical distribution performance). Conversely, the worst criterion was defined as the one perceived to have the least influence on that objective.

Step 3: In this step, the decision maker specifies a number between 1 and 9, where 1 indicates equal importance and 9 indicates extreme preference, to compare the best criterion to all others. These comparisons extends from the best-to-worst vector:

$$A_B = \left(a_{B1}, a_{B2}, ..., a_{Bj}, ..., a_{Bn} \right)$$

where a_{Bj} indicates the preference of the best criterion *B* over criterion j.

Step 4: Similarly, the decision maker compares all criteria to the worst one, using the same 1-9 scale. These comparisons are from others-to-worst vector:

$$A_W = \left(a_{1W}, a_{2W}, ..., a_{jW}, ..., a_{nW} \right)$$

where a_{jW} represents the preference of criterion *j* over the worst criterion *W*.

Step 5: Compute the optimal weights $\left(w_1^*, w_2^*, ..., w_n^* \right)$

Finaly, the optimal weights $\left(w_1^*, w_2^*, ..., w_n^* \right)$ are computed by solving an optimization problem (Equation 6). The goal is to minimize the maximum absolute difference between the derived weights and the pairwise comparisons, particularly the differences $\left\{ \left| w_B - a_{Bj} w_j \right| \, and \left| w_j - a_{jw} w_w \right| \right\}$ for all criteria (*j*).

$$\min_j \max \left\{ \left| w_B - a_{Bj} w_j \right|, \left| w_j - a_{jw} w_w \right| \right\}$$

St.

$$\sum_{j=1}^{n} w_j = 1$$

$$w_j \geq 0 \quad \text{for all } j$$

(6)

Model (6) is converted into:

min ξ

such that

$$\left| w_B - a_{Bj} w_j \right| \le \xi, \text{ for all } j$$

$$\left| w_j - a_{jw} w_w \right| \le \xi, \text{ for all } j$$

$$\sum_{j=1}^{n} w_j = 1$$

$$w_j \ge 0, \text{ for all } j$$

(7)

when the BWM optimization model (Model 7) is solved, it yields the consistency rate (ξ^*) and optimal weights of the criteria, denoted by $W^* = (w_1^*, w_2^*, \ldots, w_n^*)$. If ξ^* is close to zero, it indicates that expert judgments are highly consistent.

In a multi-level hierarchical structure, the local weights of each criterion within a branch are multiplied down the tree to compute the global weights of the sub-criteria at the final level. This process aggregates the contributions of each level, providing a comprehensive measure for the overall importance of each.

4. Results and Discussion

This study aimed to identify and evaluate the key performance dimensions and criteria relevant to the pharmaceutical distribution network. To this end, the SCOR model was first employed to extract the critical factors influencing network efficiency. Subsequently, two analytical methods, DEMATEL and BWM, were applied to examine the interrelationships among these factors and assess their relative significance. DEMATEL was instrumental in uncovering the cause-and-effect relationships between criteria, while BWM enabled the precise prioritization and the weighting of each factor. The following sections present and interpret the results of these analyses, with the goal of proposing practical strategies to improve the performance of the pharmaceutical distribution network.

4.1. Results from the DEMATEL Technique

In order to implement the DEMATEL method, we first identified the factors influencing the efficiency of the pharmaceutical distribution network using the SCOR model as the framework (Figure 2). According to this model, five main dimensions contribute to the overall performance of the distribution network, with specific evaluation criteria assigned to each dimension.
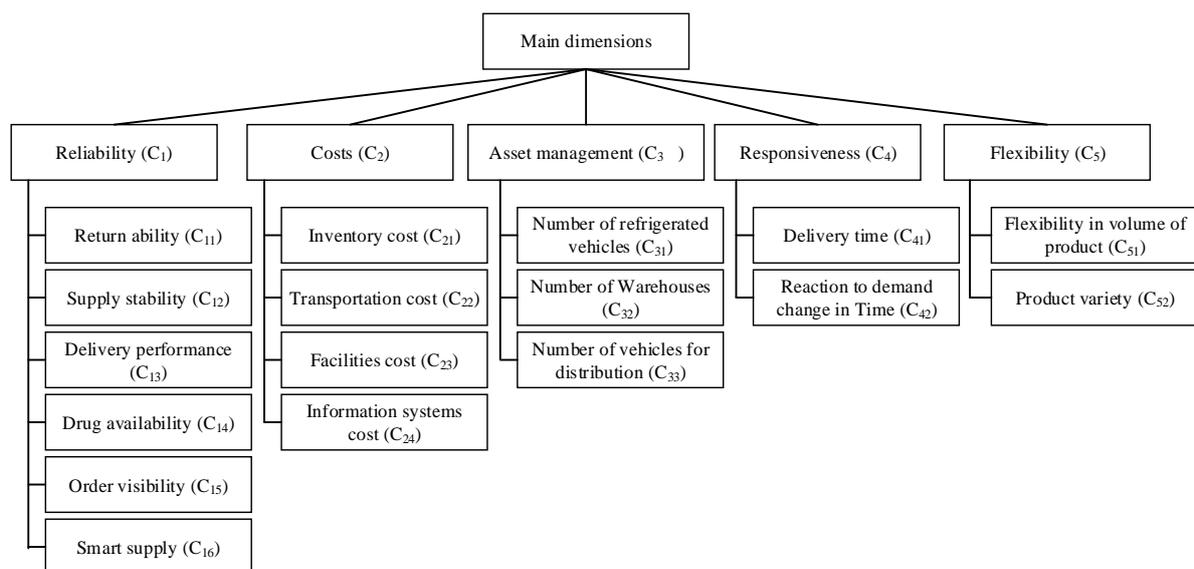

Fig. 2. Hierarchical Diagram of Main Dimensions and Criteria According to the SCOR Model

The performance of pharmaceutical distribution network was evaluated based on the opinions of 25 experts, including physicians, the representatives of pharmaceutical distribution companies, and pharmacy staff, all of whom had an average of more than 14 years of professional experience. The detailed characteristics of these experts are presented in Table 4.

