

Identification and Assessment of SAAL Supply Chain Risks in Iran Construction Industry with the HF-BWM

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ABSTRACT

The SAAL supply chain is the result of integrating four sustainable, antifragile, agile and lean chain approaches. Each type of supply chain approach has its requirements, which sometimes conflict with the provisions of other supply chain approaches. This research aims to identify the risks facing the SAAL supply chain in a chaotic environment. Due to the use of quantitative methods and its orientation, the current research is of a proof-of-concept and practical type and its methodology is multiple. The study's statistical population comprises construction industry experts who were selected using the judgemental method for sampling. This research used two fuzzy Delphi and hierarchical fuzzy best-worst methods for data analysis. Initially, 63 risks were identified through background review and interviews with experts and these 63 risks were introduced in the form of 14 main risks. Each of these supply chain approaches has a specific type of risk. These risks were screened with fuzzy Delphi and 18 risks remained. Then, the remaining risks were prioritised using the hierarchical fuzzy best-worst method. The results showed that the risks of exchange rate fluctuations with an average weight of 0.0880 and the purchasing power of the people with an average weight of 0.0852 are among the risks of a sustainable approach in the first and second priority, respectively and financing problems with a weight of 0.0791 from the lean approach in the third place, Economic stability weighs 0.0759 from the sustainable approach in the fourth place, and s the highest priority in each of the components of the SAAL supply chain. Using new marketing methods, diversifying financing tools and team approaches, paying attention to effective techniques in consumer behaviour in the future and examining changes in customer buying behaviour and their causes are the most important suggestions of the research to respond to risk.

Keywords: Supply Chain Risk, SAAL Supply Chain, Antifragile, Chaos, Construction Industry

Introduction

The supply chain includes all stages from design, supply of resources, flow of information, money, raw materials and products from the primary supplier to the delivery of the final product to the final consumer and vice versa. All these steps have many and varied risks, so supply chain risk includes all the related risks. Nevertheless, supply chain risk is the possibility of damage caused by supply disruption. In simpler terms, supply chain risk is the probability and consequences of accidents in any supply chain (Pham et al., 2023; Sadeghi et al., 2023). Each type of supply chain faces different risks depending on the nature, scope and industry.

On the other hand, no matter how much a supply chain wants to have higher requirements and qualities, it will face more and more complex risks. On the other hand, the anarchy/chaos environment is full of unexpected risks and black swans, which every business must protect itself against (Sadeghi & Sadeghi, 2023). The combination of four types of sustainable, antifragile, agile and lean (SAAL) supply chains as the main effective paradigms of the supply chain in chaotic conditions gives this space to organisations and projects to be prepared against black swans, even benefit from it while also pushing the conditions towards stability or leaving it (Sadeghi, Akbarpour & Abbasianjahromi, 2022). (Sadeghi et al., 2023). The integration of environmental, social and

economic principles into supply chain management is increasingly important as companies can address vulnerabilities and build stronger supply chains. This approach is not merely a trend but is essential for modern business success (Tsoulfas, 2024). Sustainable supply chain management is an organisational paradigm aiming to achieve profit and market share goals by reducing environmental damage while improving the environmental and social productivity of organisations, partners and their stakeholders. This paradigm focuses on social and economic purposes and environmental goals (Senthil & Muthukannan, 2022). The integration of blockchain technology, offering transformative potential in enhancing transparency, efficiency and security, has revolutionised traditional supply chain systems, introducing new paradigms of sustainable operation and management (Oriekhoe et al., 2024).

In the antifragile supply chain, it is essential to recognise external/internal shocks and threats, analyse them, respond promptly, exploit them to strengthen conditions and prepare for unknown threats. Resilience in the supply chain can be defined as the reactive capability of the supply chain to take advantage of unexpected events, respond to disturbances and improve them by maintaining the continuity of operations at the desired level of communication and control over the structure and performance. Resilience Supply chain can create a sustainable competitive advantage by promoting adaptability and developing capabilities, creating a resilient supply chain. Paying attention to antifragility, as a part of the organisation's strategic role in the uninterrupted flow of its materials and products for organisational competitiveness and success, is necessary in the current chaotic situation (Sadeghi, Sadeghi & Hajjam, 2022; Sadeghi et al., 2023b). Industry 4.0 is reshaping supply chains and collaborative interactions among value chain constituents. In this situation, sustainable and resilient supplier management is recognised as a strategic endeavour that drives value creation. These systems leverage stratified fuzzy decision-making techniques to account for the potential impacts of future events (Li et al., 2024).

The agile supply chain is used in highly variable and volatile environments where customer and market

needs are often unpredictable, so it is essential to respond quickly with affordable costs to unpredictable changes in the market and environmental shocks, both in terms of volume and variety. Lean supply is also used to maintain high quality and continuously improve quality in high volumes, low variety and predictable and reliable demand. Now, the SAAL¹ supply chain combines these four concepts and seeks to use the benefits of all four supply chain approaches (Sadeghi, Sadeghi & Hajjam, 2022; Sadeghi et al., 2023a). The research on the integration of supply chain approaches has dealt with the systematic review of the history of the combination of lean, agile, resilient, green and sustainable approaches in supply chain management. Some studies have evaluated the performance of these combined supply chains, such as AgiLean², LeAgile³ and LARG⁴. However, the focus of hybrid supply chain research is on measuring sustainability performance and how to combine different approaches in this type of supply chain. Also, some have tried to evaluate the performance of this type of supply chain in general by using decision-making methods. Some of the research carried out in the last two years is related to supply chain risks, which have also identified supply chain risks during the Corona outbreak. Those researchers have also identified the types of risks in the era of Corona and the strategies to respond to these risks. Some other research in the field of supply chain risk has focused on identifying supply chain risks in general or each of the supply chain approaches separately.

