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Analysis of barriers to blockchain adoption in the oil industry supply chain: A supply chain governance based approach

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ABSTRACT

The emergence of blockchain technology has transformed the way transactions are conducted and has reshaped the scale and operational domains of organizations. One of the key areas influenced by this transformation is the supply chain. For data-driven industries such as the oil industry, blockchain as a core enabler of supply chain digitalization can provide substantial benefits. However, the implementation of blockchain in the oil industry's supply chain, which operates within a governance-intensive and highly regulated structure, faces numerous obstacles and challenges. This study aims to identify and rank the barriers to blockchain adoption in the oil supply chain, considering technical, organizational, environmental, and particularly supply chain governance dimensions. After reviewing the theoretical literature, the barriers were identified and their relative importance was evaluated using the Bayesian Best–Worst Method (Bayesian BWM) in a case study of the National Iranian Oil Products Refining and Distribution Company. The findings indicate that the lack of necessary policies and regulations, cybersecurity threats, traceability concerns, and scalability and weak consensus protocols are the most critical barriers to blockchain adoption. These results highlight the pivotal role of governance and regulatory mechanisms in determining the success or failure of blockchain implementation. Based on the findings, managerial, operational, and governance-oriented recommendations are proposed.

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1. Introduction

In early 2020, when a series of mismatches in shipment documentation and contract verification disrupted refined-products distribution across parts of the Middle East, observers were reminded of an uncomfortable reality: despite massive investments in seismic imaging, automation, and production optimization, the informational backbone of the oil industry remains remarkably fragile. Delays in confirming transaction records, inconsistencies in quality certificates, and disputes over delivery documentation continue to create operational friction and elevate risk exposure in an industry where even short interruptions carry considerable financial and political consequences (Vazquez Melendez et al., 2024). These incidents made visible what insiders have long known—oil supply chains are not just operational infrastructures; they are governance systems whose stability depends on the integrity, synchronization, and auditability of data flows. Against this backdrop, blockchain emerged as a potential antidote to long-standing weaknesses in interorganizational coordination, transparency, and traceability (Lu et al., 2019).

The emergence of blockchain technology has influenced the way of many activities in different organizational fields(Ghorbani et al., 2025). Blockchain, understood as a distributed and tamper-resistant ledger, offers the ability to record transactions and track assets in a shared environment without relying on centralized intermediaries (Chang et al., 2022). For data-intensive sectors such as oil, where supply chains span multiple jurisdictions, diverse regulatory regimes, and heterogeneous organizational arrangements, this technology promises to reduce information asymmetries, curb opportunities for fraud, and streamline verification processes (Budak & Çoban, 2021). Yet these promises sit uneasily alongside the empirical reality. The oil industry—known for its technological prowess in exploration and production—has been markedly slower to integrate blockchain into core supply chain activities, even when the underlying technical fit appears strong (Dutta & Banerjee, 2018; Jabbar et al., 2021). This inconsistency generates a crucial empirical and theoretical tension: why does an industry that routinely adopts sophisticated engineering technologies hesitate when faced with a digital infrastructure that could, in principle, enhance transparency, collaboration, and operational efficiency?

Much of the existing literature attributes this gap to classic categories of adoption barriers, including technological immaturity, cost of implementation, interoperability challenges, and insufficient cybersecurity provisions (Cocco et al., 2017; Dasgupta et al., 2019; Hewa et al., 2021; Ko et al., 2018). These explanations illuminate parts of the puzzle but leave other aspects unresolved. They tend to treat blockchain adoption as a primarily technical or organizational decision, underplaying the fact that supply chains—especially in critical sectors such as oil—are embedded in complex governance structures. These structures define the rules of interaction, determine how responsibility and risk are allocated, and mediate what kinds of technologies become thinkable or legitimate for adoption (Kouhizadeh et al., 2021). The empirical divergence between technological potential and actual adoption suggests that barriers cannot be understood solely through a technical lens; rather, they are intertwined with policy, regulation, interorganizational coordination, and mechanisms of trust embedded in the supply chain.

