Advances in Industrial Engineering, Spring 2022, 56(2): 199-214
DOI: 10.22059/AIE.2022.341963.1834
RESEARCH PAPER

Evaluating Barriers of Blockchain-Based Platforms Implementation for Subsidized Foods Supply Chains: A Hybrid Approach Based on BWM and WINGS Methods

Alireza Shamekhi Amiri [*]**, Neda Manavizadeh**

Department of Industrial Engineering, Faculty of Engineering, Khatam University, Tehran, Iran.

Received: 21 April 2022, Revised: 05 June 2022, Accepted: 30 June 2022

Abstract

Governments use online platforms to keep track of transactions in the supply chain (SC) of subsidized foods to prevent fraud. Although regular checks of warehouses and documents were conducted, current platforms failed to resolve the issue. Blockchain technology (BT) provides governments with the ability to access transparent and real-time data to address these challenges. In this paper, we examine the key challenges influencing the implementation of a BT platform for managing subsidized food products in Iran. The barriers appear to be interconnected. We present a model that integrates the Best-Worst method (BWM) for obtaining independent weights and the Weighted Influence Non-Linear Gauge System (WINGS) using a rescaling scheme for considering the interrelatedness between the criteria. Expert opinions and literature reviews are used to identify critical factors. According to the findings, the costs of implementing and maintaining the system, as well as the regular restructuring of government rules regarding the data to be collected, are the two main challenges of implementing this new technology. Moreover, there are concerns about the cooperation with downstream entities of SC, cultural differences among partners, and their knowledge level, which may affect the complexity of downstream implementation. The results of sensitivity analysis show that WINGS gives greater weight to factors that have more impact on others. Conversely, the weight of factors that are interwoven with other factors and factors that aren't influenced by other factors is reduced as compared to the independent relative importance obtained from BWM.

Keywords:
Subsidy;
Block Chain Based Platforms;
Supply Chain Management;
Fraud Detection;
Best-Worst Method (BWM);
Weighted Influence Non-Linear Gauge System (WINGS)

Introduction

Subsidies are government incentives and financial aid to microeconomic individuals that allow access to certain products or services at reduced prices to achieve certain political and economic goals [1]. Subsidies in direct or indirect forms are applied by protectionist governments. The Government of India, for example, provides fertilizer to farmers at a controlled price [2]. The Nigerian government provides subsidies for diesel fuel [3]. Subsidies that are planned for a special period of the pandemic are another example [4]. In Iran, subsidies exist for energy [5,6], vegetable oils [7], and bread [8].

The subsidy-based pricing system is one of the main reasons for improper residential electricity consumption. This has caused significant financial strain on the government [42]. Because of the price gap between the controlled price and market price, corruption and fiscal scams in the form of theft, making fake documents, or giving out invalid information is

[*] Corresponding author: (A. Shamekhi Amiri)
Email: a.shamekhi@khatam.ac.ir

inevitable. There are leakages of subsidized products, and they are not fully delivered to the target groups, according to authorities. Despite the lack of precise statistics, it is clear that the amount of corruption exceeds billions of dollars annually. Consequently, a subsidy's supply chain (SC), including suppliers, warehouses, and distribution layer, is regularly monitored by the government. It is worth noting that the distribution of some subsidized products is handled directly by government firms, while others are handled by private firms under strict government regulation. Governments also use online platforms to keep a record of transactions and verify them to avoid fraud. There is, however, no guarantee that grabbing opportunities will be limited. It is possible for grabbers to fabricate documents or provide false information in order to acquire subsidised products. Despite the fact that authorities (or other third parties) regularly control warehouses and documents to verify the validity of documents, the current platforms are incapable of resolving the problem.

The emergence of the technology of blockchain-based platforms can help overcome these challenges by providing access to reliable data in real-time. By using the Proof-of-Authority (PoA) consensus algorithm, blockchain-based platforms can be used to manage subsidized agricultural products' SCs in a decentralized manner [4]. Blockchain-based systems simplify and automate the process of verifying and disseminating information. The system eliminates the need for third parties like reviewers and auditors [2].

The literature on implementing blockchain platforms for the management of SC operations is very supportive. Due to its decentralized nature, blockchain technology makes immutable, transparent data accessible to all involved parties [9]. Through the trustful sharing of information among entities [10,11] and the reduction of information asymmetries [12], blockchain facilitates the tracking and monitoring of SC inventories and processes [13].

In practice, BT platforms for managing SCs face significant challenges and barriers [14,15]. Risks are influenced by a number of factors, including an unestablished legal framework, cyberattacks, dependency on legacy systems, and operational issues, such as low interoperability and system flexibility [16]. Kshetri [17] examines the barriers to deploying BT platforms for managing SCs and argues that blockchain has special characteristics that can help enforce sustainability standards in developing countries. According to Farooque et al., [18], the challenges may stem from intra- and inter-organizational barriers, system barriers (e.g. access to technology, immaturity of the technology, challenges in collecting SC data in real time), and external barriers (e.g. lack of rewards and encouragement programs). Ali et al., [19] argued that while halal food SC can gain a congruent and fresh perspective through employing or superseding blockchain technology, there are significant challenges to overcome when implementing halal food SC blockchain. According to Budak and Çoban [20], management's inability to adapt to the blockchain-based environment (e.g. difficulty in changing organizational culture, lack of knowledge and expertise, lack of updated organizational policies) could be a barrier to deploying Blockchain technology in SCs. Bamakan et al. [21] evaluated the challenges and limitations of the cold chain for pharmaceuticals enabled by blockchain. It is crucial to identify the risks associated with blockchain deployment because of their impact on companies' processes, according to Özkan et al. [22].