Meanwhile, most of the research in the field of supply chain risk is focused on providing models and frameworks to evaluate and manage supply chain risk. SAAL strategy is a new strategy in supply chain that is designed for a chaotic environment. The approaches of SWOT, BSC⁵, BCG⁶, Agile, Lean, LARG, Blue Ocean, Antifragile and other strategies are designed for the complicated and complex environment (Fig. 1).

¹Sustainable, Antifragile, Agile, Lean

²Agile Lean

³Lean Agile

⁴Lean Agile Resilience Green

⁵The balanced scorecard

⁶The Boston Consulting group

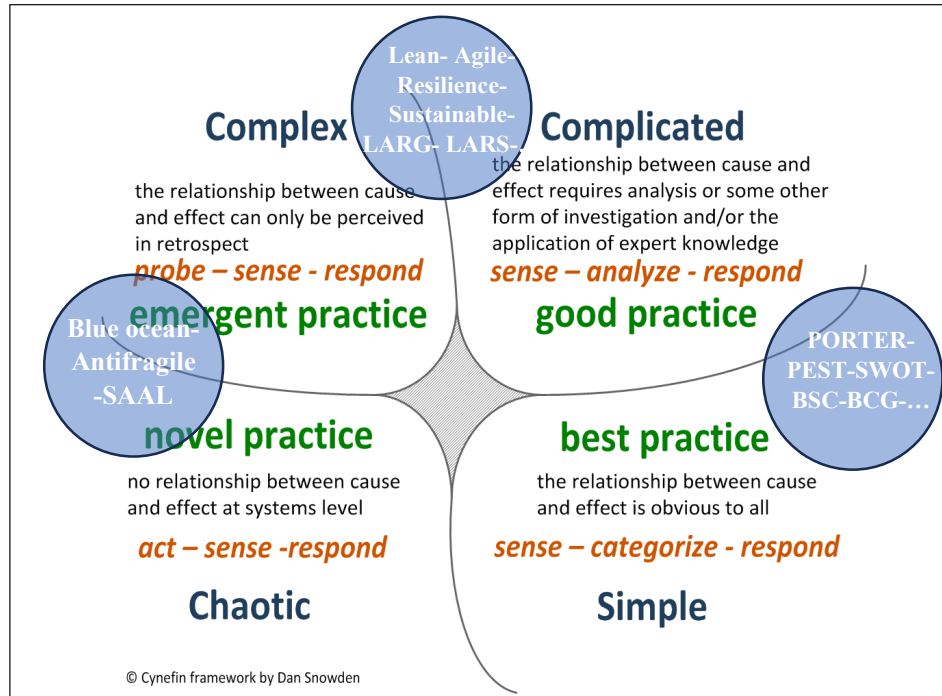


Fig. 1: Business Contexts and Strategies' Each Contexts (Nason, 2017; Sadeghi, Akbarpour & Hamidreza Abbasianjahromi, 2022)

Therefore, these approaches cannot be used. On the other hand, most business researchers use the word risk in the supply chain for some negative changes in performance and dealing with it. It is necessary to use this approach in the current atmosphere of Iran, where chaos prevails. A review of the research background shows that risk in the SAAL supply chain has yet to be considered. This strategy was presented for the first time by Sadeghi et al. (2022) during the outbreak of COVID-19 and many problems in Iran. Therefore, the identified gap is to examine the risks in the chaotic environment and the risks of implementing the SAAL supply chain, in addition to having a positive and pessimistic view of the risk category.

The SAAL supply chain has different risks that must be addressed due to the diverse requirements. Therefore, the research seeks to identify the risks of the SAAL supply chain and rank them. After determining the priority of the risks, proposals are made to manage these risks. This research seeks to respond to the three goals of identifying, prioritising and responding to essential risks. The current research questions are as follows: What risks are facing the SAAL supply chain? What is the priority of the risks facing the SAAL supply chain?

Theoretical Foundations

Each SAAL supply chain paradigm considers components not found in other paradigms. The simultaneous use of four paradigms, sustainable, antifragile, agile and lean, is an attempt to make the supply chain more competitive and stable under chaotic conditions. So that a supply chain can enjoy the advantages of sustainable, antifragile, agile and lean models at the same time (Sadeghi, Sadeghi & Hajjam, 2022; Sadeghi et al., 2023b), since in some cases, some of the components of these paradigms are not compatible with each other, in order to solve this problem, a balance should be established when using these components so that the advantages of all paradigms can be taken advantage of while at the same time the defects of each of them are also covered (Mohaghegh & Größler, 2024; Sadeghi et al., 2023b). For this reason, it should be kept in mind that the simultaneous use of several paradigms will expose the supply chain to more and more complex risks that must be known to be able to manage them. SAAL supply chain management means using sustainable, antifragile, agile and lean paradigms in managing relationships with suppliers and stakeholders

(organisations and customers) (Sadeghi et al., 2023; Sadeghi et al., 2023a).

