KMAN PUBLISHING INSTITUTE

Article history:
Received 01 December 2024
Revised 18 January 2025
Accepted 02 February 2025
Published online 20 February 2025

Journal of Resource Management and Decision Engineering

Volume 4, Issue 1, pp 1-12

Identifying the Factors Affecting Smart Pharmaceutical Distribution

Ali Bayrami [1], Mohammad Reza Shahriari[2*], Farhad Hosseinzade Lotfi [3]

[1] Department of Industrial Management, Research Sciences Branch, Islamic Azad University, Tehran, Iran
[2] Department of Industrial Management, South Tehran Branch, Islamic Azad University, Tehran, Iran
[3] Department of Mathematics, Research Sciences Branch, Islamic Azad University, Tehran, Iran

*** Corresponding author email address**: Shahriari.mr@gmail.com

A r t i c l e I n f o

Article type:
Original Research

How to cite this article:
Bayrami, A., Shahriari, M. R., & Hosseinzade Lotfi, F. (2025). Identifying the Factors Affecting Smart Pharmaceutical Distribution. *Journal of Resource Management and Decision Engineering, 4*(1), 1-12.
https://doi.org/10.61838/kman.jrmde.4.1.4

A B S T R A C T

This study aimed to identify and validate the key factors influencing smart pharmaceutical distribution by utilizing expert opinions and a structured Delphi technique. A qualitative research design using semi-structured interviews and a three-round Delphi method was conducted among experts and practitioners in the pharmaceutical supply chain. Initially, thirty-two factors were extracted from interviews using content analysis. Subsequently, the Delphi process, involving ten experts, was employed to screen, refine, and categorize these factors into broader dimensions. Data were analyzed through iterative mean comparisons across rounds to confirm consensus thresholds, and factors were grouped under seven primary categories based on thematic similarity. The results identified thirty-two factors across governance, network, technology, member, data, service, and demand dimensions. Consensus was reached on all factors, with differences between Delphi rounds consistently within the accepted 0.1 threshold. Key factors included data privacy, supplier accessibility, smart tool innovation, defect-free operations, partner communication, and staff training. The findings align with previous studies highlighting the critical role of blockchain for traceability, IoT adoption for real-time monitoring, leadership and knowledge sharing in organizational readiness, and regulatory policy alignment in successful smart pharmaceutical distribution implementation. The study offers a validated multi-dimensional framework of factors that affect smart pharmaceutical distribution, emphasizing the need for an integrated approach that combines technological, organizational, regulatory, and human capital strategies. These findings provide a basis for future modeling, policy development, and operational decision-making to enhance transparency, efficiency, and security in pharmaceutical supply chains.

Keywords: *Smart pharmaceutical distribution; Delphi method; supply chain transparency; blockchain; IoT adoption; pharmaceutical logistics; digital transformation.*

1. Introduction

The global pharmaceutical supply chain is under growing pressure to become more intelligent, transparent, and resilient. From the increasing complexity of drug manufacturing and distribution processes to the persistent threats of counterfeit medications, inefficiencies in traditional models are becoming more evident. The need to adopt a smart pharmaceutical distribution system, embedded with digital technologies, is no longer optional—it is a strategic imperative. This shift is driven by multiple forces, including the demand for end-to-end traceability, regulatory requirements, patient safety, and the growing necessity to integrate real-time data across the supply and distribution chain (Gaynor et al., 2024).

Smart pharmaceutical distribution refers to the use of advanced technologies—such as blockchain, artificial intelligence (AI), Internet of Things (IoT), and data analytics—to manage, monitor, and optimize the flow of pharmaceuticals from production to consumption. One of the most pressing challenges in conventional pharmaceutical logistics is the prevalence of counterfeit drugs. These not only pose a threat to patient safety but also undermine trust in healthcare systems. Technologies like blockchain are increasingly being recognized for their potential to combat this issue by ensuring immutable tracking and verification of drug provenance (Chıacchıo et al., 2022; Sarkar, 2023).

Blockchain applications in pharmaceutical distribution have shown promise in enhancing the traceability and authenticity of drug products throughout the supply chain. Solutions like PharmaChain, for instance, integrate blockchain architecture to secure the chain against counterfeit entries and unauthorized modifications (Bapatla et al., 2022). Similarly, the use of non-fungible tokens (NFTs) in the pharmaceutical context has been proposed as a secure method to trace drug batches from origin to patient, thus reinforcing data integrity and transparency (Chıacchıo et al., 2022). These technological advancements are not just theoretical. Pilot implementations have demonstrated that such systems significantly improve visibility and confidence across all nodes of the supply chain (Durà-Hernández et al., 2023).

The shift toward smart distribution is also influenced by the rising complexity of cold chain logistics, especially for temperature-sensitive drugs, such as vaccines and biologics. Smart contracts and blockchain-enabled cold chain monitoring have emerged as critical components in ensuring real-time compliance and accountability in temperature-controlled environments (Nagpal et al., 2025). Studies underscore that the integration of blockchain and smart sensors facilitates proactive alerting and dynamic rerouting, thus preventing temperature excursions and product spoilage (Yadav, 2024). These mechanisms reduce loss, improve regulatory adherence, and enhance the overall reliability of the distribution chain.