The literature demonstrates the benefits of blockchain platforms for managing social contracts for subsidized products; however, implementing the new platforms is fraught with difficulty. The transition from legacy systems to updated technology must be preceded by the identification of the risks and barriers. The importance of all risks and barriers may differ among industries, countries, and environments. To address the issues of blockchain implementation, it is necessary to prioritize them and plan to solve them accordingly. Our paper sought to identify the key factors influencing the implementation of a blockchain platform for distributing subsidized products in Iran. Since blockchain adoption barriers are interconnected among all players in a subsidized SC (suppliers, distribution centers, warehouses, distributors, retailers), their interdependence needs to be understood. Best-Worst method (BWM) and weighted influence non-linear gauge system (WINGS) make up the proposed model. BWM determines the importance weights for each criterion. To analyze the causal relationships among the interdependent criteria, WINGS uses ideographic causal maps.

In this vein, the following research questions arise based on these motivations:

- RQ1: What are the risk and barriers to implementing BT-technology for managing the subsidized food SCs in Iran?
- RQ2: How can we take the experts' preferences and aggregate them to weight the factors and prioritize the alternatives in a unified framework?

This study has made the following theoretical and practical contributions:

- Identifying the risks and barriers to implementing a platform based on BT to manage a subsidized food program.
- An integrated model that considers the importance of risks and barriers as well as their interrelationships, based on BWM and WINGS.
- Incorporating two methodologies with a consistent scale using a rescaling procedure.

Note that Our paper addresses barriers and risks that appear to be interconnected in the real world. Comparing their relative weights independently is therefore not feasible. So it is necessary to use a method which can handle both independent relative importance and interconnection relations among the factors. Clearly, the hybrid method of BWM and WINGS fits this issue. The advantage of using the BWM method is that it reduces the number of pairwise comparisons and improves the consistency of the results. Moreover, its results can be incorporated as the independent significance of barriers in the WINGS method. However, there is a scale issue since BWM and WINGS are independent methods with different scales. To address this issue, a rescaling approach should be used. To determine the relative importance of barriers, the total involvement is calculated, which takes into account both the direction as well as the level of influence among the factors. Such a hybrid appears to be both novel and fully applicable to our problem.

The remainder of this paper is organized as follows. Section 2 reviews related literature. The next section describes our proposed approach including the list of risks and barriers and also the assessment method. To demonstrate the effectiveness of the proposed approach, Section 4 presents a case study in Iran. Discussion and managerial implications, and conclusion, are assigned to the last sections.

Literature Review

SCs benefit greatly from blockchain technology, but its development and implementation in practice are very slow. There are a significant number of use cases that are hindered at the pilot stage or planned stage [12]. Identifying risks and barriers and ranking them accordingly is crucial. The issue of blockchain implementation risks and barriers has been discussed in a few studies. Prewett et al. [23] classified the issues into two categories, "barriers to blockchain adoption" and "risks of blockchain adoption". Researchers have examined the risks and barriers associated with blockchain-based SC platforms in manufacturing SCs [24], business SCs [25], cyber SCs [26], humanitarian SCs [27,28], global food SCs [29], industry and service sectors [30] and container shipping [16]. Risk factors have different influences on various SCs. As Vafadar-Nikjoo et al. [24] demonstrate, "transaction-level uncertainties" constitute the most critical barrier. Mathivathanan et al. [25] found the most significant barrier to implementing blockchain technology lies in the lack of company awareness and familiarity with what the technology can do for future SCs. Scalability and market-based challenges are highlighted by Biswas & Gupta [30]. Sahebi et al. [27] concluded that lack of knowledge of employee training and high sustainability costs were the main issues. According to Friedman & Ormiston [29], there are both functional and psychological barriers, as well as cooperative barriers and protection of the status quo. The study by Etemadi et al. [26] highlights "cryptocurrency volatility". A study by Kouhizadeh et al. [12] concluded that technological barriers, recruiting partners for the implementation of blockchain technology, and defining its value propositions would assist in alleviating upper-level management's difficulties.

As can be seen, there is no explicit study that identifies the risks and barriers associated with subsidized food SCs. Literature review (Table 1) and focus groups were used to identify subsidized food SCs and their barriers. Next, the factors are ranked using a combined method that includes the best-worst method (BWM), and the weighted influence non-linear gauge system (WINGS). This paper exploits the best-worst multi-criteria decision-making method proposed by Rezaei [31] for extracting factors' weights. The efficiency of this method in reducing the number of pairwise comparisons and the consistency of its results have attracted many scholars' attention [41]. Mi et al. [32] provide a comprehensive review of the applications of this method. On the other hand, ideographic causal maps are used in the WINGS method to analyze the interdependences [33,34,35]. In the WINGS method, each element is distinguished by its importance and power (internal strength). WINGS is used to model and solve a variety of problems, including reverse logistics [36], green SC [37], and high-tech selection [38].

According to the literature, there is no explicit research addressing the risks and barriers associated with the implementation of blockchain-based technology for managing subsidized food SCs. Our paper addresses this issue.