Table 4. The Specifications of the Experts

Expert	Number of experts	Experience (year)	PhD's degree	Master's degree	Bachelor's degree
Doctors	7	14.50	100%	-	-
Distribution representative in pharmacy	10	14	-	76%	24%
Distribution representative in distribution companies	8	15	-	74%	26%

To examine the relationships between factors affecting the performance of the pharmaceutical distribution network, pairwise comparisons were made between the criteria and experts' opinions on the relationships between them. Based on these comparisons, an aggregation matrix of experts' views was developed and normalized. Finally, using the sum of the direct and indirect relationship matrices, the total relation matrix was calculated and the D+R and D–R values were extracted. It should be noted that all calculations related to the DEMATEL method were performed using MATLAB software. According to Figure 3, among the main dimensions of the SCOR model, the "Cost" has the greatest impact. This dimension affects all parts of the supply chain (Anderson & Dekker, 2009), and its effective control in the pharmaceutical industry helps to smooth the distribution process (Ntais et al., 2024), reduce delays, and ensure timely delivery of drugs. This issue is especially critical, given the specific conditions of the Iranian pharmaceutical industry, including sanctions and economic problems (Cheraghali, 2013). Optimal cost management and more efficient use of resources can provide more sustainable access to vital medicines and contribute to improving healthcare services and meeting patients' needs. This figure also highlights the key role of "Asset management," as weaknesses in this area may lead to logistical problems. Therefore, proper organization of assets in the pharmaceutical distribution network is of particular importance in ensuring the timely delivery of medicines and preventing operational disruptions.
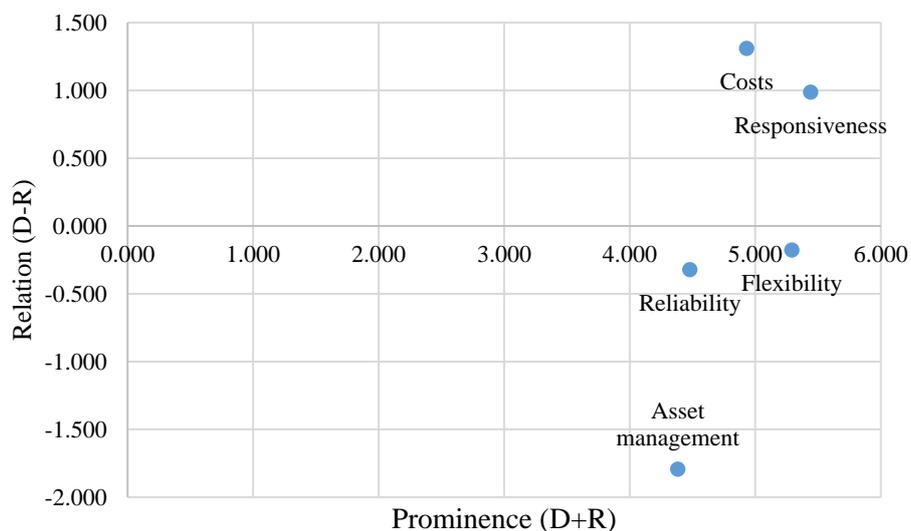
Fig. 3. D+R and D-R Values for Main Dimensions

Figure 4 illustrates the influence relationships among the sub-criteria of "Reliability." As shown, the significant prominence of "Supply stability" indicates that this criterion has strong interactions with other factors within the network. This suggests that changes in this criterion can spark a ripple effect, influencing elements such as delivery performance, drug availability, and overall network

reliability. In general, "Supply stability" plays a pivotal part in ensuring the consistent availability of medicines in real time and at the right locations (Briscoe & Hage, 2009). In the pharmaceutical industry, maintaining a stable supply chain is a strategic priority. Fluctuations in supply can lead to critical shortages that disrupt patient care. A stable supply chain, along with strong relationships with suppliers, enables pharmacies and healthcare providers to maintain reliable delivery schedules and effectively meet demand (Bilal et al., 2024).
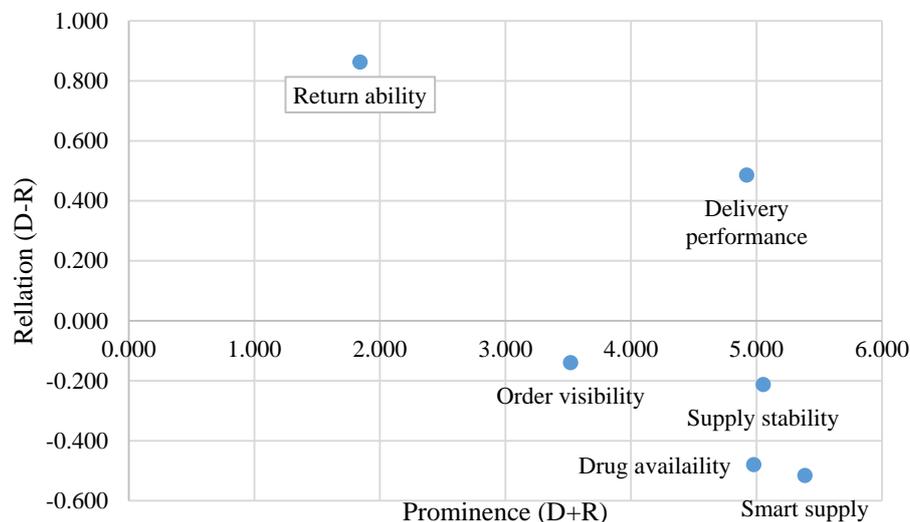
Fig. 4. D+R and D-R Values for "Reliability" Dimension

Figure 5 shows the relationships between the criteria related to "Costs." As can be seen, "Facility cost," with high importance, plays a key role in pharmaceutical distribution network and is identified as the main influential factor. A positive prominence score for this criterion indicates it as a fundamental resource that affects other costs and activities. In addition, "Information systems cost," with a moderate prominence score, is also considered important, and improvements in this area can positively impact on reducing other costs. High facility costs are primarily associated with expenses related to warehouses maintenance and physical infrastructure. By adopting solutions such as optimal warehouse management, utilizing advanced storage technologies, and making efficient use of available space, overall costs can be reduced and distribution performance can be improved (Abideen & Mohamad, 2020). Furthermore, efforts to reduce facility costs have positive spillover effects on other cost areas.
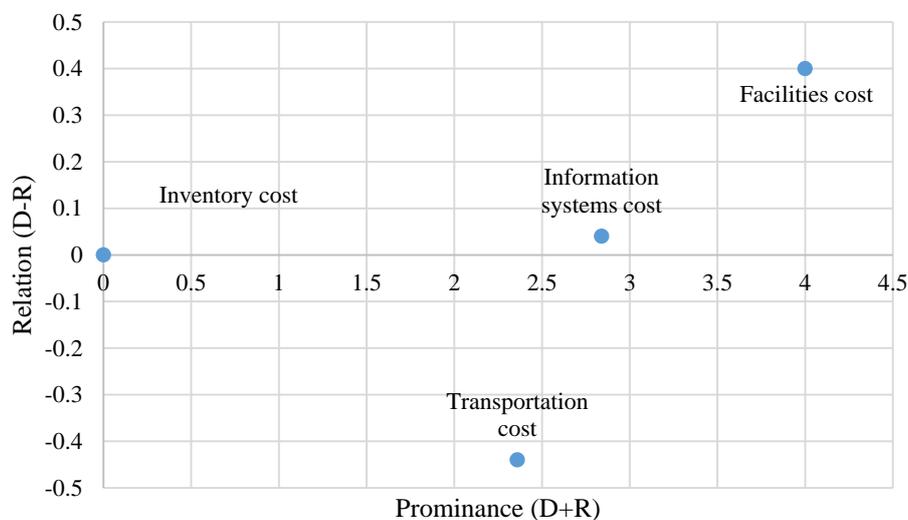
Fig. 5. D+R and D-R Values for "Costs" Dimension