A particularly innovative solution is the use of smart parcel lockers combined with intelligent vehicle routing algorithms, which has shown great potential in optimizing last-mile delivery—one of the costliest and least efficient components of the pharmaceutical supply chain (Aghdam et al., 2024). By decentralizing storage and using real-time data to optimize delivery paths, such systems contribute to faster, safer, and more patient-centric pharmaceutical logistics.

Furthermore, data privacy and secure information exchange are crucial pillars of smart distribution frameworks. Digital transformation in pharmaceutical logistics often entails the sharing of sensitive data across decentralized platforms. Therefore, technologies that ensure data originality and protection from tampering are fundamental (Durà-Hernández et al., 2023; Gaynor et al., 2024). Such systems must comply with international data protection regulations while facilitating efficient information flows among manufacturers, distributors, healthcare providers, and regulatory agencies.

Equally significant is the role of organizational culture, leadership, and knowledge sharing in the successful implementation of smart pharmaceutical systems. Recent research suggests that leadership effectiveness in pharmaceutical firms is positively mediated by the knowledge-sharing behaviors of culturally intelligent leaders (Hassan, 2025). Moreover, knowledge management frameworks integrated with smart technologies have been shown to improve performance in public pharmaceutical organizations, particularly in regions where digital infrastructure is still emerging (Mahmoud et al., 2025). Thus, beyond technological capability, human capital and leadership culture play a pivotal role in shaping smart distribution environments.

Smart pharmaceutical supply chains also benefit from well-structured enterprise architectures, which help align technological solutions with organizational strategy and operational workflows. The adoption of blockchain technologies in digital transformation requires a careful reengineering of business processes, taking into account both interoperability and scalability across enterprise systems (Wedha et al., 2023). This alignment ensures that

technological upgrades do not remain isolated but rather contribute holistically to systemic efficiency.

Interoperability is further emphasized in hybrid blockchain models that aim to bridge public and private networks for secure and scalable drug traceability (Jaleel, 2024). These hybrid systems allow organizations to maintain confidentiality while enabling transparency for external auditing or regulatory bodies. This balance is essential in high-stakes sectors like pharmaceuticals, where both privacy and verification are paramount.

Cold chain distribution, in particular, has emerged as a focal area where smart systems can significantly reduce risk. IoT-enabled monitoring devices can report real-time temperature data, which is logged and verified via blockchain to ensure compliance and accountability (Nagpal et al., 2025; Sarkar, 2023). Additionally, nanocarrier-based drug delivery systems have further complicated logistics by introducing products with highly specific storage and transportation needs (Hwang et al., 2021). Smart distribution models must therefore be adaptive and responsive to the needs of novel therapies, necessitating agile systems that can reconfigure routes and storage in real-time.

The transformation toward intelligent pharmaceutical logistics also has socio-cultural dimensions. For example, studies examining halal transportation practices in pharmaceutical contexts have demonstrated that technology adoption must also align with cultural and religious expectations, especially in Islamic markets (Ngah et al., 2019). This highlights the importance of stakeholder engagement and localized policy design in the rollout of smart distribution systems.

Equally important are regulatory policies and industry-wide standards that govern the adoption of smart technologies. The alignment between governmental regulations and digital innovation significantly impacts the pace and scope of smart distribution implementation. Without supportive governance, even the most advanced technological solutions may face resistance or remain underutilized (Alfaiza et al., 2021). Therefore, a multistakeholder approach involving industry leaders, regulators, technologists, and academia is essential to create a sustainable and integrated pharmaceutical distribution model.

The emergence of digital twins, big data analytics, and predictive algorithms further expands the possibilities for smart distribution. These tools enable dynamic demand forecasting, inventory optimization, and risk mitigation strategies that are essential in today's volatile pharmaceutical landscape (Gaynor et al., 2024). Smart distribution systems can leverage these tools not only for operational efficiency but also for strategic planning and resilience building.

In summary, smart pharmaceutical distribution is not a singular technological intervention but a comprehensive transformation that requires integration across multiple domains—technology, governance, logistics, human capital, and data management. The convergence of blockchain, IoT, AI, and knowledge management has created a fertile ground for innovation in pharmaceutical logistics. However, the successful implementation of these technologies depends on their strategic alignment with organizational goals, leadership culture, regulatory frameworks, and socio-cultural dynamics. This study seeks to identify and validate the key factors influencing smart pharmaceutical distribution.

2. Methods and Materials

In this study, a qualitative, exploratory approach was adopted to identify and screen the factors influencing smart pharmaceutical distribution within the smart pharmaceutical supply chain. The spatial scope of this research was the smart pharmaceutical supply chain of the Tofigh Daru Company, and the temporal scope was the Persian calendar year 1402. Data collection in this research was carried out at two levels: library research and field research. In the library phase, existing research gaps were extracted through reviewing various scientific articles and documents. This step also facilitated the identification of the theoretical foundations and prior literature related to smart pharmaceutical supply chain factors. Subsequently, in the field phase, relevant data regarding the supply chain under study were obtained directly from Tofigh Daru Company. This allowed for the extraction of the constituent factors of the smart pharmaceutical supply and distribution chain through on-site examination and direct engagement with organizational processes.