Risk in the supply chain means uncertainties and unpredictable events that may occur at any point in the supply chain or have a negative or positive (Sadeghi & Sadeghi, 2023) impact on its profit at any point (Mohaghegh & Größler, 2024). Reducing the adverse effects of risks and increasing their positive impact is one of the purposes of supply chain risk management. It could be achieved by developing methods and models to identify, evaluate and control supply chain risks. Supply chain risk management is a new paradigm with a strategic view of all members of the supply chain (Koc & Asli, 2021; Alamdari et al., 2023). Supply chain risk management is an integrated approach to identify, assess, rank and monitor risks and their overall and cumulative effects on the entire supply chain and respond appropriately to significant risks through forecasting, monitoring, learning and targeted action in a coordinated manner (Han et al., 2022; Wang et al., 2019). Supply chain managers must continuously identify and prepare for supply chain risks through coordination and collaborative learning (Abas et al., 2022; Shojaei & Haeri, 2019). Supply chain managers must continuously identify and prepare for supply chain risks through coordination and collaborative learning. Each type of supply chain includes different risks depending on its nature. For example, sustainable supply chains focus on environmental, economic, political and social risks and antifragile supply chains focus more on operational, resource supplier and technological risks (Gupta & Khang, 2024; Pham et al., 2023; Sadeghi et al., 2022). The current research seeks to identify the risks facing the SAAL supply chain; therefore, the research will review supply chain risk and the SAAL supply chain.

Rudolph et al. (2018) worked on critical risks in the supply chain of large-scale engineering and construction projects. This section provides a structured and prioritised view of the supply chain risk portfolio: First, they identified and categorised vital supply chain risks in the recent literature. Next, they examined large-scale project managers in several industries, mostly from supply chain management and project management. The identified risk portfolio deviates significantly from general projects and shows a high inherent risk in large-scale projects. In particular, behavioural risks are recognised as critical. In addition, a bias is found for significant underestimation of risks at project initiation. They found that the risks identified were

significantly different in their characteristics compared to common projects' supply chain risk management approaches. Therefore, they provide a new perspective on supply chain risk management in this specific environment and complement traditional risk management techniques and project risk (Rudolf & Spinler, 2018).

Shujaei et al. (2019) worked on developing supply chain risk management approaches for construction projects. They proposed a comprehensive supply chain risk management approach for construction projects that uses fuzzy cognitive mapping and grey relational analysis. They developed and evaluated different risk reduction scenarios with the proposed approach. By comparing the proposed approach with similar research in the literature, they showed that the proposed approach can show experts' perceptions of risks in an effective and time-efficient manner. In addition, decision-makers can simulate the long-term effects of different risk mitigation strategies on risks and make more informed decisions (Shojaei & Haeri, 2019).

Wang et al. (2019) worked on the construction of a supply chain financial risk management model based on the Internet of Things. They aimed to analyse the problems of information asymmetry, mode delay and high operational risk between banks and companies in the supply chain financial business practice. They proposed the business processes of three basic supply chain financing models and each model's performance shortcomings. Based on this, sources of risk and factors affecting supply chain financing were analysed and operational risks were emphasised. Finally, a new financing mode of inventory commitment was designed based on the function of Internet of Things technology and the business process of the inventory financing mode. The results showed a deep gap in the risk loss value caused by different types of loss events in the operational risk of the accrual financing mode of the supply chain inventory. Among them, the most significant loss was due to foreign fraud. By comparing the expected shortfall of the IoT-based inventory commitment financing mode with the operation risk of the traditional mode, it can be seen that the IoT-based supply chain financing mode effectively reduces the operation risk (Wang et al., 2019).

Hernadvita et al. (2020) worked on identifying risk identification and assessment tools and methods in the construction supply chain. They aim to analyse the gap

between the literature and make improvements in tools and methods for identifying and assessing risk in the construction supply chain. This research used a systematic literature review to find and check tools and methods. The four methods are the Analytical Hierarchy Process, Failure Mode Effect Analysis, Supply Chain Operations Reference (SCOR) and Hazard and Operations. Then, the strengths and weaknesses were summarised, as well as their potential use as methods and tools for identifying and assessing construction supply chain risk. Using SCOR and FMEA methods have shown practical tools and methods to identify and assess construction supply chain risk (Hernadewita & Saleh, 2020).

Cook et al. (2021) worked on life cycle risks related to stakeholders in the construction supply chain. The research was organised in two stages. A systematic literature review, in the first step and content analysis based on risks in the construction supply chain were conducted to identify research gaps, suggest future research directions and support the next steps. Then, three focus group discussions were conducted by industry representatives to (1) identify life cycle risks in the construction supply chain, (2) relate the identified risks to relevant stakeholders and (3) ascertain the role of each one of the stakeholders in the construction supply chain. The content analysis results show relationships, communication and sustainability are the most investigated research areas. At the same time, innovation and organisational learning, supplier vulnerability and negotiation are neglected in the literature. Based on the focus group sessions, 135 risks were categorised into 10 phases of the construction supply chain life cycle demand and, design, bidding and contracting, construction, procurement, delivery, inventory, installation, liquidation and control and maintenance (Koc & Gurgun Asli, 2021).

Sadeghi et al. (2022) worked on providing a lean and agile strategy for a SAAL supply chain in the construction industry. They aim to provide the appropriate Strategy among lean and agile strategies concerning antifragile sustainable supply chain management performance. This Strategy aims to maintain and improve the company's competitive status and functional and environmental criteria to deal with the complexity and chaos in the construction of residential complexes. The snowball method was used to select the statistical population. By studying the articles, criteria and performance indicators of the construction industry were extracted. Then, the

hierarchical best and worst fuzzy sequence method (HF-BWM) was used for prioritisation. The first analysis results show that economic performance, with a weight of 0.4515, is the priority and operational social performance and environmental performance, with a weight of 0.395 and 0.1533, are the second and third priority, respectively (Sadeghi, Akbarpour & Abbasianjahromi, 2022).