Figure 6 shows that the "Number of vehicles for distribution" is the most influential factor in the "Asset management" category, directly impacting the efficiency of the pharmaceutical distribution network. In the pharmaceutical industry, the timely delivery of medicines is critical, as many medicines have limited shelf lives and are urgently needed by patients (Mitchell et al., 2021; Olawale, 2024). Maintaining a sufficient number of vehicles ensures an uninterrupted delivery process, enhancing the availability and effectiveness of medicines for patients (Cometto et al., 2014). Moreover, a larger fleet of vehicles provides flexibility to respond to fluctuations in demand, for example, during flu seasons or public health emergencies (Yang et al., 2016). This adaptability helps maintain service quality even under uncertain conditions. Efficient vehicle utilization also supports equitable access to essential medicines in remote and underserved area, expanding the network's geographical coverage (Wilson et al., 2009). In the specific context of Iran, where geopolitical and logistical challenges are prominent, the importance of a strong domestic distribution system becomes even more critical. Strengthening the transportation fleet can contribute to a more stable and reliable supply chain, thereby supporting public health and economic resilience.
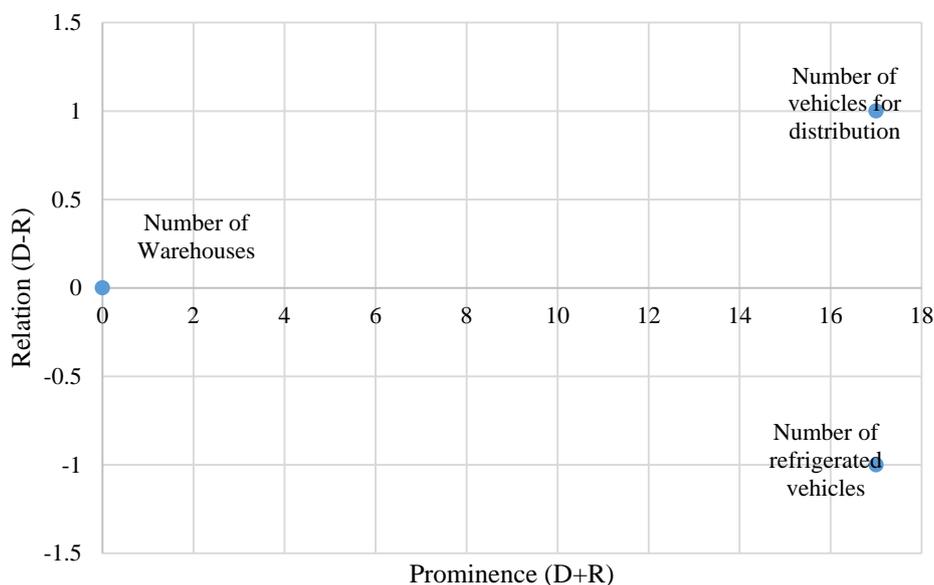
Fig. 6. D+R and D-R Values for "Asset Management" Dimension

Figure 7 illustrates that "Delivery time" is a pivotal factor in the performance of a pharmaceutical distribution network in the "Responsiveness" dimension. Timely delivery is essential in the pharmaceutical sector, as many medicines must be administered within specific timeframes to preserve their effectiveness and ensure patient safety. For instance, certain vaccines and injectable drugs require precise delivery schedules to maintain their efficacy (Michaelides et al., 2023). Moreover, many critical medications are sensitive to environmental conditions, particularly to temperature during storage and transportation. Rapid delivery ensures that these conditions are properly maintained, reducing the risk of drug degradation (Bigdeli et al., 2015). In addition, a fast and reliable delivery system enhances inventory management at pharmacies and healthcare centers. It prevents both stockouts and excessive accumulation of medicines, leading to a more efficient resource utilization (Abu Zwaida et al., 2021). Furthermore, such efficient distribution systems increase the network's ability to quickly respond to demand fluctuations, supporting a more balanced and resilient supply-demand relationship.
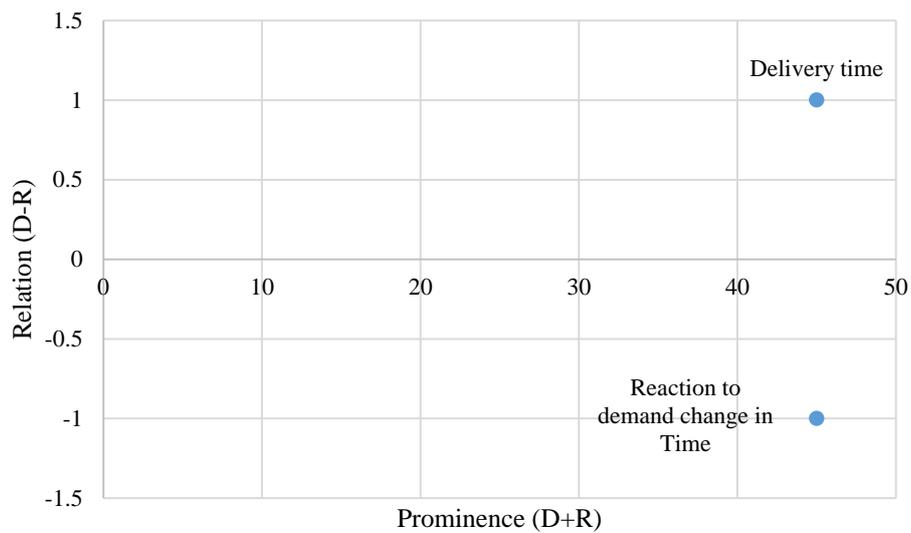
Fig. 7. D+R and D-R Values for "Responsiveness" Dimension