Three streams of literature help clarify this tension. The first focuses on the technical and functional properties of blockchain, emphasizing its capacity to ensure immutability, traceability, and secure automation through smart contracts (Hewa et al., 2021; Maesa & Mori, 2020). While these studies establish the technology's promise, they often assume that organizations face few institutional constraints when embedding distributed ledgers into existing processes.

A second stream examines barriers across business and industrial supply chains (Oliveira & Handfield, 2019). These studies report hurdles such as limited managerial expertise, inadequate digital infrastructure, misaligned incentives among supply chain partners, and uncertainty about return on investment (Dobrovnik et al., 2018; Sharma & Joshi, 2021). Although they broaden the scope beyond technology itself, they still do not fully account for the governance complexity that defines sectors like oil.

A third and more recent stream highlights the governance dimensions of blockchain adoption, arguing that the absence of regulatory clarity, standardized protocols, and cross-organizational policies can hinder implementation more severely than technical constraints (Polcumpally et al., 2024; Sciarelli et al., 2022). This body of work shows that blockchain is not merely a technological innovation but a governance innovation whose effectiveness depends on alignment among regulators, firms, and supply chain partners.

Building on these insights, this study adopts the premise that the core mechanism shaping blockchain adoption in the oil supply chain is the interaction between technical feasibility, organizational readiness, and supply chain governance capacity. Adoption is unlikely to succeed when these layers are misaligned. For example, even if technical solutions exist, a lack of standardized audit protocols or unclear responsibility-sharing arrangements may generate legal ambiguity and discourage investment. Similarly, when traceability features collide with geopolitical or sanctions-related sensitivities—as in the Iranian context—blockchain's transparency, which is a technical advantage in many sectors, may become a perceived liability (Jabbar et al., 2021; Zhao et al., 2022). Thus, the interplay among governance, coordination, and technology constitutes the causal logic that motivates this inquiry.

This logic leads to two guiding research questions:

(1) What are the principal barriers—across environmental, organizational, technological, and governance dimensions—that constrain blockchain adoption in the oil industry supply chain?

(2) How do these barriers compare in relative importance, and which ones exert the most structural influence on adoption outcomes?

To address these questions, the study applies the Bayesian Best–Worst Method (Bayesian BWM), a multi-criteria decision-making approach that integrates expert judgments while systematically managing uncertainty(Munim et al., 2022; Rezaei, 2016). This method is particularly suited to contexts such as the oil sector, where knowledge about emerging technologies is distributed unevenly across organizational actors and where coordinated judgments are essential for meaningful prioritization. The empirical setting—National Iranian Oil Products Refining and Distribution Company—provides a revealing test case. As one of the largest and most governance-intensive supply chain systems in the region, it reflects many of the institutional complexities that shape technology uptake in national energy infrastructures.

Understanding these barriers has substantial governance and managerial relevance. In supply chains that underpin national energy security, weaknesses in documentation, monitoring, and coordination can propagate across the system, reducing operational resilience and undermining regulatory oversight. Identifying the barriers that most severely constrain blockchain adoption can help policymakers, regulators, and industry leaders prioritize interventions, design capacity-building programs, and develop harmonized standards that enable trustworthy data sharing. Beyond the oil sector, the findings speak to broader debates on how digital technologies diffuse in highly regulated industries and how governance frameworks can either accelerate or impede their integration.

Building on a comprehensive and systematic review of the extant literature, the present study seeks to identify and prioritize the most significant barriers to the adoption of blockchain technology in the oil supply chain by employing a group multi-criteria decision-making framework. Accordingly, the barriers extracted from prior studies are organized as the criteria and sub-criteria of the decision-making problem, as summarized in Table 1.

Table 1.
Barriers to Blockchain Adoption in the Oil Supply Chain.