Abbas et al. (2022) worked on evaluating critical risk factors and success in the construction supply chain in Pakistan. They aim to identify risk and critical success factors that affect supply chain performance in construction projects in Pakistan. For this purpose, a questionnaire was designed to attract the opinions of contracting companies, consulting companies and project managers. Data was collected from 259 respondents and subjected to statistical analysis. The results of this study identified five important risk factors prioritised based on the severity index. The most critical risk factors identified were financing, with the highest percentage of 93.89%, followed by lack of materials/equipment, cash flow and bad weather. Communication has the highest intensity index among the success factors, with 93.23%, followed by supplier trust, risk allocation, problem-solving and collaborative work. These factors were discussed with concepts that influence and affect the performance of the construction industry (Abas et al., 2022).

Senthil et al. (2022) worked on developing lean construction supply chain risk management based on an advanced neural network. Their key findings focus on quality management and quality assurance processes and graph-based automation of a wide range of finite-quantity lean construction projects. This research presents a multispecies/large quantity continuous management method model and an approach proposed by the lean construction project. Their results put much emphasis on standardisation and improvement management (Senthil & Muthukannan, 2022).

Han et al. (2022) worked on general research and a general review of prefabricated construction supply chain management. They aim to examine the current state and future direction of the prefab construction supply chain by reviewing existing research. They collected and reviewed 131 articles related to prefabricated construction supply chain management from 2000 to 2022. By reviewing the materials, they obtained visual maps and main research topics in the field of prefabricated construction supply chain management. The results show that supply chain

intelligence and information are hot topics (Han et al., 2022).

Marandi et al. (2023) worked on supply chain risk factors in green construction. They aim to identify and assess potential risks, leading to more appropriate risk mitigation strategies to overcome disruptions that affect higher performance. Their results showed that technical expertise, skilled workforce, key customers and company culture are the elements with the most driving force and the final product and logistics coordination and supply chain configuration are known as the most dependent risk factors. The managerial implications address the most fundamental sources of risk and suggest practical, proactive risk management approaches to maximise green supply chain performance (Alamdari et al., 2023).

Sadeghi et al. (2023) worked on evaluating the gap analysis of SAAL supply chain management in Iran's construction industry. The statistical sample includes 246 people from this industry who were randomly selected. First, the gap between each indicator's existing and ideal situation and requirements of SAAL supply chain management strategies was calculated. Then, the weight of the indicators and requirements is determined using the hierarchical best and worst fuzzy method (HF-BWM) and based on that, the weight gap of each is calculated and analysed. The research results show that antifragile and sustainable strategies are the critical SAAL supply chain management strategies for evaluating Iran's construction industry's supply chain management performance (Sadeghi et al., 2023).

Pahm et al. (2023) worked on supply chain risk management in construction for a systematic review. Using a specific six-step review process, this study proposes to overcome such shortcomings of previous literature reviews. Based on this, 30 related articles published in the last two decades were first extracted from Scopus and Web of Science databases. Then, descriptive and content analysis were used to review these articles. It has been found that considerable focus has been devoted to hazard identification and assessment, while hazard mitigation and monitoring have not yet received much attention from researchers. Finally, research opportunities and gaps are presented to guide further studies (Pham et al., 2023).

Oriekhoe et al. (2024) worked on a comprehensive analysis of the implementation, challenges and future

prospects of blockchain technology in supply chain management. Their study explores the historical evolution of supply chain management systems and the comparative effectiveness of blockchain-based models against traditional systems. Their primary aim is to systematically review current research on blockchain in supply chain management, focusing on its implementation, inherent challenges and future development prospects. Their recommendations are to leverage blockchain's potential for competitive advantage and sustainable supply chain practices (Oriekhoe et al., 2024).

Li et al. (2024) worked on a multi-agent digital twin-enabled decision support system based on Industry 4.0 for sustainable and resilient supplier management. They introduced a digitally enabled decision support system for facilitating an intelligent and customised supplier management process in complex environments. The effectiveness of this system was demonstrated through its successful implementation within a solar water pump manufacturing company (Li et al., 2024).

Tsoulfas (2024) worked on building resilient and sustainable supply chains through environmental, social and governance integration. First, he outlines the challenges companies face, such as supply chain complexities, environmental, social and governance data collection and ensuring supplier compliance. Then he describes that despite these challenges, there are significant opportunities, including enhanced brand reputation and competitive advantage, that arise from overcoming these obstacles. By adopting these strategies, companies can address vulnerabilities and build stronger supply chains (Tsoulfas, 2024).

Research Methodology

In terms of its purpose and method, the present research is exploratory and of an applied survey type, so it has multiple methodologies. Two fuzzy Delphi methods will be used to analyse the research data: screening and the hierarchical fuzzy best-worst methods for prioritisation. The statistical population of this research comprises experts and managers of the construction industry in Karaj. According to the nature of the study, the sampling method was purposeful and the research experts were selected according to the risk issue. Since this research is a continuation of the previous research, the selected statistical population is the target. In addition, the supply

chain in construction operations needs to be better known and is generally confused with logistics or purchasing (Sadeghi et al., 2022). Also, the supply chain of SAAL is a nascent topic; from this point of view, the statistical

population has decreased significantly. The sample size in this research is 71 people with expertise in various supply chain fields and knowledge of sustainable, agile and lean approaches (Table 1).