Figure 8 illustrates the relationship between the two criteria in the "Flexibility" category, highlighting "Flexibility in product volume" as the influential factor. The capacity to adjust the volume of pharmaceutical products in response to changing demand is vital (Bam et al., 2017). In the pharmaceutical industry, demand fluctuations may result from disease outbreaks, seasonal trends, or changes in healthcare policies (Redshaw et al., 2013). "Flexibility in product volume" enables the distribution process to continue smoothly, minimizing the risk of shortages or delivery delays. Moreover, the ability to handle varying volumes supports the management of a wide range of pharmaceutical products (Yu et al., 2021). Ultimately, companies that can efficiently operate across different volume levels are better equipped to accommodate diverse drug types and meet the evolving needs of various patient groups.
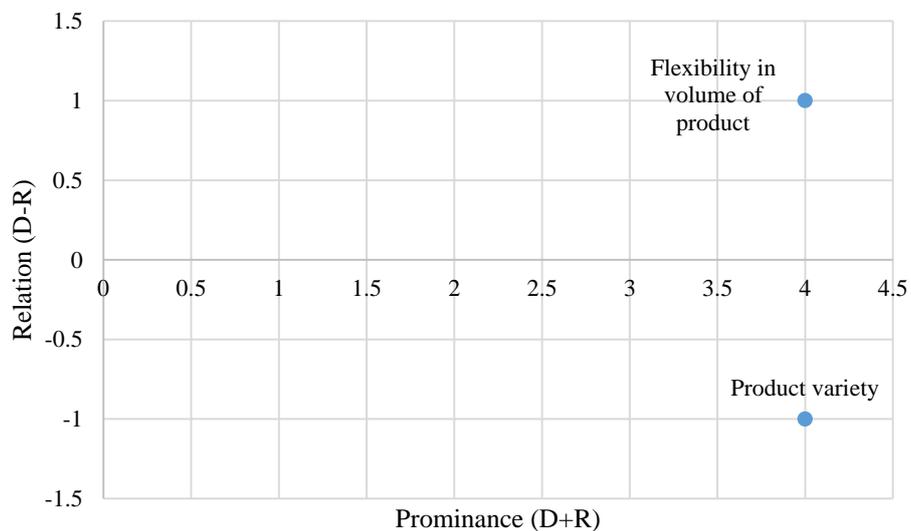
Fig. 8. D+R and D-R Values for "Flexibility" Dimension

4.2. The Results of BWM

In this study, the linear programming model related to BWM was solved using Excel Solver 2019. The results confirmed that the model converged appropriately and produced an optimal and feasible solution, indicating acceptable consistency in expert judgments. This section presents the findings derived from the BWM method. As shown in Table 5, experts assigned the highest importance to the

"Reliability" dimension. Given the critical need for a consistent and dependable supply of medications to hospitals and pharmacies, pharmaceutical distribution network must ensure the continuity and quality of its services. To achieve this, companies can adopt supply chain management technologies, implement tracking and monitoring systems, and develop data-driven platforms to better manage inventories and ensure timely drugs delivery (Akram et al., 2024). In addition, maintaining strategic buffer stocks during crises can mitigate the risk of sudden shortages. The "Responsiveness" dimension ranks second, highlighting the need for companies to meet their commitments to customers within the agreed-upon timelines (Uzir et al., 2021). Establishing performance monitoring and feedback loops can help organizations track service quality, identify weaknesses, and respond effectively to customer demands. The "Cost" dimension, which follows in importance, suggests that organizations must implement proactive cost management strategies. This may include negotiating long term contracts with suppliers to stabilize prices and conducting detailed cost analyses to identify inefficiencies and optimize resource allocation (Lal et al., 2022). Finally, the dimensions of "Flexibility" and "Asset management" are ranked fourth and fifth, respectively, indicating relatively lower, but still notable levels of strategic emphasis.

Table 5. The Weights of Main Dimensions

Main Dimensions	Weight	Rank
Reliability (C_1)	0.279	1
Costs (C_2)	0.230	3
Asset management (C_3)	0.087	5
Responsiveness (C_4)	0.273	2
Flexibility (C_5)	0.132	4

According to the findings obtained through the BWM approach for the criteria within each dimension (as shown in Table 6), "Drug availability" is considered the most important factor within the "Reliability" dimension from the experts' perspective. This criterion refers to the ability of distribution network to consistently supply essential medications to the market.

In the context of Iran, given ongoing economic fluctuations (Olyaaeemanesh et al., 2021), companies must ensure a stable and uninterrupted supply of medicines through meticulous planning and the development of robust distribution networks. The emphasis on "Drug availability" in this study aligns with the study conducted by George and Elrashid (2023) and Kumar et al. (2024), both underscoring the critical role of continuous access to medicines in pharmaceutical supply chains.

The second-ranking criterion within this dimension is "Supply stability," emphasizing the importance of minimizing disruptions. To achieve this, pharmaceutical distribution network should reduce dependency on imports by fostering local supply chains and collaborating with multiple suppliers. The criteria "Order visibility," "Smart supply," and "Returnability" follow in third to sixth positions, respectively.

In the "Responsiveness" dimension, "Delivery time," with a weight of 0.760, is identified as the most critical factor and must be prioritized to optimize performance. Considering Iran's geographical and infrastructure challenges, pharmaceutical distribution networks need to implement route optimization and logistics strategies to reduce delays (Akbarpour et al., 2020). This finding is in agreement with Ortíz-Barrios et al. (2023) and Sharma and Modgil (2020), which highlight the importance of operational efficiency and timely response in the pharmaceutical supply chain.

In the "Flexibility" dimension, "Flexibility in product volume" received the highest weight, indicating that companies must be capable of adjusting distribution volumes dynamically in response to fluctuating demand to fulfill real time needs.

Within the "Costs" dimension, "Transportation costs" hold the greatest weight (0.429), which is reasonable given the high fuel costs and transportation infrastructure challenges in Iran. This is followed by "Facilities cost," "Information system cost," and "Inventory cost," respectively.

Finally, in the "Asset management" dimension, the "Number of vehicles for distribution" ranks first, with a notable margin over the other two criteria. This suggests that increasing the number of distribution vehicles and improving their utilization efficiency can significantly reduce delivery time and enhance the overall performance of the distribution system.

Table 6. The Weights of Criteria in Five Dimensions

Main Dimensions	Criteria	Weight	Rank
Reliability (C_1)	Returnability (C_{11})	0.057	6
	Supply stability (C_{12})	0.219	2
	Delivery performance (C_{13})	0.184	3
	Drug availability (C_{14})	0.342	1
	Order visibility (C_{15})	0.10	4
	Smart supply (C_{16})	0.095	5
Costs (C_2)	Inventory cost (C_{21})	0.084	4
	Transportation cost (C_{22})	0.429	1
	Facilities cost (C_{23})	0.330	2
	Information systems cost (C_{24})	0.156	3
Asset management (C_3)	Number of refrigerated vehicles (C_{31})	0.124	3
	Number of Warehouses (C_{32})	0.270	2
	Number of vehicles for distribution (C_{33})	0.606	1
Responsiveness (C_4)	Delivery time (C_{41})	0.760	1
	Reaction to demand change in Time (C_{42})	0.240	2
Flexibility (C_5)	Flexibility in the volume of product (C_{51})	0.700	1
	Product variety (C_{52})	0.300	2

Table 7 presents the global weights of the sub-criteria that directly influence the performance of the pharmaceutical distribution network. As shown, "Delivery time" ranks first by a considerable margin, indicating its critical role in the overall system. This can be attributed to its direct impact on patient health outcomes, the urgency often associated with pharmaceutical needs, and its significant effect on customer satisfaction and trust within the healthcare supply chain.