Table 1. Summary of literature review of risks and barriers for implementation of blockchain-based SC platform

Reference	Factors	Sector	Method
[23]	Barriers: Scalability, System integration, Lack of standardization, Complexity, Regulatory uncertainty, knowledge/skills/employee training barriers. Risks: Architecture and design risk, Endpoint/oracle risk, Data security and confidentiality, Storage, Smart contract, Compliance, Vendor, Contractual and Private key management risks	General	-
[12]	Technological context: Security, access to technology, negative perception toward technology, immutability, and immaturity of the technology. Organizational context: Financial constraints, management commitment and support, organizational policies for using technology, knowledge and expertise, changing organizational culture, Hesitation to convert to more sophisticated systems, Lack of tools for technology implementation Environmental context (SC view): customers’ awareness and tendency about blockchain technology, collaboration, communication and coordination, information disclosure policy between partners, integrating sustainable practices and blockchain technology, Cultural differences between partners Environmental Context (External view): governmental policies, Market competition and uncertainty, external stakeholders’ involvement, industry involvement in blockchain adoption and ethical and safe practices, rewards and incentives	General	DEMATE L
[16]	Initiative risks: technical aspects of blockchain and external factors transitional risks: traditional information CSORs (e.g. cargo misdeclaration) that cannot be entirely eliminated by applying blockchain solutions sequel risks: physical or payment	container shipping	directed acyclic graph (DAG)
[24]	Transaction-level uncertainties, usage in the underground economy, managerial commitment, challenges in scalability, privacy	manufacturing SCs	N-AHP
[23]	Barriers: Scalability, System integration, Lack of standardization, Complexity, Regulatory uncertainty, knowledge/skills/employee training barriers.	General	-

Reference	Factors	Sector	Method
	Risks: Architecture and design risk, Endpoint/oracle risk, Data security and confidentiality, Storage, Smart contract, Compliance, Vendor, Contractual and Private key management risks		
[25]	Impede blockchain adoption, Business Owner's unwillingness, Unfamiliarity with Technology, Data privacy/security, Regulatory, Technological infeasibility, Complexity in setup/use, Uncertain benefits, Dependence on Blockchain operators, Lack of Cooperation among SC partners	business SCs.	TISM
[26]	Cryptocurrency volatility, regulatory provisions, technology immaturity, dependent on input information from external oracles, scalability and bandwidth, and smart contract	cyber SC	
[30]	Scalability, Market-based Risks, Transaction-level Uncertainties, Technology, High Sustainability Costs, Poor Economic Behavior in the Long Run, Privacy, Usages in the underground economy, cyber-attacks, Legal and Regulatory	industry and service sectors	
[27]	Scalability, Integrating Problems, Standardization, Complexity of Establishing, Regulatory, Knowledge/Employee Training, Market-based Risks, Technology, High Sustainability Costs, Low/No Transaction Fees, Privacy, Usage in Underground Economy, Cyber-Attacks, cryptocurrency experts, Contractual Risk	humanitarian SC	Fuzzy Delphi and BWM
[28]	Lack of resources to implement blockchain-based systems, financial slacks, privacy, change management, engagement with new technology, technical skills, regulatory framework, issues with data quality and standardization, scalability, governance model, integration, complexity of implementation in downstream	humanitarian SC	
[29]	Actively protecting the status quo, cooperative barriers, functional and psychological barriers.	global food SCs	

Proposed Approach

From the literature review, a comprehensive set of adoption barriers is shown in Table 1. It shows that each paper focused on the implementation of blockchain in a specific industry. In this paper, we seek to identify the list of adoption barriers in the subsidized food chain. Filtering the factors within Table 1 allowed us to combine the literature-derived factors with expert opinions. Table 2 shows the final factor list.

In addition to expert inputs and literature, the paper details the obstacles to the successful implementation of blockchains in the humanitarian supply chain. Then, the barriers were discussed, and finally, these barriers were categorized. Based on our analysis, we then rank the barriers by using a combined method that includes the BWM and WINGS as follows:

Phase 1: Weight the factors using the best-worst method [31,41]:

- **Step 1.1.** Determine the most important and the least important factors.
- **Step 1.2.** Using the linguistic phrase presented in Table 3, construct the best-to-others vector $BOC_{BO} = (BO_{b1},...,BO_{bj},...,BO_{bn})$ where BO_{bj} is the preference of the best criterion over criterion $j; j=1,...,n$. Note that $BO_{bb} = 1$.

Table 2. Risk factors for implementing blockchain technology in subsidized food SC

Aspect	Criteria	References
Technical barriers (TR0)	Technical simplicity of transition: complexity of set up/use including implementation in downstream (TR1)	[23,25,28,29]
	Process standardization and existing data quality (TR2)	[23,28,30]
	Vendor / Suppliers' previous experiences in deploying the platform in the sector (TR3)	Expert panel.
	Security (TR4)	[12]
	Costs of implementing and maintaining the new technology (TR5)	Expert panel.
	Availability of fraud traceability features (TR6)	[20], Expert panel.
Cultural barriers (CR0)	Negative perception of managers toward technology (CR1)	[12,24]
	Resistance of scammers (CR2)	Expert panel.
	Hesitation to convert to more sophisticated systems (CR3)	[12]
	Cultural differences and cooperation among partners (CR4)	[12,25]
External barriers (ER0)	Changing of government rules: data required to collect (ER1)	Expert panel.
	Presence of skilled blockchain engineers (ER2)	[27]
	Customers' awareness (ER3)	[12]

Table 3. Relative importance scale [31]

Verbal Phrase	Relative importance score
Extremely important	9
Very strongly to extremely important	8
Very strongly important	7
Strongly to very strongly important	6
Strongly important	5
Moderately to strongly important	4
Moderately important	3
Equally to moderately important	2
Equally important	1

- **Step 1.3.** Construct the others-to-worst vector $OWC_{OW} = (OW_{1w},...,OW_{jw},...,OW_{nw})$ as well, where OW_{jw} indicates the preference of criterion j over the worst criterion. Note that $OW_{ww} = 1$.
- **Step 1.4.** Calculate the independent weights as follow:

$$
\begin{aligned}
& Min\ k \\
& s.t. \\
& \left| w_b - BO_{bj} \times w_j \right| \leq k \\
& \left| w_j - OW_{jw} \times w_w \right| \leq k \\
& \sum_j w_j = 1 \\
& w_j \geq 0 \qquad \forall j
\end{aligned}
\tag{1}
$$

where W_j denotes the independent weight of criterion j and k denotes the consistency of pairwise comparisons.