Criterion	Sub-criterion	Source
C1. Environmental Barriers	C11. Need for partner collaboration	(Kouhizadeh et al., 2021)
	C12. Customer uncertainty	
	C13. Market pressures	(Mukherjee et al., 2023)
	C14. Limited involvement of the oil industry in blockchain adoption	
C2. Organizational Barriers	C21. Lack of technological expertise	(Komulainen & Nätti, 2023)
	C22. Lack of implementation tools	
	C23. Lack of benchmark data	(Treiblmaier et al., 2021)
	C24. Absence of relevant policies and regulatory frameworks	
C3. Supply Chain–Related Barriers	C31. Lack of customer awareness of the technology	(Khan et al., 2023)
	C32. Lack of supply chain partner collaboration	(Oliveira & Handfield, 2019)
	C33. Lack of partner coordination	
C4. Technological Barriers	C41. Technological immaturity	(Khan et al., 2023)
	C42. Limited infrastructure	(Liu et al., 2022)
	C43. Cybersecurity threats	(Hewa et al., 2021)
	C44. Scalability issues and weak protocols	
	C45. Traceability limitations	

The remainder of the article unfolds in a manner consistent with this logic of inquiry. The following section details the research methodology, explaining the Bayesian Best–Worst Method (BWM) and the empirical procedures applied to evaluate and rank the identified barriers. The results section presents and discusses the prioritized barriers and their implications for the oil supply chain. Finally, the article concludes by offering governance-oriented recommendations and outlining directions for future research.

2. Methods

The present study is descriptive-analytical in terms of its applied purpose and data collection. Because it has identified, described, and analyzed the barriers to the use of blockchain technology in the oil industry supply chain. In the present study, a library method was used to identify these barriers. On the other hand, a field study was used to distribute a questionnaire among experts in this field, which consisted of a team of 7 people with excellent backgrounds in the field of oil supply chain management, complete familiarity with the topic of blockchain, and interest in collaborating on this research, to prioritize these factors. Because multi-criteria decision-making methods are mainly expert-based and are highly sensitive to the quantity and quality of experts, and the most relevant experts to the research topic should be selected with the least number of experts, the purposive sampling method was judgmental. Considering the purpose of the study, in this study, barriers to the use of blockchain in the supply chain were first identified by a comprehensive review of the research literature. Then, a questionnaire was provided to the experts for pairwise comparisons of indicators, and finally, the importance of the barriers was calculated using the Bayesian BWM technique in the case of studies. Finally, based on the results of statistical analyses, operational solutions were presented to better deal with these obstacles.

The BWM method is one of the modern decision-making techniques that was created in response to the shortcomings and disadvantages of other methods based on pairwise comparison. Based on this method, the best and worst indicators are determined by the decision-maker and a pairwise comparison is made between each of these two indicators (best and worst) and other indicators. Then, a min-max problem is formulated and solved to determine the weights of different indicators(Rezaei, 2016). The Bayesian best-worst method was developed by Mohammadi and Rezaei (2020) to improve the effectiveness of calculating weights and integrating multiple experts. In this study, the following steps were taken to implement the Bayesian BWM method.

Step 1: The set of decision-making indicators is determined.

Step 2: The most important and least important indicators from the perspective of each expert are determined. Also, under each index, the most important and least important sub-index from the point of view of each expert has been determined.

Step 3: The priority of the best index over other indices from the point of view of each expert has been determined with the numbers 1 to 9. Also, in each index, the priority of the best sub-index over all other sub-indexes has been determined with the numbers 1 to 9.

Step 4: The priority of all indices over the worst index from the point of view of each expert has been determined with the numbers 1 to 9. Also, in each index, the priority of the sub-indexes over the worst sub-index has been determined with the numbers 1 to 9.