Furthermore, the final rankings reveal that "Transportation cost," "Drug availability," "Facilities cost," "Flexibility in the volume of product," "Supply stability" along with the "Delivery time" collectively account for approximately %65 of the total weight assigned to the evaluated criteria. In particular, these criteria are considered vital since they serve as core determinants for maintaining the continuity of material and service flows throughout the supply chain. For instance, "Flexibility in the volume of product" enhances the network's ability to adapt to demand fluctuations, thereby mitigating the risk of supply disruptions.

By prioritizing these critical factors, pharmaceutical companies can significantly enhance their operational efficiency, responsiveness to patient needs, and economic sustainability across various levels of the supply chain. The remaining sub-criteria are ranked next, with marginal differences in weight, reflecting their secondary roles in supporting distribution performance.

Table 7. The Results of the Global Weights of Sub-Criteria

Criteria	Global weight	Rank
Delivery time (C_{41})	0.228	1
Transportation cost (C_{22})	0.098	2
Drug availability (C_{14})	0.087	3
Facilities cost (C_{23})	0.086	4
Flexibility in the volume of product (C_{51})	0.083	5
Supply stability (C_{12})	0.076	6
Number of vehicles for distribution (C_{33})	0.059	7
Delivery performance (C_{13})	0.046	8
Product variety (C_{52})	0.043	9
Information systems cost (C_{24})	0.037	10
Reaction to demand change in Time (C_{42})	0.036	11
Order visibility (C_{15})	0.034	12
Smart supply (C_{16})	0.026	13
Returnability (C_{11})	0.017	14
Inventory cost (C_{21})	0.016	15
Number of Warehouses (C_{32})	0.016	16
Number of refrigerated vehicles (C_{31})	0.011	17

Overall, within the BWM results, "Delivery time" holds the highest weight, underscoring its ultimate priority and critical role in evaluating the performance of the pharmaceutical distribution network. However, the DEMETL analysis reveals that "Delivery time" does not serve as a strong

causal driver within the network structure, instead, it is more of a dependent criterion influenced by other factors.

This integration of findings from both approaches suggests that enhancing "Delivery time" requires addressing its upstream drivers, specifically, "Supply stability," "Drug availability," and "Order visibility." Accordingly, improvements in "Delivery time" can be best achieved indirectly by modifying and strengthening these influential criteria. Such insights are particularly valuable for resource allocation, as they provide a strategic foundation for prioritizing interventions. By accurately understanding both the causal dynamics and the ultimate significance of each criterion, managers can implement targeted improvements that yield more sustainable and systematic performance gains.

5. Sensitivity Analysis

In this study, sensitivity analysis was conducted by introducing ±10% variations in the weights of the top five criteria. This change range was selected based on standard procedures in the MCDM literature (Gorcun et al., 2021; Malefaki et al., 2025). Applying limited and controlled adjustments to the weights helps evaluate the stability and robustness of the model's results. A 10% adjustment was chosen, as it is large enough to capture the impact of potential fluctuations in input data and expert opinions; however, it is still small enough to avoid unrealistic distortions in the model structure (Gorcun et al., 2021). The outcomes of the sensitivity analysis are presented in Table 8.

As shown in Table 8, "Delivery time" consistently holds the top rank across all scenarios, with a notable margin compared to other criteria. This indicates its strong robustness and importance. "Transportation cost" also retains the second position throughout all scenarios, further confirming the stability of the prioritization structure. Minor fluctuations are observed in the mid-ranked criteria. For instance, the three criteria, namely "Drug availability," "Facilities cost," and "Flexibility in the volume of product," fluctuate slightly between ranks three and six. These minor and reasonable variations suggest a moderate sensitivity of these indicators to weight changes. The remaining criteria maintained their rankings across all scenarios, suggesting that adjustment in the main criteria weights had little impact on their positions.

Overall, the results of the sensitivity analysis demonstrate that even with ±10% changes, the overall ranking structure remains intact. This confirm the robustness of the model and the high stability of key criteria, indicating that the weighting process was both accurate and reliable.

6. Validation

To assess the outcomes of integrating MCDM methods with the SCOR model, feedback was collected from 11 experts who participated in the criteria weighting phase. The panel included two physicians and nine professionals working in pharmaceutical distribution centers, such as pharmacies, hospitals, and pharmaceutical distribution companies. Data were gathered through semi-structured interviews. Participants were first asked whether they agreed with the obtained results and were then invited to explain their reasons for agreement or disagreement. As shown in Table 9, "Delivery time" received the highest approval rate, with %91 of experts agreeing on its importance, while the "Number of vehicles for distribution" received the lowest support, with only 55% agreement. Experts attributed the strong consensus on "Delivery time" to its critical role in emergency situations, where even short delays can lead to serious consequences for patients and healthcare providers. They emphasized that "Delivery time" is a concrete and impactful criterion, directly influencing both customer satisfaction and the operational efficiency of distribution network. In contrast, experts disagreeing with the importance of the "Number of vehicles for distribution," argued that this metric, independently and disregarding planning and operational efficiency, does not accurately reflect distribution performance. They noted that this criterion represents a purely quantitative measure, whose effectiveness heavily depends on other infrastructural and managerial factors.

Overall, more than %70 of the interviewed experts agreed with the obtained weights. His agreement was particularly strong for criteria such as "Delivery time" and "Drug availability." This level of expert consensus indicates that the proposed model aligns well with the professional understanding and real-world experience of pharmaceutical industry practitioners, supporting its conceptual validity. As such, the results offer a solid foundation for informed decision making within the pharmaceutical distribution network.