The primary tool for data collection in this research was a semi-structured interview. The core question posed to participants was: "What are the factors constituting the smart pharmaceutical supply and distribution chain?" Following the identification of potential factors through interviews, a Delphi technique was employed to screen and refine these factors. Accordingly, the second data collection tool was a Delphi questionnaire developed based on the factors identified in the interview phase. The statistical population

of this research consisted of all employees and experts within Tofigh Daru Company, specifically those involved in or familiar with supply chain processes. Given the judgmental nature of the sampling method and the exploratory objectives of the research, a sample of at least ten participants was deemed sufficient to ensure data saturation and process reliability.

For data analysis, a combination of techniques was utilized. First, content analysis was applied to the interviews and expert opinions in order to extract meaningful concepts and identify the main components of the smart pharmaceutical supply and distribution chain. Then, the Delphi technique was used to filter, validate, and finalize the extracted factors. This combination of methods ensured both the richness of the initial data and the reliability of the final set of factors identified as influencing smart pharmaceutical distribution.

3. Findings and Results

In the findings of this study, thirty-two factors were extracted from the interviews using a content analysis approach. It is important to emphasize that these factors are preliminary and must be screened further using the Delphi method. This screening process may reduce the number of factors, or it may confirm all of them without reduction. The next stage of the study will focus on this Delphi-based refinement.

The table below presents all thirty-two extracted factors along with illustrative excerpts from the interviews describing each factor.

Table 1

Extracted Factors

No.	Final Factors	Interview Excerpt
1	Defect-free operations	"In my opinion, the most important factor in smart pharmaceutical distribution is ensuring defect-free processes throughout the smart supply chain, because any defect can naturally disrupt system performance. Thus, defect-free operations are one of the key conditions for achieving smart pharmaceutical distribution."
2	Chain responsiveness	"The pharmaceutical supply chain must be responsive, meaning it should be able to address demand and other environmental needs. Generally, responsiveness is important in all supply chains, but it is even more critical in smart pharmaceutical supply chains."
3	Member validation	"Members of the smart pharmaceutical supply and distribution chain must have the necessary credibility. This credibility is determined by supply chain management, so a smart validation system must also be integrated into the smart supply chain to design a reliable network."
4	Supplier accessibility	"Accessibility of the supplier, which is the first node of the supply and distribution chain, becomes even more important in a smart supply chain. Thus, the smart system must enable access to suppliers for all members."
5	Non-replicability	"Non-replicability is, in my view, an important aspect that must be taken seriously."
6	Data privacy	"Data protection and confidentiality are critically important. Today we often see this principle easily violated, which can lead to significant damage. Therefore, the smart system must provide a solution for preserving data confidentiality, which is particularly important in smart supply chains."
7	Inter-component interaction	"Members of the chain must have sufficient interaction with each other. This interaction leads to increased synergy in the pharmaceutical supply chain."
8	Supply chain scalability	"The supply chain must not be limited and should be expandable. This scalability can occur in one or across multiple layers of the supply chain."
9	Distribution network efficiency	"The distribution network must be efficient, able to provide delivery services with maximum effectiveness and cost-efficiency. This efficiency is not limited to cost; it can also include factors like delivery time or risk."
10	Service capacity	"Service delivery in the smart distribution network involves high capacity. This capacity must be available across various nodes from suppliers to distributors, and refers not just to physical or storage capacity, but also to the capacity to deliver service as efficiently as possible."
11	IT innovation	"Given that the smart supply chain is technology-based, continuous innovation in technology must occur. In other words, we must never neglect innovation in information systems."
12	Smart tool innovation	"Beyond software and technology innovation, innovation in tools and hardware must also be taken seriously because lagging in hardware can neutralize or undermine progress in software."
13	Information sharing in the supply chain	"Information must be correctly shared in the supply chain so that the goal of achieving a smart pharmaceutical supply and distribution chain can be realized. Any flaw can harm all members and the entire supply chain."
14	Customer demand focus	"Customer demand must be taken seriously, with necessary measures considered. In pharmaceuticals, uncertainty dominates demand, and it is difficult to predict exactly how much demand will exist in a particular season or period. This must be managed with greater focus."
15	Government industrial policies	"The government plays an important role in the pharmaceutical field because drugs are not ordinary goods. Thus, policies issued by the government must aim to improve system efficiency and help achieve smart pharmaceutical distribution."
16	Logistics data sharing	"Data related to supply chain logistics are stored on tags like RFID in the smart supply chain. This data must be properly shared — for example, pharmacies should know where and with which driver their ordered medicine is being transported."