Table 1: Characteristics of the Statistical Population

Gender	Number	Position	Number	Education	Number	Age	Number
Male	57	Executive managers	38	Master's degree	31	30-35	12
Female	14	Observers	8	Doctorate	40	36-40	33
		Marketing and sales managers	3			41-45	21
		designers	12			46-50	5
		Supplier managers	10				

SAAL supply chain risks were initially extracted using background review and expert interviews. In the next step, these risks were analysed using an expert questionnaire and the fuzzy Delphi method. Weak risks were removed and the rest were considered as input to the HF-BWM method for final prioritisation. The prioritisation criterion in HF-BWM was each risk's weight or relative importance. Therefore, two standard questionnaires were designed. In multi-indicator decision-making methods, several options are evaluated according to several indicators to select the best choice. Based on the HF-BWM method, the best and worst indicators are identified by the decision maker and a pairwise comparison is made between each of these

indicators (best and worst) and other indicators. Then, a maximum-minimum problem is formulated and solved to identify the weight of different indicators. The best-worst fuzzy hierarchical method steps are as follows (Sadeghi, Akbarpour & Abbasianjahromi, 2022).

Step 1. Determining the best and worst criteria (the most important and the least important): This step was determined using experts' opinions.

Step 2. Pairwise comparison of the best criterion and other criteria with the worst criterion: In this step, the most common spectrum for the fuzzy best-worst method is the 5-phase fuzzy spectrum in Table 2.

Table 2: Inconsistency Rate and Verbal Range of Fuzzy Best-Worst Method (Guo & Zhao, 2017)

Language Expressions	Equal Importance	More Important	More Important	Much More Important	More Important
\tilde{a}_{BW}	(1,1,1)	$(\frac{2}{3}, 1, \frac{3}{2})$	$(\frac{3}{2}, 2, \frac{5}{2})$	$(\frac{5}{2}, 3, \frac{7}{2})$	$(\frac{7}{2}, 4, \frac{9}{2})$
	3.00	3.80	5.29	6.69	8.04

Step 3. Creation of the fuzzy best-worst method model: In this step, the weight of the factors can be calculated using the non-linear programming model (equation 1).

$$\text{mine}^L + \sum_j e_j^L$$

s.t.

$$|\tilde{W}_B - \tilde{a}_{Bj} \cdot \tilde{W}_j| \leq e^L, \forall_j$$

$$|\tilde{W}_j - \tilde{a}_{jW} \cdot \tilde{W}_W| \leq e^L, \forall_j$$

$$|\tilde{W}_B^j - \tilde{a}_{Bk}^j \cdot \tilde{W}_k^j| \leq e^L_j, \forall_j \& \forall_k$$

$$|\tilde{W}_k^j - \tilde{a}_{kW}^j \cdot \tilde{W}_W^j| \leq e^L_j, \forall_j \& \forall_k$$

$$G\tilde{W}_k^j = \tilde{W}_j \cdot \tilde{W}_k^j, \forall_k$$

$$\sum_j R(\tilde{W}_j) = 1, 0 \leq l_j^W \leq m_j^W \leq u_j^W, \forall_j$$

$$\sum_j R(W_k^j) = 1, 0 \leq l_k^{Wj} \leq m_k^{Wj} \leq u_k^{Wj}, \forall_j \& \forall_k \quad (1)$$

In the hierarchical fuzzy best-worst method, the weights obtained from each expert are merged after solving and calculating the criteria weights.

Step 4. Defuzzification: After collecting opinions, they should be defuzzified. There are many and complex methods for defuzzification. One of the simple methods to defuzzify the average of triangular fuzzy numbers in the form of equation 2 (Emovon, 2016):

$$F_{AVG} = (L, M, U)$$

$$X_m^1 = \frac{L + M + U}{3}$$

$$X_m^2 = \frac{L + 2M + U}{4}$$

$$X_m^3 = \frac{L + 4M + U}{6}$$

$$z = \max(X_{max}^1, X_{max}^2, X_{max}^3) \tag{2}$$

Step 5. Calculating the compatibility index: This section introduces the compatibility index for the best-worst proposal method. Then, the value of the compatibility rate is obtained using e^* (equation 3) and the compatibility rate (Table 2) related to it as follows:

$$CI = \frac{e^*}{CR} \tag{3}$$

Research Findings

Reliability and Validity

For the first questionnaire, since the research risks were identified with the aid a comprehensive review of articles and interviews with experts, the expert questionnaire has content validity. Since the best-worst method is used, the consistency rate is used to measure the reliability of the second questionnaire. If this rate is less than 0.1, the desired model has the necessary reliability. The results of the questionnaire are shown in Table 3.

Table 3: CI

Approach	Sustainable	Antifragile	Agile	Lean
CI	0.022	0.023	0.082	0.023

Because the CI of paired comparison questionnaires was less than 0.1, the second questionnaire of the research has reliability.

Analysis Results

This section lists the risks faced by each SAAL supply chain, which are the SAAL supply chain components, in the table below. To increase the validity and reliability of the research, the researchers confirmed them by considering the risks extracted from the background and the structured interview of the experts. The analysis showed that the experts confirmed that more than 90% of the risks are related to the SAAL supply chain. Each type of supply chain approach has different risks depending on its nature and each category of risks includes sub-risks. For example, environmental, social and economic risks are important in a sustainable supply chain. In the antifragile supply chain, risks are generally external. The most critical concerns in the agile supply chain are market issues, quick response and flexibility. The risks in the lean supply chain are related to operations, financing cost reduction and continuous improvement. Table 4 shows the risks facing the SAAL supply chain that have been extracted using the literature study.