Step 5: The optimal weight values of each index have been determined. In this step, the weight of each index is calculated based on the concept of statistical distribution. The joint probability distribution equation of group decision-making in this method is Equation 1. By calculating the aforementioned equation, Equation 2 can be used to calculate the probability of each person's variable. In this relation, x and y are random variables. Finally, in the last step, it is necessary to calculate the optimal group weights. The optimal group weight depends on the optimal weight of each decision maker. The equation used to calculate the joint probability distribution is as described in Equation 3. The probability of Equation 3 is calculated by specifying the probability distribution of each element of this equation. The polynomial distribution is as described in Equation 4. After finalizing the probability distribution of all parameters, the posterior probability distribution is calculated using the Markov chain Monte Carlo.

1) $P\ (w^{agg}.w^{1:k} \wr A_B^{1:k}.A_W^{1:k})$

2) $PP\ (x) = \sum_y P\ (x.y)$

3) $P\ (w^{agg}.w^{1:k} | A_B^{1:k}.A_W^{1:k}) \propto p\ (A_B^{1:k}.A_W^{1:k} | w^{agg}.w^{1:k}) P\ (w^{agg}.w^{1:k})$

4) $A_B^k \Big| w^k) \sim multinomial\ \left(\frac{1}{w^k}\right).(A_W^k | w^k) \sim multinomial(w^k). \forall_k = 1.2. \dots .k$

5) $P(C_i > C_j) = \int I\left(W_i^{agg} > W_j^{agg}\right) P\ (W^{agg})$

After calculating the factor weights, the consistency of the results should also be checked. This is achieved by calculating the confidence level of the factor rankings. The probability that C_i is better than C_j is calculated with equation 5. In this equation, W^{agg} is the group weight of the factor, $P\ (W^{agg})$is the posterior probability of W^{agg}, and I is the condition parameter. This parameter can be calculated when the condition $W_i^{agg} > W_j^{agg}$ is satisfied, otherwise the value of the parameter is zero.

3. Results

In this section, using the Bayesian BWM method, the weighting and determination of barriers to the use of blockchain technology in the oil industry supply chain are discussed. Initially, the experts were asked to form a pairwise comparison matrix of the best (most important) index and sub-index to other indices and sub-indexes and a matrix of the worst (least important) index and indices to other indices and sub-indexes based on the identified barriers of the research, which are shown in Table 2 in Table 3, for comparing the best index to other indices, from the perspective of expert number 1, the C4 index is the most important index and is shown with an acquired value of 1 in the matrix. In addition, from the perspective of this expert, the C4 index is 5 times more preferable than the C1 index, 3 times more preferable than the C2 index, and 6 times more preferable than the C3 index. Also, Table 4 and Table 5 show the matrix of pairwise comparisons of the least important index/sub-indices to other indices and sub-indices.

Table 2.
Pairwise comparison matrix of the best index to other indices.

Expert number	1	2	3	4	5	6	7
Best indicator	C4	C4	C4	C4	C2	C2	C2
C1	5	6	5	4	4	4	5
C2	3	4	3	2	1	1	1
C3	6	5	6	6	7	5	7
C4	1	1	1	1	2	2	3

Due to the size limitation of the article, the pairwise comparison matrices of the best and worst sub-index to the other sub-indexes of the second to fourth are not included here, and only the pairwise comparison matrix of the best (and worst) sub-index to the other sub-indexes of the first index is referred to as an example.

Table 3.
Pairwise comparison matrix of the best sub-index to other sub-indexes of the first index.

Expert number	1	2	3	4	5	6	7
Best indicator	C11	C11	C12	C12	C12	C12	C14
C11	1	1	3	4	4	4	3
C12	2	3	1	1	1	1	2
C13	5	7	5	6	6	6	7
C14	4	2	4	5	5	5	1

Table 4.
Pairwise comparison matrix of the worst index to other indices.

Expert number	1	2	3	4	5	6	7
Worst indicator	C3	C3	C3	C3	C1	C1	C3
C1	3	4	4	4	1	1	3
C2	5	6	5	6	4	5	5
C3	1	1	1	1	3	3	1
C4	8	8	8	8	9	9	7

Table 5.
Pairwise comparison matrix of the worst index to other indices.