Phase 2: Modify the weight by considering their causal relationship using WINGS method [39,40]:

Step 2.1. Choosing an arbitrary value (e.g. 1.1), rescale all weights proportionally:

$$v_j = 1.1 \times \frac{w_j}{\underset{j}{Min}\ w_j} \tag{2}$$

- **Step 2.2.** Transsform the independent weights into internal strengths **(**d_{ii}):

$$d_{jj} = 1 - \frac{1}{w_j} \tag{3}$$

- **Step 2.2.** Draw the digraph of interdependency of factors and ask the experts to determine their causal relations verbally and convert them to the scale $[\underset{j}{Min}\ d_{jj}, \underset{j}{Max}\ d_{jj}]$.
- **Step 2.3.** Construct the strength-influence matrix D as follows:
  - d_{jj} s are inserted into the basic diagonal, d_{ij} (i.e. influences of factor i on factor j) are inserted so that $i \neq j$.
  - The scale of the Matrix D as follows:

$$S = \frac{1}{s} D \tag{4}$$

where the scaling factor is given by:

$$s = \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij} \tag{5}$$

- **Step 2.4.** Construct the Matrix T as the cumulative effect of all direct and indirect impacts:

$$T = S + S^2 + S^3 + \ldots = S\left(I - S\right)^{-1} \tag{6}$$

- **Step 2.4.** The measure for the *total impact* I_i exerted by component i on all the other system components (note that i and j are allias):

$$I_i = \sum_{j=1}^{n} t_{ij} \tag{7}$$

- **Step 2.5.** Normalize the *total involvement* as the relative importance of the factor:

$$\psi_i = \frac{I_i}{\sum_{i=1}^{n} I_i} \tag{8}$$

Case Study

In the previous section, the key risk factors and barriers to the implementation of a blockchain platform for distributing subsidized products were discussed. First, we determine the weight of the criteria using the BWM. After understanding their interdependence, the final weights are calculated using the WING method. The preferences of five experts were submitted, all of whom are involved in the food distribution industry.

Phase 1: Weight the factors using the best-worst method:

- **Step 1.1.** The committee determines which factors are most and least important. The results are shown in Table 4.

Table 4. The most and the least important risk factors

Best criteria	Worst criteria
Technical barriers (TR0)	External barriers (ER0)

Criteria	Best sub-criteria	Worst sub-criteria
Technical barriers (TR0)	Vendor / Suppliers' previous experiences in deploying the platform in the sector (TR3)	Security (TR4)
Cultural barriers (CR0)	Resistance of scammers (CR2)	Cultural differences and cooperation among partners (CR4)
External barriers (ER0)	Change of government rules: data required to collect (ER1)	Customers’ awareness (ER3)

- **Step 1.2.** Here, we present the best-to-others vector in Table 5. In order to obtain the results, pairwise comparisons are performed between the most relevant criterion and other criteria (Table 5(a) for main criteria and 5(b) for sub-criteria).
- **Step 1.3.** Table 6 presents the others-to-worst importance vector (Table 6(a) for main criteria and 6(b) for sub-criteria).
- **Step 1.4.** Based on model 1, these weights were extracted. The weights of the criteria were found by solving the model with GAMS software and the CPLEX solver. For each subcriteria group, we calculated independent local weights using a similar procedure. In Table 7, we present the optimal independent local weights for the criteria and sub criteria as well as the consistency ratios (CR), which are all less than 0.1 and, therefore, consistent.

Table 5. The best-to-others vectors ((a) criteria and (b) subcriteria)

CRITERIA	RELATIVE IMPORTANCE SCORE
TR0	1
CR0	2
ER0	3
Subcriteria	**Best-to-other importnce**
TR1	5
TR2	3
TR3	1
TR4	7
TR5	2
TR6	2
CR1	3
CR2	1
CR3	5
CR4	7
ER1	1
ER2	3
ER3	7

Table 6. The others-to-worst importance ((a) criteria and (b) subcriteria)

CRITERIA	RELATIVE IMPORTANCE SCORE
TR0	3
CR0	2
ER0	1

Subcriteria	others-to-worst importnce
TR1	4
TR2	5
TR3	7
TR4	1
TR5	4
TR6	5
CR1	2
CR2	7
CR3	2
CR4	1
ER1	7
ER2	3
ER3	1

Phase 2: Weigh the factors using best-worst method:

- **Step 2.1 and Step 2.2.** v_j, d_{jj}, $Min(d_{jj})$ and $Max(d_{jj})$ are calculated and presented in Table 7. The scale should be in the range of $[\underset{j}{Min}\, d_{jj}, \underset{j}{Max}\, d_{jj}] = [0.09, 0.93]$.
- **Step 2.3.** The cognitive map of interrelations among the risk factors are depicted in Fig. 1. Strength-influence matrix *D* is shown in Table 8. Table 9 summarizes the cumulative impact of all direct and indirect impacts (matrix *T*) without reporting the details of the calculations.
- **Steps 2.4 and 2.5.** The total involvement as the relative importance of the factor (I_i) is reported in Table 9. The normalized importance of the risk factors (ψ_i) are reported in Table 10. It is clear that this is the final weight after considering interrelation.