Table 4: Risks Facing the SAAL Supply Chain

Type of Supply Chain Approach	Main Risks	Secondary Risks	References
Sustainable	Environmental	Improper Reporting Frameworks, Sustainable Resources Reaction of Stakeholders Emission Standards and Leed, Air Pollution, Publication of Toxic Substances Production of Waste Low Quality of Recycled Materials, Weakness of Recycling Processes and Technology	(Han et al., 2022; Koc & Gurgun Asli, 2021; Sadeghi, Akbarpour, et al., 2023; Soheil Sadeghi, Saman Sadeghi, & Zahra Hajjam, 2022; Wang et al., 2019)
	Economic	Exchange rate fluctuations, Downturn, Liquidity required by related industries, People’s purchasing power, Fall of financial markets	(Abas et al., 2022; Hernadewita & Saleh, 2020; Marandi Alamdari et al., 2023; Soheil Sadeghi, Abbas Akbarpour, & Hamidreza Abbasianjahromi, 2022; Sadeghi, Sadeghi, et al., 2023b)

Type of Supply Chain Approach	Main Risks	Secondary Risks	References
	Social and cultural	Demographic changes, Changing people's tastes Local-regional cultural, ideological and religious issues Employment of local employees Not using psychological empowerment Not using the co-creation approach Elite migration	(Koc & Gurgun Asli, 2021; Pham et al., 2023; Sadeghi, Akbarpour, et al., 2023; Sadeghi, Sadeghi, et al., 2023b; Wang et al., 2019)
Antifragile	Modularization - integration	Creating modular systems (materials, technology, operations, suppliers), The possibility of creating decentralized integrated systems, The possibility of standardization (processes, operations, materials) Failure to use the flexible financing method The possibility of creating a resilient infrastructure	(Abas et al., 2022; Soheil Sadeghi, Abbas Akbarpour, & Hamidreza Abbasianjahromi, 2022; Sadeghi, Sadeghi, et al., 2023b)
	Political	The possibility of implementing the functional independence strategy of the units Changing the perspective from risk management to uncertainty management and creating local flexibility and more dynamic assessments foreign sanctions, Domestic laws Change of managers Political instability	(Han et al., 2022; Hernadewita & Saleh, 2020; Sadeghi, Sadeghi, et al., 2023a, 2023b)
	Legal	Beneficiary Organizations Rules regulations and standards, Tax and customs laws, Changes to the rules	(Gupta & Khang, 2024; Koc & Gurgun Asli, 2021; Soheil Sadeghi, Saman Sadeghi, & Zahra Hajjam, 2022; Senthil & Muthukannan, 2022)
Agile	Market	the intensity of competition, Fluctuations in market demand Substitutability of products, Poor marketing methods	(Hernadewita & Saleh, 2020; Koc & Gurgun Asli, 2021; Marandi Alamdari et al., 2023; Sadeghi, Akbarpour, et al., 2023; Sadeghi, Sadeghi, et al., 2023a; Wang et al., 2019)
	Production/ manufacturing process	Failure to correctly predict market demand, production/manufacturing planning errors, Product design changes	(Han et al., 2022; Koc & Gurgun Asli, 2021; Sadeghi, Sadeghi, et al., 2023a, 2023b; Wang et al., 2019)
	Supply	You are using incorrect supplier selection methods. Working with a poor supplier Lack of timely supply of materials and information	(Hernadewita & Saleh, 2020; Pham et al., 2023; Rudolf & Spinler, 2018; Senthil & Muthukannan, 2022; Shojaei & Haeri, 2019)
Lean	Operational	Failure of devices and equipment, human resources risk, Cultural and teamwork risk low quality of the operation line, Low build quality operational risks (supply, purchase, transport, maintenance, operation) Poor quality control processes	(Han et al., 2022; Koc & Gurgun Asli, 2021; Sadeghi & Sadeghi, 2023; Soheil Sadeghi, Saman Sadeghi, & Zahra Hajjam, 2022; Sadeghi, Sadeghi, et al., 2023a)

Type of Supply Chain Approach	Main Risks	Secondary Risks	References
	Informational	Weakness of information infrastructure. failure of information systems and processes, Lack of access to the correct information. Inadequate control of supply chain processes Information Sharing	(Abas et al., 2022; Koc & Gurgun Asli, 2021; Oriekhoe et al., 2024; Pham et al., 2023; Soheil Sadeghi, Saman Sadeghi, & Zahra Hajjam, 2022; Sadeghi, Sadeghi, et al., 2023a)
	Financial	financing problems, Non-receipt of financial claims from customers, increase in energy costs, Increase in the price of materials and resources Increase in transportation cost	(Hernadewita & Saleh, 2020; Marandi Alamdari et al., 2023; Rudolf & Spinler, 2018; Soheil Sadeghi, Abbas Akbarpour, & Hamidreza Abbasianjahromi, 2022; Soheil Sadeghi, Saman Sadeghi, & Zahra Hajjam, 2022)

In this research, the threshold limit is considered equal to 0.60. The fuzzy Delphi results show that the average importance of 18 factors is more than 0.6. These extraction risks can be seen in Table 5. Next, the risks related to each supply chain approach are prioritised using the HF-BWM technique. Due to the length of the content, in Table 5, the

priority sub-indicators in each main risk are given along with the corresponding weight. Fig. 2 shows the weight of sub-risks and their ranking and Fig. 3 shows the weight of risks in the main areas.