Expert number	1	2	3	4	5	6	7
Worst indicator	C13	C13	C13	C13	C13	C13	C13
C11	8	8	6	6	6	7	5
C12	6	6	9	9	9	9	7
C13	1	1	1	1	1	1	1
C14	3	5	5	5	5	5	9

Then, according to what was mentioned in the description of this method, after collecting the data, using Matlab R2022a software and the developed computational package, the weights of the indicators and sub-indices of the problem were calculated. Finally, the final weights of the sub-indices were calculated by multiplying the weights of the indicators by the local weight of the sub-indices. Table 6 shows the final weights of each of the indicators and sub-indices.

Table 6.
The final weights of research indices and sub-indices.

Index	Index Weight	Sub-Index	Sub-Index Local Weight	Sub-Index Final Weight
C1	0.14989	C11	0.2921	0.043783706
		C12	0.3844	0.057618818
		C13	0.1005	0.015064233
		C14	0.2228	0.033396131
C2	0.29367	C21	0.2522	0.074064522
		C22	0.1307	0.038383160
		C23	0.1202	0.035299586
		C24	0.4967	0.145867756
C3	0.10808	C31	0.1314	0.053209585
		C32	0.3761	0.053209585
		C33	0.4923	0.053209585
C4	0.44834	C41	0.0992	0.044476292
		C42	0.0660	0.029591081
		C43	0.2923	0.131052623
		C44	0.2671	0.119754210
		C45	0.2751	0.123341008

After calculating the weights of the research indicators and sub-indices, it is time to calculate and rank the factors with confidence. Fig. 1 shows the ranking confidence level of the research indicators. These confidence levels indicate how much the results of the weights obtained from the model are in total desired by the experts providing opinions on the importance of these indicators. As stated in Table 6, technological, organizational, and environmental barriers were the most important barriers to blockchain adoption in the oil supply chain studied, which are arranged in Fig. 1 from top to bottom. The lower the index, the lower its relative importance. On the vectors between the indicators, the degree of confidence indicates the superiority of the arrow origin index over the arrow destination index from the experts' perspective. Overall, at the level of the problem indicators, there is an average of 98% confidence in the opinions, which is considered a high number and indicates high convergence and agreement among the experts.

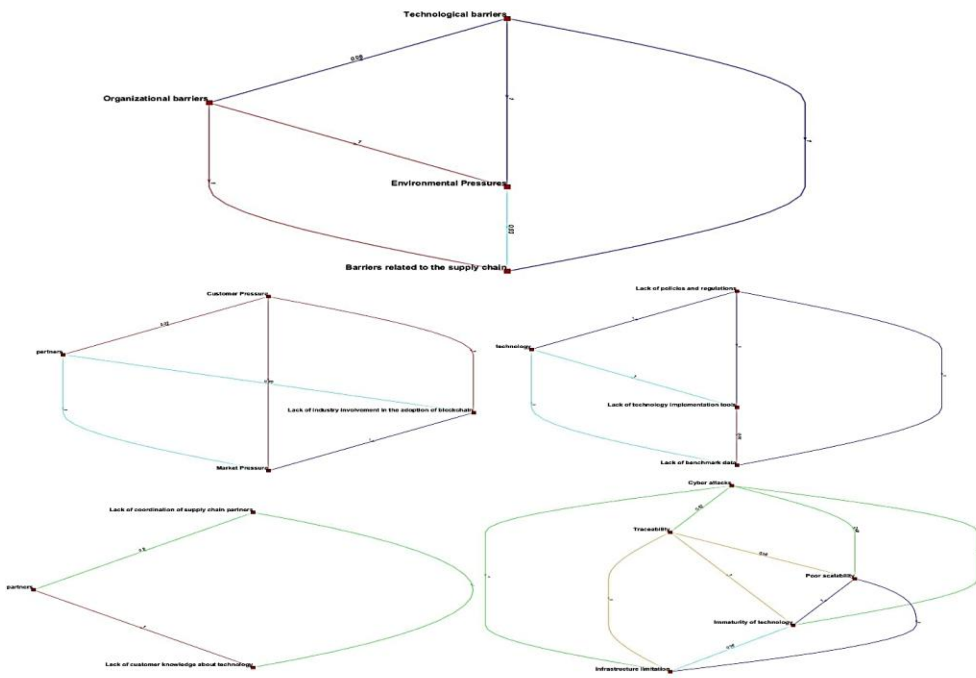

Fig. 1. Confidence degree of priority of research indicators and sub-indices.