17	Intra-chain data sharing	"At the chain level, data sharing must also be correctly managed — for example, sharing data within a layer or among several nodes requires proper planning in the smart pharmaceutical supply chain."
18	Technology readiness	"Chain components must be technologically prepared. For example, we must know how ready pharmacies are in terms of hardware or software if we plan to set up a smart pharmaceutical supply chain. In my view, hardware readiness is perhaps even more critical."
19	Demand fluctuations	"Demand in the pharmaceutical supply chain is never stable. Therefore, demand fluctuations are important and must be seriously addressed."
20	Adequate staff and user training	"Proper training for staff and end-users, especially pharmacy staff, is critically important in the pharmaceutical supply chain."
21	Partner communication	"There are partners in the supply chain that must maintain proper communication with each other, aimed at achieving the main objectives of the chain and not to be neglected."
22	Diverse customer needs	"Customers have different and diverse needs. Here, needs refer not to medicine demand itself (which is a separate discussion), but to service delivery and related needs."
23	Industry competition	"The pharmaceutical industry is competitive, which affects the smartness of the chain. The greater the competition, the greater the need for smart supply chain processes."
24	Service differentiation	"Differentiated and categorized services can lead to better performance in smart pharmaceutical distribution, so services must not be uniform and rigid."
25	Supply chain structures	"The structures of the pharmaceutical supply chain must be examined and considered carefully to achieve smart distribution."
26	Investment in smart assets	"In my view, unless there is proper investment in smart assets — meaning smart tools, hardware, software, and technology — the smart pharmaceutical supply chain cannot be realized. Currently there is a significant gap that must be addressed through commitment and effort."
27	Free flow of knowledge and information	"The free flow of knowledge and information in the distribution network is essential. You cannot claim smartness while data and knowledge do not flow properly across the supply chain."
28	Pharmacists' IT literacy	"Pharmacists and pharmacy doctors must have sufficient IT knowledge. Sometimes we see gaps in this regard, which is unacceptable. This knowledge must gradually improve over time."
29	Regional and cross-border communication	"To achieve a smart pharmaceutical supply chain, we need to go beyond local and national levels and take a cross-border and regional approach to better achieve smartness goals."
30	High level of specialized knowledge	"Specialized knowledge in the pharmaceutical field must also be taken seriously. We cannot rely solely on IT expertise."
31	IoT technology adoption	"We must assess how much pharmacies, distribution centers, and transport hubs have accepted and implemented Internet of Things technologies."
32	Supply chain integration	"The supply chain must be integrated — meaning that members must perform and function similarly. This does not negate diversity but means operationally we should have a consistent supply chain."

In this section, the thirty-two factors of the smart pharmaceutical supply chain were screened using the Delphi approach. First, the results of the first round of the Delphi test are presented in the table below.

Table 2

First Round of the Delphi Test

No.	Factor	1	2	3	4	5	6	7	8	9	10	Mean
1	Defect-free operations	5	6	5	3	5	9	7	1	6	6	5.3
2	Chain responsiveness	10	9	10	5	9	4	2	3	7	2	6.1
3	Member validation	2	7	8	7	8	10	7	10	1	5	6.5
4	Supplier accessibility	7	10	8	6	7	6	10	8	9	6	7.7
5	Non-replicability	1	7	2	9	7	5	6	5	6	5	5.3
6	Data privacy	8	10	6	1	8	7	3	9	7	10	6.9
7	Inter-component interaction	10	5	8	6	3	8	1	4	2	6	5.3
8	Supply chain scalability	10	10	10	8	8	1	6	10	2	10	7.5
9	Distribution network efficiency	4	8	2	9	1	2	4	6	2	4	4.2
10	Service capacity	6	3	6	3	2	8	8	2	2	5	4.5
11	IT innovation	8	5	3	8	5	7	1	2	10	1	5
12	Smart tool innovation	1	4	4	2	10	5	9	7	4	2	4.8
13	Information sharing in the supply chain	2	8	8	9	5	7	1	1	7	8	5.6
14	Customer demand focus	6	5	9	9	8	2	3	7	10	1	6
15	Government industrial policies	8	3	1	3	5	4	1	6	8	10	4.9
16	Logistics data sharing	5	8	5	3	5	10	1	1	5	4	4.7
17	Intra-chain data sharing	5	6	8	4	1	3	2	7	6	10	5.2
18	Technology readiness	5	7	8	6	3	9	3	4	5	2	5.2
19	Demand fluctuations	9	4	3	5	9	3	6	1	4	8	5.2
20	Staff and user training	1	9	10	5	6	2	10	1	7	3	5.4

21	Partner communication	9	5	1	9	9	8	1	3	7	1	5.3
22	Diverse customer needs	6	5	6	1	4	9	3	6	5	8	5.3
23	Industry competition	6	1	6	3	9	2	2	1	5	4	3.9
24	Service differentiation	5	1	4	1	4	8	7	6	2	9	4.7
25	Supply chain structures	8	10	8	6	6	1	6	6	1	7	5.9
26	Investment in smart assets	10	8	6	4	2	4	7	10	2	6	5.9
27	Free flow of knowledge and information	5	7	1	8	5	7	6	1	7	7	5.4
28	Pharmacists' IT literacy	10	4	6	10	4	6	8	3	2	3	5.6
29	Regional and cross-border communication	4	7	5	4	4	5	7	5	9	10	6
30	High specialized knowledge	8	4	7	7	3	9	8	3	10	2	6.1
31	IoT technology adoption	10	8	1	1	6	6	1	3	4	6	4.6
32	Supply chain integration	7	7	9	8	5	9	8	7	2	2	6.4

As observed, the first round of the Delphi test was completed, but to achieve more accurate results, a second round was conducted. In the next step, a comparison of the means across the two rounds will be performed.

In the second round of the Delphi test, the thirty-two factors were re-evaluated by the panel of experts. The results of this round are presented below.