Table 7. The independent local weights of criteria and subcriteria

criteria	Criteria weight	Sub-Criteria	Local weight	Independent weight	v_j	d_{jj}
TR0	0.542	TR1	0.082	0.044	3.23	0.69
		TR2	0.136	0.074	5.43	0.82
		TR3	0.337	0.183	13.42	0.93
		TR4	0.038	0.021	1.54	0.35
		TR5	0.204	0.111	8.14	0.88
		TR6	0.204	0.111	8.14	0.88
		CR	0.071			
CR0	0.292	CR1	0.195	0.057	4.18	0.76
		CR2	0.598	0.175	12.83	0.92
		CR3	0.126	0.037	2.71	0.63
		CR4	0.08	0.023	1.69	0.41
		CR	0.034			
ER0	0.167	ER1	0.673	0.112	8.21	0.88
		ER2	0.236	0.039	2.86	0.65
		ER3	0.091	0.015	1.10	0.09
		CR	0.036	-	$Min(d_{jj})$	0.09
CR	0.042	-	-	-	$Max(d_{jj})$	0.93

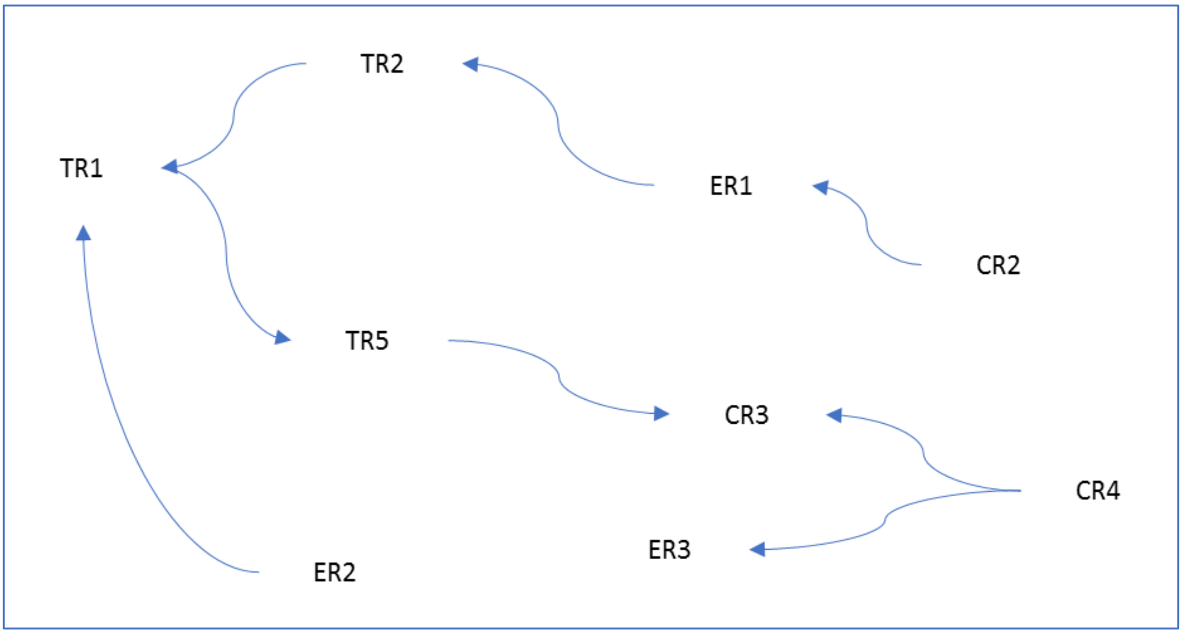

Fig. 1. The map of interrelations among the risk factors

Table 8. The strength-influence matrix (*D*)

	TR1	**TR2**	**TR3**	**TR4**	**TR5**	**TR6**	**CR1**	**CR2**	**CR3**	**CR4**	**ER1**	**ER2**	**ER3**
TR1	0.69	0	0	0	0.8	0	0	0	0	0	0	0	0
TR2	0.7	0.816	0	0	0	0	0	0	0	0	0	0	0
TR3	0	0	0.925	0	0	0	0	0	0	0	0	0	0
TR4	0	0	0	0.351	0	0	0	0	0	0	0	0	0
TR5	0	0	0	0	0.877	0	0	0	0.9	0	0	0	0
TR6	0	0	0	0	0	0.877	0	0	0	0	0	0	0
CR1	0	0	0	0	0	0	0.761	0	0	0	0	0	0
CR2	0	0	0	0	0	0	0	0.922	0	0	0.4	0	0
CR3	0	0	0	0	0	0	0	0	0.631	0	0	0	0
CR4	0	0	0	0	0	0	0	0	0.7	0.407	0	0	0.5
ER1	0	0.8	0	0	0	0	0	0	0	0	0.878	0	0
ER2	0.65	0	0	0	0	0	0	0	0	0	0	0.65	0
ER3	0	0	0	0	0	0	0	0	0	0	0	0	0.091

Table 9. the cumulative impact of all direct and indirect impacts (*T*)

	TR1	TR2	TR3	TR4	TR5	TR6	CR1	CR2	CR3	CR4	ER1	ER2	ER3	I_i
TR1	0.05	0	0	0	0.06	0	0	0	0.0	0	0	0	0	0.117
TR2	0.05	0.06	0	0	0.0	0	0	0	0.0	0	0	0	0	0.118
TR3	0	0	0.07	0	0	0	0	0	0	0	0	0	0	0.069
TR4	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0.025
TR5	0	0	0	0	0.07	0	0	0	0.07	0	0	0	0	0.135
TR6	0	0	0	0	0	0.07	0	0	0	0	0	0	0	0.065
CR1	0	0	0	0	0	0	0.06	0	0	0	0	0	0	0.056
CR2	0.0	0.0	0	0	0.0	0	0	0.07	0.0	0	0.03	0	0	0.103
CR3	0	0	0	0	0	0	0	0	0.05	0	0	0	0	0.046
CR4	0	0	0	0	0	0	0	0	0.05	0.03	0	0	0.04	0.118
ER1	0.0	0.06	0	0	0.0	0	0	0	0.0	0	0.07	0	0	0.132
ER2	0.05	0	0	0	0.0	0	0	0	0.0	0	0	0.05	0	0.101
ER3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.006