Table 5: The Weighting of SAAL Supply Chain Risks using the HF-BWM Method

Type of Supply Chain Approach	Secondary Risks	Normalized Weight	Rank	Type of Supply Chain Approach	Secondary Risks	Normalized Weight	Rank
Sustainable supply chain	Release of toxic substances	0.0387	15	Agile supply chain	Intensity of competition	0.0493	12
	Waste production	0.0256	17		Using incorrect supplier selection methods	0.0304	16
	Exchange rate fluctuations	0.0880	1		Lack of timely supply of materials and information	0.0701	6
	Downturn	0.0759	4	Lean supply chain	Low build quality	0.0396	14
	People’s purchasing power	0.0852	2		Lack of access to the correct information.	0.0198	18
	Not using the co-creation approach	0.0442	13		Financing problems	0.0791	3
Antifragile supply chain	Creating a modular system	0.0518	10		Increase in the price of materials and resources	0.0733	5
	Not using the flexible financing method	0.0536	9		Increase in transportation cost	0.0631	7
	Beneficiary Organizations Rules	0.0610	8				
	Changes to the rules	0.0513	11				

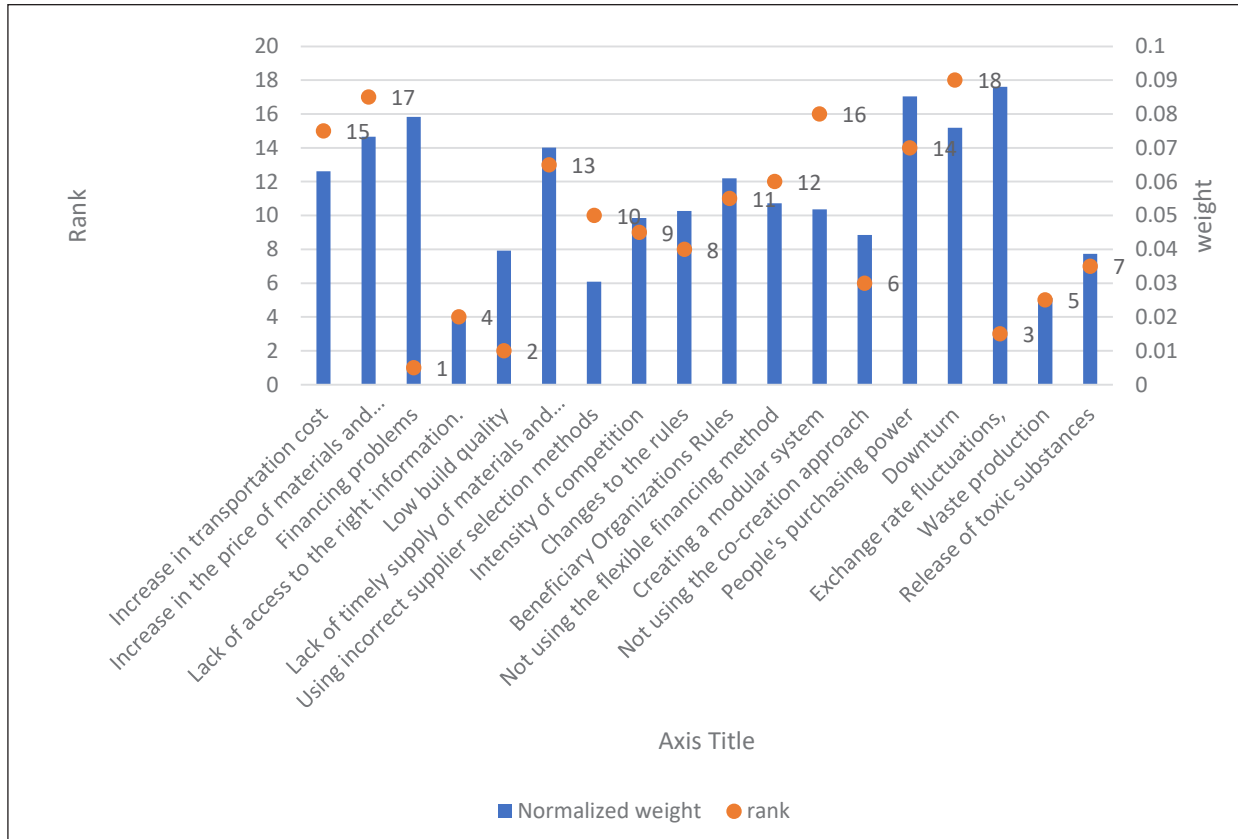


Fig. 2: Weight and Ranking of Sub-Risks

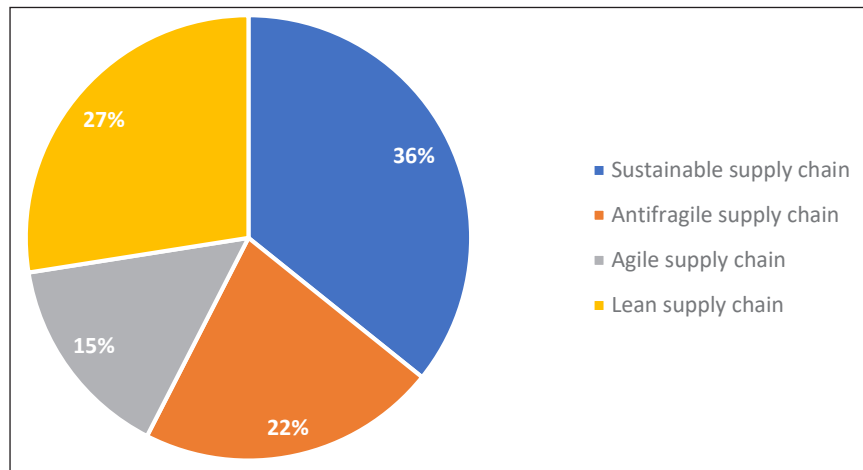


Fig. 3: Risk Weight of the Main Areas

As can be seen from Table 5 and Fig. 2, the risk of exchange rate fluctuations has an average weight of 0.0880 and the purchasing power of people has an average weight of 0.0852 from the risks of a sustainable approach in the first and second priority, respectively. Financing problems with a weight of 0.0791 from the lean approach is in the third place, economic burden