4. Discussion

Based on the results obtained according to Table 6 and Fig. 1, technological barriers are by far the most important challenge to the adoption of blockchain technology in the oil supply chain of the National Petroleum Refining and Distribution Company. After that, organizational barriers, environmental barriers, and supply chain-related barriers are the most important challenges to the adoption of blockchain in the oil supply chain in this study, respectively. Also, among the sub-indices of environmental barriers, customer uncertainty, the need for cooperation of supply chain partners, and lack of industry involvement in the adoption of blockchain technology, in the sub-indices of organizational barriers, the sub-indices of lack of necessary policies and regulations, in the supply chain-related barriers index, the sub-indices of lack of coordination of supply chain partners and lack of cooperation of supply chain partners, among the sub-indices of the technological barriers index, the sub-indices of cyber attacks, traceability and scalability, and weak protocols were of the greatest importance. Also, among all the sub-indices of the research, the lack of necessary policies and regulations, cyber attacks, traceability and scalability, and weak protocols were, according to the research experts, the most important barriers to the adoption of blockchain technology in the oil supply chain. The lack of necessary policies and regulations is one of the main barriers to the growth of blockchain, which is the most important challenge in the National Petroleum Refining and Distribution Company. It is noteworthy that despite the lower weight of the organizational barriers index compared to technological barriers, the lack of LARM policies and regulations, which is itself one of the sub-indices of organizational barriers, has acquired the highest local weight. This indicates a severe legislative gap in this area. For the widespread use of this technology and the exploitation of its advantages, the necessary laws must be enacted. To bridge the gap between the performance of this technology and regulations and instructions, it is suggested that senior managers of the Ministry of Oil take a major step, based on the successful experiences of competitors and expert advice, in removing this obstacle to the application of blockchain technology in the oil industry supply chain. This is consistent with the results of the research by Farsijani and Alah Karam Pour (2022).

Regarding other organizational barriers, it is suggested that the company increase organizational expertise in technology by holding applied scientific courses at specialized universities in this field and holding related workshops within the company. Another suggested way to increase expertise in this technology is to attract specialists in the company. Due to the sensitivity of information and data and the criticality of the continuity of this company's supply chain, infrastructure outsourcing is not recommended.

The order of technological challenges is specified according to Table 6 and Fig. 1. The immaturity of blockchain technology in our country causes technological barriers. The most important technological challenge in this research is cyber attacks. In previous years, we witnessed cyber attacks on this company's supply chain. A cyberattack on gas stations on November 25, 2021 caused serious disruptions in the fuel supply process across the country. This cyberattack caused the purchase of gasoline at the government rate, known as rationed gasoline, to be removed from the circuit, and refueling at the free rate was only possible at some gas stations. The company's customers and supply chain partners must accept that their electronic transactions are safer and more complete on a network based on blockchain technology. In blockchain, failure in transactions is not possible, but in the event of theft or loss of private keys, there is a possibility of theft of data and digital assets. Therefore, senior managers and final decision-makers of the company are advised to minimize this risk by building or using an infrastructure network based on blockchain technology. Another risk in this area is the manipulation of 51% of the network nodes, which is practically eliminated when using a blockchain network at the national level. This is in complete agreement with the results of Hewa et al. (2021).