Table 10. The importance of risk factors according to BWM and BWM+WINGD by considering interrelations

Risk and Barriers		**BWM**		**BWM+WINGS**		
		weight	**rank**	**weight**	**rank**	**difference**
Costs of implementing and maintaining the new technology	TR5	0.111	4	0.124	1	11.6%
Changing of government rules: data required to collect	ER1	0.112	3	0.121	2	7.8%
Process standardization and existing data quality	TR2	0.074	6	0.108	3	46.4%
Cultural differences and cooperation among partners	CR4	0.023	11	0.108	4	370.0%
Technical simplicity of transition: complexity of set up/use including implementation in downstream	TR1	0.044	8	0.107	5	144.0%
Resistance of scammers	CR2	0.175	2	0.094	6	-46.3%
Presence of skilled blockchain engineers	ER2	0.039	9	0.092	7	136.4%
Vendor / Suppliers' previous experiences in deploying the platform in the sector	TR3	0.183	1	0.063	8	-65.4%
Availability of fraud traceability features	TR6	0.111	4	0.060	9	-46.2%
Negative perception of managers toward technology	CR1	0.057	7	0.051	10	-9.9%
Hesitation to convert to more sophisticated systems	CR3	0.037	10	0.042	11	14.2%
Security	TR4	0.021	12	0.023	12	9.4%
Customers' awareness	ER3	0.015	13	0.006	13	-61.0%

Discussion and Managerial Implications

In Table 10, two methods are compared (basic BWM without considering interrelationships and BWM+WING with considering interrelationships). We sorted the results based on BWM+WING's final weights. We also provided the rankings for each factor for both methods.

Analytical insights and effects of interdependency in the final weight

In this section, we present insight from an analytical and mathematical point of view:

1. For most instances in which one factor influences another, the final weight derived from BWM+WINGS is decreased compared to the basic BWM model. BWM+WING indicates that "the cost of implementing and maintaining the new technology (TR5)" is the biggest roadblock to the implementation of a blockchain-based platform for managing food subsidies. If the interrelationships of the factors are ignored, it comes in at rank 4. The importance of this factor increased by 11.6% after taking into account the interrelationships. As can be seen from Fig. 1, it is derived from its influence on "Hesitation to convert to more sophisticated systems (CR3)" with a very high degree of influence (i.e. 0.9). This comparison shows the effect of considering the interrelationships among the factors. Similarly, the second most significant factor also played a role. "Changing of government rules: data required to collect (ER1)" is considered second when considering the relationships, whereas it was third when ignoring them. Its weight increased within BWM+WINGS. It can be concluded from Fig. 1 that this increase occurred as a result of its influence on "Process standardization and existing data quality (TR2)". The third significant risk factor is "Cultural differences and cooperation among partners (TR2)", while it had a rank of 6 in the simple model. The increase in its rank is attributed to its impact on "Technical simplicity of transition: setting up/using it for downstream (TR1)". "Resistance of scammers (CR2)" is the only exception. It has the lowest influence on the other factors.
2. Accordingly, the weight of the factors influenced by other factors is reduced as compared to the basic model. Customer awareness (ER3) has the lowest rank in both models. Compared to the basic model, its weight decreased by -61%. As shown in Fig. 1, it is only influenced by "Cultural differences and cooperation among partners (CR4)" and doesn't affect any other factors.
3. It can be inferred that the important weight of the factors that are not intertwined with other factors is decresead without exception. the important factor of "Negative perception of managers toward technology (CR1)", "Availability of fraud traceability features (TR6)" and "Vendor / Suppliers' previous experiences in deploying the platform in the sector (TR3)" decreased. From Fig. 1, it can be inferred that they do not have been influenced from or influence on other factors.

In conclusion, taking the interrelation into account changes the weightings according to the mechanism. WINGS give greater weight to factors that have an impact on others. Since this is a very realistic situation, this method is valid in our case.

Managerial insights

1. In addition, the cost of implementation ranks fourth in a simple analysis. In light of the interrelations, it has become the most significant barrier to the implementation of a block-chain based platform for an SC of subsidised food. There is a possibility that there could be uncertainty in the transition costs to the newly developed technology. To solve this problem, it is recommended that the supplier implements the system in a very small scope that includes all layers of suppliers and distributors.
2. "Changing of government rules: data required to collect (ER1)" and "Process standardization and existing data quality (TR2)" relate to processes in both aspects of the regulatory environment and agility of internal systems. It is interesting that their importance increased once their interrelationships were taken into consideration. ER1 also directly influences TR2. Because subsidized foods are constantly monitored by the government and they may impose new data collection policies, it is very natural for the government to be concerned with improving the complex government rules. It is

essential that decision-makers understand the complexity of upgrading the rules in the platform.

3. "Cultural differences and cooperation among partners (CR4)" and "Technical simplicity of transition: the complexity of implementation in downstream (TR1)" are in the third and fourth ranks, suggesting a good relationship between SC managers and downstream organizations. Downstream organizations typically have a lower level of education or evolution, and it's critical to foster a constructive working relationship with them.
4. The importance of "customer awareness (ER3)" is the lowest. They may not have access to the platform in its current state for a variety of reasons. It may be that the decision makers have a concrete vision in which the customers do not have to be involved. However, blockchain-based platforms may provide an efficient solution.
5. In Table 11, the cumulative score of each aspect is calculated for both basic BWM without considering interrelationships and BWM+WING with considering interrelationships. It is very interesting that the cumulative dependent weight of External barriers (ER0) increases about 32% in comparison to the independent weight. This shows that by ignoring the interrelations of the factors, it may gain insufficient importance.