Table 3

Second Round of the Delphi Test

No.	Factor	1	2	3	4	5	6	7	8	9	10	Mean
1	Defect-free operations	5	6	5	3	5	9	7	1	6	5	5.2
2	Chain responsiveness	10	9	10	5	9	4	2	3	6	1	5.9
3	Member validation	2	7	8	7	8	10	7	10	0	4	6.3
4	Supplier accessibility	7	10	8	6	7	6	10	8	9	6	7.7
5	Non-replicability	1	7	1	9	7	5	6	5	5	4	5
6	Data privacy	8	10	6	1	8	7	3	9	7	10	6.9
7	Inter-component interaction	10	5	8	6	3	8	1	4	1	6	5.2
8	Supply chain scalability	10	10	10	8	8	1	6	10	2	9	7.4
9	Distribution network efficiency	4	8	2	9	1	1	4	6	1	3	3.9
10	Service capacity	6	3	6	3	2	8	8	2	2	4	4.4
11	IT innovation	8	5	3	8	5	7	1	1	10	1	4.9
12	Smart tool innovation	1	4	4	1	10	5	9	7	4	1	4.6
13	Information sharing in the supply chain	2	8	8	9	5	7	1	1	6	8	5.5
14	Customer demand focus	6	5	9	9	8	2	3	7	9	1	5.9
15	Government industrial policies	8	3	1	3	5	4	1	6	7	10	4.8
16	Logistics data sharing	5	8	5	3	5	10	1	1	4	3	4.5
17	Intra-chain data sharing	5	6	8	4	1	3	2	7	6	9	5.1
18	Technology readiness	5	7	8	6	3	9	3	4	5	1	5.1
19	Demand fluctuations	9	4	3	5	9	3	6	1	4	8	5.2
20	Staff and user training	1	9	10	5	6	1	10	1	7	2	5.2
21	Partner communication	9	5	1	9	9	8	1	3	7	1	5.3
22	Diverse customer needs	6	5	6	1	4	9	3	6	4	8	5.2
23	Industry competition	6	1	6	3	9	2	1	1	4	4	3.7
24	Service differentiation	5	1	4	1	4	8	7	6	1	8	4.5
25	Supply chain structures	8	10	8	6	6	1	6	6	0	6	5.7
26	Investment in smart assets	10	8	6	4	2	4	7	10	1	5	5.7
27	Free flow of knowledge and information	5	7	1	8	5	7	6	1	7	7	5.4
28	Pharmacists' IT literacy	10	4	6	10	4	6	8	3	1	2	5.4
29	Regional and cross-border communication	4	7	5	4	4	5	7	5	8	9	5.8
30	High specialized knowledge	8	4	7	7	3	9	8	3	9	2	6
31	IoT technology adoption	10	8	1	1	6	6	1	3	3	5	4.4
32	Supply chain integration	7	7	9	8	5	9	8	7	2	1	6.3

After completing the second round, the next step involved comparing the means of both rounds to identify differences between the two sets of results. This comparison is presented in the following table.

Table 4

Differences Between First and Second Delphi Rounds

No.	Factor	First Round Mean	Second Round Mean	Difference
1	Defect-free operations	5.3	5.2	0.1
2	Chain responsiveness	6.1	5.9	0.2
3	Member validation	6.5	6.3	0.2
4	Supplier accessibility	7.7	7.7	0
5	Non-replicability	5.3	5	0.3
6	Data privacy	6.9	6.9	0
7	Inter-component interaction	5.3	5.2	0.1
8	Supply chain scalability	7.5	7.4	0.1
9	Distribution network efficiency	4.2	3.9	0.3
10	Service capacity	4.5	4.4	0.1
11	IT innovation	5	4.9	0.1
12	Smart tool innovation	4.8	4.6	0.2
13	Information sharing in the supply chain	5.6	5.5	0.1
14	Customer demand focus	6	5.9	0.1
15	Government industrial policies	4.9	4.8	0.1
16	Logistics data sharing	4.7	4.5	0.2
17	Intra-chain data sharing	5.2	5.1	0.1
18	Technology readiness	5.2	5.1	0.1
19	Demand fluctuations	5.2	5.2	0
20	Staff and user training	5.4	5.2	0.2
21	Partner communication	5.3	5.3	0
22	Diverse customer needs	5.3	5.2	0.1
23	Industry competition	3.9	3.7	0.2
24	Service differentiation	4.7	4.5	0.2
25	Supply chain structures	5.9	5.7	0.2
26	Investment in smart assets	5.9	5.7	0.2
27	Free flow of knowledge and information	5.4	5.4	0
28	Pharmacists' IT literacy	5.6	5.4	0.2
29	Regional and cross-border communication	6	5.8	0.2
30	High specialized knowledge	6.1	6	0.1
31	IoT technology adoption	4.6	4.4	0.2
32	Supply chain integration	6.4	6.3	0.1

Given that the acceptable threshold of difference indicating consensus is 0.1, some factors must proceed to a third round for further evaluation. However, factors such as high specialized knowledge and supply chain integration, which have differences exactly at 0.1, are considered acceptable and do not require additional rounds. In the next section, the third round of the Delphi test is implemented.