In the context of oil sanctions, blockchain traceability, which is one of the advantages of this technology, becomes a challenge and concern. The risk of financial tracking and accurate identification of buyers and business partners of the company under study makes traceability a challenge for blockchain adoption in the oil supply chain. In other words, data traceability may be subject to abuse by people who have access to the blockchain network. This result is not consistent with the results of research such as Fathi and Sadeghi (2021), Mousavi et al. (2022), and Aslam et al. (2023). This inconsistency is due to the sanctions conditions of the company under study in this study.

Scalability and weak protocols are one of the obstacles to the growth of blockchain, which was also considered a priority in the case of this study. The records of all transactions are recorded in the network, but due to the main limitation of block size and the time interval for creating a new block, the blockchain cannot meet the need to process millions of transactions in real time. On the other hand, there is no possibility of exchange and interaction between two different blockchain protocols. For example, none of the virtual currencies under the Ethereum protocol has the ability to be added to the digital wallet of another currency in the Ethereum protocol. These results are consistent with the results of research such as Aghajani Mir et al. (2022) and Sanka et al. (2021).

5. Conclusions

For a data-driven industry, such as the oil industry, blockchain technology, one of the tools for digitizing the supply chain, can significantly help the industry in various ways. Blockchain is a growing technology that has multiple application areas in the oil industry, which in turn can improve the efficiency of the industry. The oil industry currently has little knowledge about blockchain technology, which is expected to bring transparency, security, and convenience in one place.

Despite the potential role of blockchain in the oil industry supply chain, its application faces obstacles that must be managed appropriately to achieve a competitive blockchain-based supply chain management framework. This study attempted to provide a specific framework to identify the challenges of blockchain technology in the supply chain of the National Petroleum Refining and Distribution Company, and to determine the importance of the challenges so that they can be managed effectively and centrally according to their priority.

In this study, 16 barriers were identified in 4 areas: environmental, organizational, supply chain-related, and technological, and the relative importance of each was calculated using the best-worst Bayesian technique, one of the most modern multi-attribute group decision-making methods. Among all the barriers to the research, the lack of necessary policies and regulations, cyber attacks, traceability and scalability, and weak protocols were, according to the research experts, the most important barriers to the adoption of blockchain technology in the oil supply chain, respectively.

This study was the first in the country to rank the local barriers to the use of blockchain technology in the oil supply chain. Although most of the results of previous research conducted in a similar international environment were confirmed in this study, traceability was specifically stated as a serious challenge in the case of this study.

The results of this study help managers of the National Petroleum Refining and Distribution Company to understand the challenges of adopting blockchain technology and prioritize them in their company, so that, given the limited financial and time resources, they can focus their efforts on important and priority areas. Based on the results of this study, in order to fill the gap between the operationalization of blockchain technology in the oil industry supply chain and the instructions, it is recommended that senior managers of the Ministry of Oil take a major step based on the successful experiences of competitors and specialized consultations in removing the obstacle of "lack of necessary policies, regulations and regulations" in the way of applying blockchain technology in the oil industry supply chain. Increasing the company's expertise in this technology is also one of the other suggestions of this study to senior managers, which was explained in detail in the previous section. Creating a native blockchain network is also recommended to senior managers and decision-makers of this company to eliminate the obstacle of cyber attacks.

The results of this study, which identify “lack of necessary policies and regulations” as one of the most important barriers, in fact reflect a governance vacuum and indicate that to increase the likelihood of blockchain adoption in the oil supply chain, more attention should be paid to the design and implementation of policy and regulatory frameworks than to purely technical or educational solutions. In practice, this means developing national and corporate policies for secure data sharing, standardizing formats and interaction protocols, and establishing coordination mechanisms between actors. At the same time, it is suggested that pilots based on shared governance models and providing compliance templates at the inter-organizational level be pursued as medium-term steps to reduce risk and increase trust in the technology.

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Conflicts of interest

The authors declare no conflict of interest.

Authors contribution statement

Sepehr Ghorbani: Data collection, literature review, methods, analysis, writing.

Yaser Ghaseminezhad: Conceptualization.

Mohammad Taghi Taghavifard: review, editing.

Yingli Wang: review.

Data Availability Statement

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

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