Table 11. The commutative importance of factors a) according to BWM and b) according to BWM+WINGD by considering interrelations

Aspect	BWM	BWM+WINGS	difference
Technical barriers (TR0)	0.54	0.49	-0.11
Cultural barriers (CR0)	0.29	0.30	0.01
External barriers (ER0)	0.17	0.22	0.32

Conclusion

This paper analyzes the risks and barriers of using blockchain-based platforms for SCs of food supply chains in Iran. In the literature, it is well documented that such platforms provide immutable, transparent data to all parties involved. Governments can use these features to improve the current platform of managing SCs of subsidized foods. For subsidized products, it is important to avoid faking documents and giving false information. Implementing BT platforms for managing SCs poses significant challenges and barriers in practice. Prior to implementing new technology, it is important to identify the risks and barriers. To resolve the issues of blockchain implementation, it is important to prioritize them and plan for a solution. Using a blockchain platform to distribute subsidized products in Iran, we aimed to identify the key factors affecting its implementation. Because blockchain adoption barriers are interconnected among all players in a subsidized SC (suppliers, distribution centers, warehouses, distributors, retailers), there is a need to understand their interdependence. In the proposed model, the Best-Worst method (BWM) and a weighted influence non-linear gauge system (WINGS) are utilized. The Best-Worst method determines the importance weights for each criterion. WINGS uses ideographic causal maps in order to analyze the causal relationships among interdependent criteria. Implementation of a blockchain-based platform for managing food subsidies is hindered most by the cost of developing and maintaining the new technology. Transition costs for the new technology may be uncertain, as can be predicted. This problem may be solved if the supplier implements the system in a very small scope including all layers including suppliers and distributors. In the absence of relationships in the calculations of the rankings, "Changing of government rules: data required to collect" is ranked second. Changes in government rules: data collection required, and process standardization and data quality concern processes in both aspects of the regulatory environment and agility of internal systems.

After considering their interrelations with other factors, the importance of these variables has increased. Since the government constantly monitors subsidized foods and may impose additional data collection measures, it is very natural that decision makers are concerned about the issue of upgrading the complex governmental rules. It is imperative that decision-makers have a clear understanding of how the process of upgrading rules works. Overall, it can be concluded that examining the interrelation changes the weightings. WINGS gives more weight to factors that affect one another.

For future research, we propose two following directions:

1. We propose that some work on that which feature is the most important to be embedded in the platform of managing the SCs of the subsidized foods.
2. Also, analyzing the risk and barriers of the platform which allows the buy and sell of the final product (suitable programs for fair distribution of fuel subsidy in Iran).

References

[1] Zhang, H., An, R., & Zhong, Q. (2019). Anti-corruption, government subsidies, and investment efficiency. China Journal of Accounting Research, 12(1), 113-133.

[2] Singh, B., Sharma, K. P., Sharma, N., & Kumar, P. (2021). Blockchain-based Claim Verification and Approval System for Disbursing Fertilizer Subsidy. Available at SSRN 3814155.

[3] Adewuyi, A. (2020). Challenges and prospects of renewable energy in Nigeria: A case of bioethanol and biodiesel production. Energy Reports, 6, 77-88.

[4] Bala, K., & Kaur, P. D. (2022). Transparent subsidized agri- product distribution during pandemics with reputation based PoA blockchain. Concurrency and Computation: Practice and Experience, e6863.

[5] Farajzadeh, Z., & Bakhshoodeh, M. (2015). Economic and environmental analyses of Iranian energy subsidy reform using Computable General Equilibrium (CGE) model. Energy for Sustainable Development, 27, 147-154.

[6] Barkhordar, Z. A., Fakouriyan, S., & Sheykhha, S. (2018). The role of energy subsidy reform in energy efficiency enhancement: Lessons learnt and future potential for Iranian industries. Journal of Cleaner Production, 197, 542-550.

[7] Khalilian, S., & Yuzbashkandi, S. S. (2021). Analysis of vegetable oil demand and its price reform in Iran: using rural and urban household level data. International Journal of Agriculture Environment and Food Sciences, 5(1), 122-132.

[8] Mosavi, S. H. (2016). Energy price reform and food markets: The case of bread supply chain in Iran. Agricultural Economics, 47(2), 169-179.

[9] Baharmand, H., Maghsoudi, A., & Coppi, G. (2021). Exploring the application of blockchain to humanitarian supply chains: insights from Humanitarian Supply Blockchain pilot project. International Journal of Operations & Production Management.

[10] Wang, B., Luo, W., Zhang, A., Tian, Z., & Li, Z. (2020). Blockchain-enabled circular supply chain management: A system architecture for fast fashion. Computers in Industry, 123, 103324.

[11] Cole, R., Stevenson, M. and Aitken, J. (2019), Blockchain technology: implications for operations and supply chain management, Supply Chain Management, 24 (4), 469-483.

[12] Kouhizadeh, M., Saberi, S., & Sarkis, J. (2021). Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers. International Journal of Production Economics, 231, 107831.

[13] Kamble, S. S., Gunasekaran, A., & Sharma, R. (2020). Modeling the blockchain enabled traceability in agriculture supply chain. International Journal of Information Management, 52, 101967.

[14] Irannezhad, M., Shokouhyar, S., Ahmadi, S., & Papageorgiou, E. I. (2021). An integrated FCM-FBWM approach to assess and manage the readiness for blockchain incorporation in the supply chain. Applied Soft Computing, 112, 107832.