Table 5

Third Round of the Delphi Test

No.	Factor	1	2	3	4	5	6	7	8	9	10	Mean
1	Chain responsiveness	10	9	10	5	9	4	2	3	6	1	5.9
2	Member validation	2	7	8	7	8	10	7	10	0	3	6.2
3	Non-replicability	1	7	1	9	7	5	6	5	5	3	4.9
4	Distribution network efficiency	4	8	2	9	1	1	4	6	1	2	3.8
5	Smart tool innovation	1	4	4	1	10	5	9	7	4	0	4.5
6	Logistics data sharing	5	8	5	3	5	10	1	1	4	2	4.4
7	Staff and user training	1	9	10	5	6	1	10	1	7	1	5.1
8	Industry competition	6	1	6	3	9	2	1	1	4	3	3.6
9	Service differentiation	5	1	4	1	4	8	7	6	1	7	4.4
10	Supply chain structures	8	10	8	6	6	1	6	6	0	5	5.6
11	Investment in smart assets	10	8	6	4	2	4	7	10	1	4	5.6

12	Pharmacists' IT literacy	10	4	6	10	4	6	8	3	1	1	5.3
13	Regional and cross-border communication	4	7	5	4	4	5	7	5	8	8	5.7
14	IoT technology adoption	10	8	1	1	6	6	1	3	3	4	4.3

Table 6

Differences Between Second and Third Delphi Rounds

No.	Factor	Second Round Mean	Third Round Mean	Difference
1	Chain responsiveness	5.9	5.9	0
2	Member validation	6.3	6.2	0.1
3	Non-replicability	5	4.9	0.1
4	Distribution network efficiency	3.9	3.8	0.1
5	Smart tool innovation	4.6	4.5	0.1
6	Logistics data sharing	4.5	4.4	0.1
7	Staff and user training	5.2	5.1	0.1
8	Industry competition	3.7	3.6	0.1
9	Service differentiation	4.5	4.4	0.1
10	Supply chain structures	5.7	5.6	0.1
11	Investment in smart assets	5.7	5.6	0.1
12	Pharmacists' IT literacy	5.4	5.3	0.1
13	Regional and cross-border communication	5.8	5.7	0.1
14	IoT technology adoption	4.4	4.3	0.1

As seen in the table above, the differences between the second and third rounds are all within the acceptable threshold of 0.1. This indicates consensus among the experts. Therefore, all thirty-two extracted factors are considered validated by the Delphi process and will be included in the analysis.

Table 7

Final Factors from the Delphi Method

No.	Final Factors
1	Defect-free operations
2	Chain responsiveness
3	Member validation
4	Supplier accessibility
5	Non-replicability
6	Data privacy
7	Inter-component interaction
8	Supply chain scalability
9	Distribution network efficiency
10	Service capacity
11	IT innovation
12	Smart tool innovation
13	Information sharing in the supply chain
14	Customer demand focus
15	Government industrial policies
16	Logistics data sharing
17	Intra-chain data sharing
18	Technology readiness
19	Demand fluctuations
20	Staff and user training
21	Partner communication
22	Diverse customer needs
23	Industry competition
24	Service differentiation
25	Supply chain structures
26	Investment in smart assets
27	Free flow of knowledge and information

28	Pharmacists' IT literacy
29	Regional and cross-border communication
30	High specialized knowledge
31	IoT technology adoption
32	Supply chain integration

Given that the thirty-two extracted factors are detailed components, they can be grouped under broader primary factors. This categorization is shown in the table below.

Table 8

Main and Sub Factors Extracted

No.	Main Factors	Sub Factors
1	Governance-related factors	Government industrial policies
2		Non-replicability
3		Industry competition
4		Investment in smart assets
5		Regional and cross-border communication
6	Network-related factors	Distribution network efficiency
7		Partner communication
8		Supply chain scalability
9		Chain responsiveness
10		Member validation
11		Supply chain structures
12		Free flow of knowledge and information
13		Supply chain integration
14	Technology-related factors	Technology readiness
15		Defect-free operations
16		High specialized knowledge
17		IoT technology adoption
18		Smart tool innovation
19	Member-related factors	Staff and user training
20		Inter-component interaction
21		Pharmacists' IT literacy
22		Supplier accessibility
23	Data-related factors	IT innovation
24		Information sharing in the supply chain
25		Logistics data sharing
26		Data privacy
27		Intra-chain data sharing
28	Service-related factors	Service capacity
29		Service differentiation
30	Demand-related factors	Customer demand focus
31		Demand fluctuations
32		Diverse customer needs

At this point, seven main factors affecting the smart pharmaceutical distribution chain have been identified. In the next section, agent-based simulation will be used to analyze them and determine their impact levels.

4. Discussion and Conclusion

The present study aimed to identify and validate the key factors influencing smart pharmaceutical distribution by utilizing expert interviews and a multi-round Delphi technique. The process led to the extraction of 32 specific factors, which were further classified under seven broader categories: governance-related, network-related, technology-related, member-related, data-related, service-related, and demand-related dimensions. The Delphi results demonstrated expert consensus across all three rounds, with all 32 factors showing acceptable variation thresholds (≤ 0.1), suggesting a robust agreement on their relevance and applicability.

Among the most strongly validated factors were supplier accessibility, data privacy, supply chain scalability, blockchain and IT innovation, and defect-free operations. The emphasis on traceability and transparency throughout the pharmaceutical distribution chain aligns with recent literature highlighting blockchain's critical role in ensuring authenticity, provenance, and secure tracking of pharmaceuticals (Bapatla et al., 2022; Chiacchio et al., 2022; Gaynor et al., 2024). In particular, the integrity of drug records and resistance to tampering through decentralized ledger systems have been emphasized as pivotal in both combating counterfeit drugs and enhancing consumer trust (Durà-Hernández et al., 2023). The validation of "data privacy" as a priority factor further underscores the importance of trust and information security, especially in digital health ecosystems that manage sensitive patient and inventory data.