Table 8. The Result of Sensitivity Analysis

	Delivery time				Transportation cost				Drug availability				Facilities cost				Flexibility in product			
Criteria	-10%	Rank	10%	Rank	-0.1	Rank	0.1	Rank	-0.1	Rank	0.1	Rank	-0.1	Rank	0.1	Rank	-0.1	Rank	0.1	Rank
Delivery time	0.205	1	0.251	1	0.231	1	0.225	1	0.230	1	0.226	1	0.230	1	0.226	1	0.230	1	0.226	1
Transportation cost	0.101	2	0.095	2	0.088	2	0.108	2	0.099	2	0.097	2	0.099	2	0.098	2	0.098	2	0.097	2
Drug availability	0.090	3	0.084	3	0.088	3	0.086	4	0.078	**5**	0.096	3	0.088	3	0.087	**4**	0.087	3	0.086	**4**
Facilities cost	0.089	4	0.083	4	0.087	4	0.086	3	0.087	**3**	0.085	4	0.077	**5**	0.095	**3**	0.086	4	0.085	**5**
Flexibility in the volume of product	0.085	5	0.081	5	0.084	5	0.083	5	0.084	**4**	0.082	5	0.084	**4**	0.082	5	0.075	**6**	0.091	**3**
Supply stability	0.078	6	0.074	6	0.077	6	0.076	6	0.077	6	0.075	6	0.077	6	0.076	6	0.077	**5**	0.075	6
Number of vehicles for distribution	0.061	7	0.057	7	0.060	7	0.059	7	0.060	7	0.058	7	0.060	7	0.059	7	0.059	7	0.058	7
Delivery performance	0.047	8	0.045	8	0.047	8	0.046	8	0.046	8	0.046	8	0.046	8	0.046	8	0.046	8	0.046	8
Product variety	0.044	9	0.042	9	0.043	9	0.043	9	0.043	9	0.043	9	0.043	9	0.043	9	0.043	9	0.043	9
Information systems cost	0.038	10	0.036	10	0.037	10	0.037	10	0.037	10	0.037	10	0.037	10	0.037	10	0.037	10	0.037	10
Reaction to demand change in Time	0.037	11	0.035	11	0.036	11	0.036	11	0.036	11	0.036	11	0.036	11	0.036	11	0.036	11	0.036	11
Order visibility	0.035	12	0.033	12	0.034	12	0.033	12	0.034	12	0.034	12	0.034	12	0.034	12	0.034	12	0.034	12
Smart supply	0.027	13	0.025	13	0.026	13	0.026	13	0.026	13	0.026	13	0.026	13	0.027	13	0.029	13	0.026	13
Return ability	0.018	14	0.017	14	0.018	14	0.017	14	0.018	14	0.019	14	0.019	14	0.017	14	0.019	14	0.019	14
Inventory cost	0.017	15	0.015	15	0.017	15	0.015	15	0.016	15	0.018	15	0.017	15	0.014	15	0.016	15	0.017	15
Number of warehouses	0.015	16	0.014	16	0.015	16	0.012	16	0.015	16	0.013	16	0.014	16	0.012	16	0.015	16	0.014	16
Number of refrigerated vehicles	0.013	17	0.013	17	0.012	17	0.011	17	0.012	17	0.011	17	0.011	17	0.011	17	0.013	17	0.011	17

Table 9. The Results of Interviews

Results of BWM	Level in hierarchical structure	No. of votes		Reasons	
		In favor	Against	Experts who agree	Experts who disagree
Reliability	First	9 (82%)	2 (18%)	• Reliability enhances the credibility of the distribution company. • It is considered the most essential factor in pharmaceutical supply chains.	• Reliability alone is not sufficient; it must be balanced with cost-efficiency. • These experts believe cost and responsibility are more critical than reliability.
Drug availability	Second (Reliability)	9 (82%)	2 (18%)	• It reflects the efficiency of warehouse operations and demand forecasting systems. • It is the most important criterion to guarantee uninterrupted service.	• Greater emphasis should be placed on shortening delivery times.
Delivery time	Second (Responsiveness)	10(91%)	1 (9%)	• Timely delivery of medicines is a top priority for hospitals and pharmacies. • Customer dissatisfaction most often stems from delays in delivery.	• If a medicine is not available, fast delivery becomes irrelevant.
Flexibility in the volume of product	Second (Flexibility)	7(64%)	4(36%)	• It becomes even more important during times of crisis or uncertainty. • It allows for quick adaptation to changing demand patterns.	• Focusing too much on this factor may complicate the distribution system unnecessarily.
Transportation cost	Second (Costs)	8(73%)	3(22%)	• It supports the economic optimization of distribution processes. • For private companies, reliability is a key competitive advantage.	• In the long term, optimizing other cost-related factors may have a more sustainable impact.
Number of vehicles for distribution	Second (Asset management)	6(55%)	5(45%)	• Increasing the availability of transportation resources can improve both accessibility and delivery time.	• Simply having more delivery vehicles does not guarantee efficiency; proper planning is also required.

7. Conclusion

This study addresses key challenges in the pharmaceutical supply chain by adopting an integrated performance evaluation framework based on the SCOR model and MCDM techniques. The proposed SCOR-MCDM framework offers several advantages over traditional evaluation methods. By combining DEMATEL and BWM, it enables the identification of interactions among performance criteria while determining their relative importance, which is an aspect often overlooked in conventional MCDM approaches. Unlike models that merely rank alternatives, this framework provides a detailed evaluation of performance criteria and can be adapted to diverse operational contexts. Furthermore, by emphasizing critical criteria, it supports more focused and effective decision-making in pharmaceutical distribution networks. Using the SCOR model, the study categorized essential performance factors into five main dimensions: "Costs," "Asset management," "Reliability," "Flexibility," and "Responsiveness." These categories represent the core operational elements of the pharmaceutical distribution network. The DEMATEL method revealed the causal relationships among these factors, highlighting the most influential drivers within the system. This insight enables organizations to address the root causes of inefficiencies and better manage complexities of the pharmaceutical supply chain. Subsequently, the BWM method was employed to quantify the relative importance of each factor. The result indicated that "Reliability," "Responsiveness," and "Cost" are the most critical dimensions. Prioritizing these key areas enables organizations to allocate resources more effectively and achieve substantial improvements in distribution performance. The overall ranking results also showed that the "Delivery time" has the highest importance among the criteria. As noted earlier, the DEMATEL and BWM methods were applied in a complementary fashion in this study. For example, if a highly weighted criterion such as "Delivery time" is to be improved, the DEMATEL results can help identify other criteria that exert influence over it. This enables decision-makers to design targeted interventions by focusing on the most impactful and interconnected factors, thereby enhancing overall distribution performance. Therefore, the combination of these methods provides a holistic framework for both evaluation and improvement in complex supply chain environments. In this regard, based on the analysis, several actionable strategies are recommended to improve performance, including the adoption of advanced

supply chain management and tracking technologies, the establishment of long-term supplier agreements to stabilize costs and the optimization of vehicle utilization to reduce delivery times.

These measures are expected to enhance cost-efficiency, asset utilization, and supply chain reliability. Ultimately, these improvements can lead to better public health outcomes and increased patient satisfaction through more reliable and timely access to essential medicines. While the SCOR-MCDM framework has been validated through expert judgment, applying it to real-world case studies, using actual performance data from Iranian pharmaceutical distribution companies, would further enhance its empirical relevance and practical applicability.