[15] Sternberg, H. S., Hofmann, E., & Roeck, D. (2021). The struggle is real: insights from a supply chain blockchain case. Journal of Business Logistics, 42(1), 71-87.
[16] Nguyen, S., Chen, P. S. L., & Du, Y. (2020). Risk identification and modeling for blockchain-enabled container shipping. International Journal of Physical Distribution & Logistics Management.
[17] Kshetri, N. (2021). Blockchain and sustainable supply chain management in developing countries. International Journal of Information Management, 60, 102376.
[18] Farooque, M., Jain, V., Zhang, A., & Li, Z. (2020). Fuzzy DEMATEL analysis of barriers to Blockchain-based life cycle assessment in China. Computers & Industrial Engineering, 147, 106684.
[19] Ali, M. H., Chung, L., Kumar, A., Zailani, S., & Tan, K. H. (2021). A sustainable Blockchain framework for the halal food supply chain: Lessons from Malaysia. Technological Forecasting and Social Change, 170, 120870.
[20] Budak, A., & Çoban, V. (2021). Evaluation of the impact of blockchain technology on supply chain using cognitive maps. Expert Systems with Applications, 184, 115455.
[21] Bamakan, S. M. H., Moghaddam, S. G., & Manshadi, S. D. (2021). Blockchain-enabled pharmaceutical cold chain: applications, key challenges, and future trends. Journal of Cleaner Production, 302, 127021.
[22] Özkan, B., Kaya, İ., Erdoğan, M., & Karaşan, A. (2019, July). Evaluating blockchain risks by using a MCDM methodology based on pythagorean fuzzy sets. In International conference on intelligent and fuzzy systems (pp. 935-943). Springer, Cham.
[23] Prewett, K. W., Prescott, G. L., & Phillips, K. (2020). Blockchain adoption is inevitable—Barriers and risks remain. Journal of Corporate accounting & finance, 31(2), 21-28.
[24] Vafadarnikjoo, A., Badri Ahmadi, H., Liou, J. J., Botelho, T., & Chalvatzis, K. (2021). Analyzing blockchain adoption barriers in manufacturing supply chains by the neutrosophic analytic hierarchy process. Annals of Operations Research, 1-28.
[25] Mathivathanan, D., Mathiyazhagan, K., Rana, N. P., Khorana, S., & Dwivedi, Y. K. (2021). Barriers to the adoption of blockchain technology in business supply chains: a total interpretive structural modelling (TISM) approach. International Journal of Production Research, 59(11), 3338-3359.
[26] Etemadi, N., Van Gelder, P., & Strozzi, F. (2021). An ism modeling of barriers for blockchain/distributed ledger technology adoption in supply chains towards cybersecurity. Sustainability, 13(9), 4672.
[27] Sahebi, I. G., Masoomi, B., & Ghorbani, S. (2020). Expert oriented approach for analyzing the blockchain adoption barriers in humanitarian supply chain. Technology in Society, 63, 101427.
[28] Baharmand, H., Saeed, N., Comes, T., & Lauras, M. (2021). Developing a framework for designing humanitarian blockchain projects. Computers in Industry, 131, 103487.
[29] Friedman, N., & Ormiston, J. (2022). Blockchain as a sustainability-oriented innovation?: Opportunities for and resistance to Blockchain technology as a driver of sustainability in global food supply chains. Technological Forecasting and Social Change, 175, 121403.
[30] Biswas, B., & Gupta, R. (2019). Analysis of barriers to implement blockchain in industry and service sectors. Computers & Industrial Engineering, 136, 225-241.
[31] Rezaei, J. (2015). Best-worst multi-criteria decision-making method. Omega, 53, 49-57.
[32] Mi, X., Tang, M., Liao, H., Shen, W., & Lev, B. (2019). The state-of-the-art survey on integrations and applications of the best worst method in decision making: Why, what, what for and what's next?. Omega, 87, 205-225.
[33] Michnik, J., & Adamus-Matuszyńska, A. (2015). Structural analysis of problems in public relations. Multiple Criteria Decision Making, (10), 105-123.
[34] Banaś, D., & Michnik, J. (2019). Evaluation of the Impact of Strategic Offers on the Financial and Strategic Health of the Company—A Soft System Dynamics Approach. Mathematics, 7(2), 208.
[35] Michnik, J., & Grabowski, A. (2020). Modeling Uncertainty in the Wings Method Using Interval Arithmetic. International Journal of Information Technology & Decision Making, 19(01), 221–240.

[36] Kaviani, M.A., Tavana, M., Kumar, A., Michnik, J., Niknam, R. and Campos, E.A.R. (2020). An Integrated Framework for Evaluating the Barriers to Successful Implementation of Reverse Logistics in the Automotive Industry. Journal of Cleaner Production, https://doi.org/10.1016/j.jclepro.2020.122714.

[37] Wang, W., Tian, Z., Xi, W., Tan, Y. R., & Deng, Y. (2020). The influencing factors of China's green building development: An analysis using RBF-WINGS method. Building and Environment, 107425.

[38] Tavana, M., Mousavi, H., Nasr, A. K., & Mina, H. (2021a). A Fuzzy Weighted Influence Non-linear Gauge System with Application to Advanced Technology Assessment at NASA. Expert Systems with Applications, In press.

[39] Michnik, J. (2013). Weighted Influence Non-linear Gauge System (WINGS)–An analysis method for the systems of interrelated components. European Journal of Operational Research, 228(3), 536-544.

[40] Tavana, M., Nasr, A. K., Mina, H., & Michnik, J. (2021b). A private sustainable partner selection model for green public-private partnerships and regional economic development. Socio-Economic Planning Sciences, 101189.

[41] Bozorgi-Amiri, A., Ranjbar, A., & Jamali, A. (2019). A Novel Hybrid MCDM Method for Optimal Location Selection of Free Trade Zones, Case Study: Mazandaran Province. Advances in Industrial Engineering, 53(3), 79-92.

[42] Barzinpour, F., & Karimi, S. (2014). Forecasting Effects of Scenarios of Subsides Removal on Residential Electricity Consumption by Artificial Neural Networks. Advances in Industrial Engineering, 48(Special Issue), 83-90.