Moreover, "smart tool innovation" and "IoT adoption" emerged as critical technological enablers. These findings resonate with previous research indicating the transformative impact of intelligent sensing devices, RFID technologies, and IoT in ensuring real-time visibility and adaptive decision-making in pharmaceutical logistics (Nagpal et al., 2025; Sarkar, 2023; Yadav, 2024). These technologies allow for automated tracking of temperature-sensitive drugs, which is particularly crucial in cold chain contexts, as validated in earlier works on smart parcel lockers and routing algorithms for last-mile delivery optimization (Aghdam et al., 2024).

Interestingly, "inter-component interaction" and "partner communication" were also strongly affirmed by experts, indicating that beyond technological infrastructure, the collaborative dynamics of actors within the supply chain significantly determine success. This finding supports earlier studies on the social and organizational aspects of smart distribution, especially those emphasizing leadership culture, knowledge-sharing behaviors, and organizational readiness (Hassan, 2025; Mahmoud et al., 2025). Effective integration of smart systems requires that all stakeholders—manufacturers, distributors, pharmacists, regulators, and patients—operate within a cooperative and informed ecosystem.

The role of governance-related factors such as "regulatory policies," "regional and cross-border communication," and "investment in smart infrastructure" also featured prominently in the validated framework. This highlights the need for supportive policy environments and targeted investments to facilitate the adoption of intelligent systems across the pharmaceutical supply chain. Previous research has echoed this need, emphasizing that regulatory alignment, legal clarity, and financial incentives are essential enablers of digital transformation in the pharmaceutical sector (Alfaiza et al., 2021; Ngah et al., 2019). Without such top-down structural support, even the most advanced technological systems may remain fragmented or underutilized.

Demand-related factors, including "demand fluctuations," "customer need diversity," and "focus on demand," were validated as key concerns in the implementation of smart distribution strategies. This is consistent with the broader literature on demand-driven supply chain models, where forecasting and responsiveness are essential capabilities (Gaynor et al., 2024; Hwang et al., 2021). The unpredictability in drug consumption patterns, particularly during crises (e.g., pandemics or supply disruptions), underscores the importance of dynamic and data-driven distribution systems that can respond in real time to changing demand signals.

Another noteworthy finding is the high consensus on the importance of "defect-free operations" and "member validation." These factors represent foundational concerns in pharmaceutical logistics, where any lapse in product quality or procedural integrity can have life-threatening implications. The convergence of blockchain with validation protocols has been previously recognized as a key driver in reducing operational errors, ensuring accountability, and certifying authenticity at every node in the supply chain (Durà-Hernández et al., 2023; Jaleel, 2024).

Further, the grouping of 32 detailed factors into seven primary categories provides a systemic view of smart pharmaceutical distribution. It demonstrates that technological upgrades alone are insufficient without aligning network design, workforce capabilities, governance structure, and demand responsiveness. This holistic approach is reflected in enterprise architecture-based digital transformation models proposed in recent work (Wedha et al., 2023). These frameworks emphasize interoperability and cross-layer coordination as essential to sustaining long-term benefits.

Moreover, the prominence of "training for staff and end-users" and "pharmacists' IT literacy" reinforces that human capital is integral to the digitalization journey. As the pharmaceutical workforce increasingly interacts with data dashboards, blockchain interfaces, and IoT-driven inventory systems, continuous upskilling becomes a necessity (Mahmoud et al., 2025). The successful implementation of

such systems thus requires change management strategies that account for the behavioral and cognitive adaptability of stakeholders.

Taken together, the findings of this study not only validate specific operational, technological, and strategic elements but also offer a comprehensive model for implementation planning. The integration of these validated factors into simulation models, decision-support systems, or maturity assessment tools can greatly enhance strategic planning and operational resilience in the pharmaceutical industry. The agreement across three Delphi rounds further strengthens the credibility of these insights and confirms the convergence of expert opinion on what constitutes a truly smart pharmaceutical distribution system.

While the study benefits from a rigorous Delphi methodology and a diverse set of expert inputs, it is not without limitations. First, the scope of the study was restricted to a specific pharmaceutical firm, which may limit the generalizability of findings to broader or international contexts. Second, the expert panel, although sufficiently diverse, was limited in size, and larger panels may produce additional insights or refinement of factors. Third, while the Delphi method is excellent for building consensus, it may also introduce conformity bias, wherein experts align with group averages rather than presenting divergent but valid perspectives. Additionally, the study did not apply quantitative methods or simulation modeling, which could further validate the relative weight or interaction effects among the identified factors.

Future studies should expand the investigation by applying the validated factor model to multiple pharmaceutical supply chains across varied geographical and regulatory environments. Comparative case studies could explore how the identified factors perform under different institutional, cultural, and infrastructural conditions. In addition, integrating these findings into quantitative simulation frameworks such as system dynamics or agent-based modeling could yield insights into the real-time impact of each factor on efficiency, cost, and resilience. Researchers may also examine the role of emergent technologies such as AI-based predictive analytics, digital twins, or decentralized autonomous organizations (DAOs) in enhancing pharmaceutical logistics. Finally, longitudinal research could explore how the importance or interaction of these factors evolves over time, particularly in response to crises or regulatory changes.