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Appendix A

Table A-1. Total-Relation Matrix "Main dimensions"

	C₁	C₂	C₃	C₄	C₅
C₁	0.303	0.681	0.529	0.655	0.233
C₂	0.438	0.438	0.479	0.611	0.262
C₃	0.520	0.749	0.426	0.708	0.332
C₄	0.279	0.527	0.440	0.346	0.220
C₅	0.538	0.819	0.683	0.802	0.248

Table A-2. Total-Relation Matrix "Reliability"

	C₁₁	C₁₂	C₁₃	C₁₄	C₁₅	C₁₆
C₁₁	0.036	0.085	0.076	0.072	0.123	0.097
C₁₂	0.277	0.367	0.594	0.542	0.340	0.514
C₁₃	0.197	0.412	0.357	0.489	0.290	0.473
C₁₄	0.276	0.561	0.623	0.367	0.339	0.564
C₁₅	0.163	0.399	0.420	0.285	0.177	0.387
C₁₆	0.404	0.597	0.635	0.495	0.421	0.400

Table A-3. Total-Relation Matrix "Cost"

	C₂₁	C₂₂	C₂₃	C₂₄
C₂₁	0.000	0.000	0.000	0.000
C₂₂	0.000	0.240	0.800	0.360
C₂₃	0.000	0.480	0.600	0.720
C₂₄	0.000	0.240	0.800	0.360

Table A-4. Total-Relation Matrix "Asset Management"

	C₃₁	C₃₂	C₃₃
C₃₁	4.00	0.00	5.00
C₃₂	0.00	0.00	0.00
C₃₃	4.00	0.00	4.00

Table A-5. Total-Relation Matrix "Responsiveness"

	C₄₁	C₄₂
C₄₁	11.00	11.00
C₄₂	12.00	11.00

Table A-6. Total-Relation Matrix "Flexibility"

	C₅₁	C₅₂
C₅₁	0.750	0.750
C₅₂	1.750	0.750

Appendix B

Table B-1. Pairwise Comparisons of Experts for the "Main dimensions"

Best to Other	Flexibility	Cost	Asset management	Reliability	Responsibility
Expert 1	4	1	3	2	2
Expert 2	4	5	7	1	3
Expert 3	3	2	4	3	1
Expert 4	4	1	3	2	2
Expert 5	3	2	4	3	1
Expert 6	4	5	7	1	3
Expert 7	5	6	8	1	2
Expert 8	4	3	5	4	1
Expert 9	3	2	3	2	1
Expert 10	4	1	3	2	2
Expert 11	4	4	7	1	3
Expert 12	3	2	4	2	1
Expert 13	3	1	3	2	2
Expert 14	4	3	5	1	2
Expert 15	4	5	7	1	3
Expert 16	5	6	8	1	2
Expert 17	4	3	5	1	3
Expert 18	3	2	3	2	1
Expert 19	4	1	3	2	2
Expert 20	4	4	7	1	3
Expert 21	3	2	4	2	1
Expert 22	3	1	3	2	2
Expert 23	4	1	2	2	2
Expert 24	3	2	4	3	1
Expert 25	4	1	3	2	2

Other-to-Worst	Flexibility	Cost	Asset management	Reliability	Responsibility
Expert 1	1	5	3	5	4
Expert 2	6	4	1	7	5
Expert 3	3	5	1	4	4
Expert 4	1	4	3	2	2
Expert 5	3	2	1	3	4
Expert 6	4	5	1	7	3
Expert 7	5	5	1	8	2
Expert 8	4	3	1	3	5
Expert 9	3	2	1	2	3
Expert 10	4	5	3	1	2
Expert 11	4	4	1	7	3
Expert 12	3	2	1	2	4
Expert 13	1	4	3	2	2
Expert 14	4	3	1	5	2
Expert 15	4	5	1	7	3
Expert 16	5	6	1	8	2
Expert 17	4	3	1	5	3
Expert 18	3	2	1	2	5
Expert 19	1	4	3	2	2
Expert 20	4	4	1	7	3
Expert 21	3	2	1	2	5
Expert 22	3	4	1	2	2
Expert 23	1	4	2	2	2
Expert 24	3	2	1	3	4
Expert 25	1	4	3	2	2

Table B-2. Pairwise Comparisons of Experts for "Reliability"

Best-to-Other	Returnability	Supply stability	Delivery performance	Drug availability	Order visibility	Smart supply
Expert 1	6	5	4	1	7	5
Expert 2	8	1	4	2	2	7
Expert 3	8	2	2	1	7	5
Expert 4	5	4	3	1	6	5
Expert 5	7	1	3	3	2	6
Expert 6	9	4	3	1	8	6
Expert 7	5	4	4	1	8	5
Expert 8	7	1	3	3	3	6
Expert 9	8	2	2	1	7	5
Expert 10	6	4	3	1	5	7
Expert 11	5	1	3	3	2	4
Expert 12	8	3	2	1	7	5
Expert 13	6	3	4	1	4	6
Expert 14	6	1	3	2	5	3
Expert 15	6	3	3	1	5	7
Expert 16	4	4	3	1	5	4
Expert 17	8	1	3	3	2	7
Expert 18	7	4	3	1	6	5
Expert 19	5	4	4	1	7	5
Expert 20	6	1	3	3	3	5
Expert 21	9	4	4	1	8	5
Expert 22	6	4	3	1	7	5
Expert 23	7	1	3	3	2	6
Expert 24	8	3	2	1	7	5
Expert 25	7	4	3	1	4	6

Other-to-Worst	Returnability	Supply stability	Delivery performance	Drug availability	Order visibility	Smart supply
Expert 1	6	5	4	7	1	5
Expert 2	1	8	4	2	2	7
Expert 3	1	2	2	8	7	5
Expert 4	5	4	3	6	1	5
Expert 5	1	7	3	3	2	6
Expert 6	1	4	3	9	8	6
Expert 7	5	4	4	8	1	5
Expert 8	1	7	3	3	3	6
Expert 9	1	2	2	8	7	5
Expert 10	6	4	3	7	5	1
Expert 11	1	5	3	3	2	4
Expert 12	1	3	2	8	7	5
Expert 13	5	3	4	6	4	1
Expert 14	1	6	3	2	3	5
Expert 15	6	3	3	7	5	1
Expert 16	4	4	3	5	1	4
Expert 17	1	8	3	3	2	7
Expert 18	1	4	3	7	6	5
Expert 19	5	4	4	7	1	5
Expert 20	1	6	3	3	3	5
Expert 21	1	4	4	9	8	5
Expert 22	6	4	3	7	1	5
Expert 23	1	7	3	3	2	6
Expert 24	1	3	2	8	7	5
Expert 25	1	4	3	7	4	6