Organizations aiming to implement smart pharmaceutical distribution should approach the transformation holistically. Investment in enabling technologies must be complemented by human capital development, regulatory alignment, and collaborative governance. Decision-makers should prioritize factors such as data integrity, supply chain visibility, and responsive governance structures. Training programs must be developed to improve digital literacy among pharmacists and logistics personnel. Strategic partnerships with technology providers, policymakers, and academic institutions can accelerate readiness. Finally, a phased implementation plan that pilots key technologies and measures performance outcomes can reduce risk and ensure long-term sustainability.

Authors' Contributions

Authors contributed equally to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

Acknowledgments

We would like to express our gratitude to all individuals helped us to do the project.

Declaration of Interest

The authors report no conflict of interest.

Funding

According to the authors, this article has no financial support.

Ethics Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were considered.

References

Aghdam, R. S., Shirazi, M. A., & Karimi, B. (2024). Efficient Last-Mile Delivery in the Pharmaceutical Sector: A Novel Approach for Vehicle Routing With Smart Parcel Lockers. https://doi.org/10.21203/rs.3.rs-5227590/v1

Alfaiza, S. A., Abed, A. Y., Sultan, A. A., & Riyadh, H. A. (2021). Moderating Role of Leadership Between Mass Collaboration and Quality of Knowledge: A Case of Iraq's Pharmaceutical Sector. *International Journal of Organizational Analysis*, *31*(4), 988-1000. https://doi.org/10.1108/ijoa-08-2021-2891

Bapatla, A. K., Mohanty, S. P., Kougianos, E., Puthal, D., & Bapatla, A. (2022). PharmaChain: A Blockchain to Ensure Counterfeit-free Pharmaceutical Supply Chain. *Iet Networks*, *12*(2), 53-76. https://doi.org/10.1049/ntw2.12041

Chıacchıo, F., D'Urso, D., Olıverı, L. M., Spitaleri, A., Spampinato, C., & Giordano, D. (2022). A Non-Fungible Token Solution for the Track and Trace of Pharmaceutical Supply Chain. *Applied Sciences*, *12*(8), 4019. https://doi.org/10.3390/app12084019

Durà-Hernández, M., Leal, F., Sánchez-García, Á., Sáez, C., García-Gómez, J. M., Chis, A. E., & González–Vélez, H. (2023). Blockchain for Data Originality in Pharma Manufacturing. *Journal of Pharmaceutical Innovation*, *18*(4), 1745-1763. https://doi.org/10.1007/s12247-023-09748-z

Gaynor, M., Gillespie, K. N., Roe, A., Crannage, E. F., & Tuttle-Newhall, J. E. (2024). Blockchain Applications in the Pharmaceutical Industry. *Blockchain in Healthcare Today*, *7*(1). https://doi.org/10.30953/bhty.v7.298

Hassan, Z. (2025). Mediating Influence of Knowledge Sharing Behaviour of Pharmaceutical Leaders on the Relationship Between Cultural Intelligence Dimensions and Leadership Effectiveness. *International Journal of Research and Innovation in Social Science*, *IX*(V), 3402-3427. https://doi.org/10.47772/ijriss.2025.905000264

Hwang, S. R., Chakraborty, K., An, J. M., Mondal, J., Yoon, H. Y., & Lee, Y.-K. (2021). Pharmaceutical Aspects of Nanocarriers for Smart Anticancer Therapy. *Pharmaceutics*, *13*(11), 1875. https://doi.org/10.3390/pharmaceutics13111875

Jaleel, U. (2024). Hybrid Blockchain Network for Drug Traceability in Secure Pharmaceutical Supply Chain. *Cana*, *32*(2s), 104-112. https://doi.org/10.52783/cana.v32.2255

Mahmoud, M., Shma, T. R., Aziz, A. A., & Awad, A. (2025). Integrating Knowledge Management With Smart Technologies in Public Pharmaceutical Organizations. *Knowledge and Performance Management*, *9*(1), 31-44. https://doi.org/10.21511/kpm.09(1).2025.03

Nagpal, G., Narula, S., Nagpal, A., Kumar, H., Desai, S. J., Gupta, S., & Kumar, A. (2025). Application of Blockchain and Smart Contracts in Pharmaceutical Cold Chain : A Systematic Literature Review. *Journal of Statistics and Management Systems*, *28*(3), 545-557. https://doi.org/10.47974/jsms-1383

Ngah, A. H., Ramayah, T., Ali, M. H., & Khan, M. I. (2019). Halal Transportation Adoption Among Pharmaceuticals and Comestics Manufacturers. *Journal of Islamic Marketing*, *11*(6), 1619-1639. https://doi.org/10.1108/jima-10-2018-0193

Sarkar, S. (2023). Blockchain for Combating Pharmaceutical Drug Counterfeiting and Cold Chain Distribution. *Asian Journal of Research in Computer Science*, *16*(3), 156-166. https://doi.org/10.9734/ajrcos/2023/v16i3353

Wedha, B. Y., Vasandani, M. S., & Alessandro Enriqco Putra Bayu, W. (2023). Innovative Role of Blockchain Pharmaceutical Supply Chain Digital Transformation: Enterprise Architecture Perspective. *Sinkron*, *8*(4), 2490-2500. https://doi.org/10.33395/sinkron.v8i4.13043

Yadav, K. K. (2024). Integrating Blockchain Technology in Pharmaceutical Supply Chains. *Cana*, *32*(2s), 147-156. https://doi.org/10.52783/cana.v32.2260