Table B-3. Pairwise Comparisons of Experts for "Cost"

Best-to-Other	Inventory cost	Transportation cost	Facilities cost	Information systems cost
Expert 1	7	3	1	5
Expert 2	5	1	2	4
Expert 3	7	1	4	5
Expert 4	8	4	1	6
Expert 5	6	1	3	5
Expert 6	5	2	1	4
Expert 7	4	1	3	5
Expert 8	6	1	5	4
Expert 9	9	5	1	7
Expert 10	7	1	4	6
Expert 11	5	1	4	6
Expert 12	6	4	1	5
Expert 13	6	1	3	5
Expert 14	5	1	2	5
Expert 15	7	3	1	5
Expert 16	5	1	4	4
Expert 17	6	3	1	5
Expert 18	3	1	4	6
Expert 19	6	1	5	4
Expert 20	8	4	1	6
Expert 21	5	1	2	2
Expert 22	6	1	3	5
Expert 23	4	1	3	5
Expert 24	5	4	1	2
Expert 25	5	1	4	3

Other-to-Worst	Inventory cost	Transportation cost	Facilities cost	Information systems cost
Expert 1	1	3	7	5
Expert 2	1	5	3	4
Expert 3	1	7	5	5
Expert 4	1	4	8	6
Expert 5	1	6	4	5
Expert 6	1	3	5	4
Expert 7	4	5	3	1
Expert 8	1	6	5	5
Expert 9	1	6	9	7
Expert 10	1	7	5	6
Expert 11	5	6	4	1
Expert 12	1	4	6	5
Expert 13	1	6	4	5
Expert 14	1	5	2	4
Expert 15	1	4	7	5
Expert 16	1	5	3	4
Expert 17	1	4	6	5
Expert 18	4	6	5	1
Expert 19	1	6	5	4
Expert 20	1	5	8	6
Expert 21	1	5	3	2
Expert 22	1	6	4	5
Expert 23	2	5	3	1
Expert 24	1	4	5	3
Expert 25	1	5	4	4

Table B-4. Pairwise Comparisons of Experts for "Asset management"

Best-to-Other	Number of refrigerated vehicles	Number of Warehouses	Number of vehicles for distribution
Expert 1	5	3	1
Expert 2	7	5	1
Expert 3	5	4	1
Expert 4	6	4	1
Expert 5	8	6	1
Expert 6	5	1	3
Expert 7	9	6	1
Expert 8	6	4	1
Expert 9	5	1	2
Expert 10	6	3	1
Expert 11	7	5	1
Expert 12	6	1	2
Expert 13	8	4	1
Expert 14	5	4	1
Expert 15	6	4	1
Expert 16	9	5	1
Expert 17	7	4	1
Expert 18	6	1	4
Expert 19	5	4	1
Expert 20	7	5	1
Expert 21	6	1	3
Expert 22	5	2	1
Expert 23	6	3	1
Expert 24	6	1	2
Expert 25	8	2	1

Other-to-Worst	Number of refrigerated vehicles	Number of Warehouses	Number of vehicles for distribution
Expert 1	1	3	5
Expert 2	1	5	7
Expert 3	1	4	5
Expert 4	1	4	6
Expert 5	1	5	8
Expert 6	1	5	4
Expert 7	1	5	9
Expert 8	1	5	6
Expert 9	1	5	3
Expert 10	1	4	6
Expert 11	1	5	7
Expert 12	1	6	3
Expert 13	1	5	8
Expert 14	1	4	5
Expert 15	1	5	6
Expert 16	1	6	9
Expert 17	1	5	7
Expert 18	1	6	4
Expert 19	1	4	5
Expert 20	1	5	7
Expert 21	1	6	4
Expert 22	1	2	5
Expert 23	1	3	6
Expert 24	1	6	2
Expert 25	1	2	8

Table B-5. Pairwise Comparisons of Experts for "Flexibility"

Best-to-Other	Flexibility in volume of product	Product variety
Expert 1	1	4
Expert 2	1	4
Expert 3	4	1
Expert 4	1	5
Expert 5	1	6
Expert 6	5	1
Expert 7	1	5
Expert 8	1	3
Expert 9	3	1
Expert 10	1	5
Expert 11	1	4
Expert 12	4	1
Expert 13	1	5
Expert 14	1	6
Expert 15	5	1
Expert 16	1	5
Expert 17	1	7
Expert 18	6	1
Expert 19	1	4
Expert 20	1	3
Expert 21	4	1
Expert 22	1	6
Expert 23	1	5
Expert 24	5	1
Expert 25	3	1

Other-to-Worst	Flexibility in volume of product	Product variety
Expert 1	4	1
Expert 2	4	1
Expert 3	1	4
Expert 4	5	1
Expert 5	6	1
Expert 6	1	5
Expert 7	5	1
Expert 8	3	1
Expert 9	1	3
Expert 10	5	1
Expert 11	4	1
Expert 12	1	4
Expert 13	5	1
Expert 14	6	1
Expert 15	1	5
Expert 16	5	1
Expert 17	7	1
Expert 18	1	6
Expert 19	4	1
Expert 20	3	1
Expert 21	1	4
Expert 22	6	1
Expert 23	5	1
Expert 24	1	5
Expert 25	1	3

Table B-6. Geometric Mean Value of Pairwise Comparisons for "Responsiveness"

Best-to-Other	Delivery time	Reaction to demand change in Time
Expert 1	1	4
Expert 2	1	4
Expert 3	4	1
Expert 4	1	5
Expert 5	1	6
Expert 6	5	1
Expert 7	1	5
Expert 8	1	3
Expert 9	3	1
Expert 10	1	5
Expert 11	1	4
Expert 12	4	1
Expert 13	1	5
Expert 14	1	6
Expert 15	5	1
Expert 16	1	5
Expert 17	1	7
Expert 18	6	1
Expert 19	1	4
Expert 20	1	3
Expert 21	4	1
Expert 22	1	6
Expert 23	1	5
Expert 24	5	1
Expert 25	3	1

Other-to-Worst	Delivery time	Reaction to demand change in Time
Expert 1	5	1
Expert 2	7	1
Expert 3	6	1
Expert 4	8	1
Expert 5	6	1
Expert 6	9	1
Expert 7	1	3
Expert 8	7	1
Expert 9	1	2
Expert 10	4	1
Expert 11	3	1
Expert 12	9	1
Expert 13	3	1
Expert 14	6	1
Expert 15	4	1
Expert 16	9	1
Expert 17	5	1
Expert 18	4	1
Expert 19	1	2
Expert 20	6	1
Expert 21	1	3
Expert 22	3	1
Expert 23	3	1
Expert 24	5	1
Expert 25	1	2