with a weight of 0.0759 from the sustainable approach is in the fourth place and the increase in the price of materials and resources is in the fifth place with a weight of 0.0733. According to the extracted data, financial issues, according to what we see in the country, are among the most significant risks and concerns of the people involved in this industry.

According to Fig. 3, sustainable supply chain risk, 36% and lean supply chain risk, 27%, are the most important. Another issue investigated is the extent of managers' awareness of supply chain approaches and the need to use them. It should be mentioned that according to the experience gained from previous research, we knew that the level of knowledge of experts in this field about the

supply chain is low, so we did not consider this issue from the beginning because the statistical population, even considering all the experts involved in this industry, was shallow. Therefore, their level of knowledge about agile, lean, sustainable approaches and project management was paid more attention to and the statistical population increased relatively. The results are presented in Fig. 4.

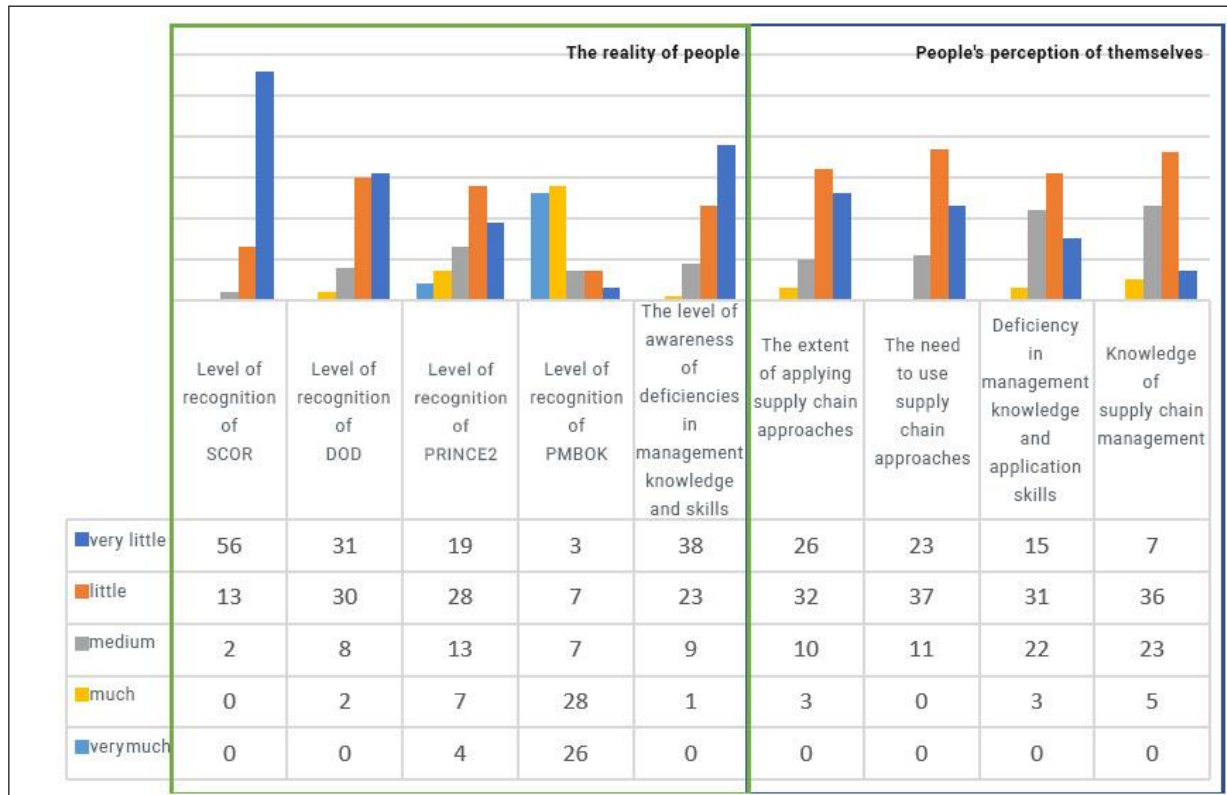


Fig. 4: Managers' Knowledge of the Supply Chain

As shown in Fig. 3, a large segment of the statistical community needs to gain more knowledge of the supply chain and its approaches, so they do not see the need to use it. Since this research follows its previous study regarding the SAAL supply chain strategy implementation, this result was also observed in previous research and the selected community was used. This lack of self-awareness increases the risk of operations in the supply chain, especially under chaotic conditions. The reason for that is the need for more training and awareness of people in the areas of management knowledge in the construction industry. People had a good knowledge of the PMBOK guide but needed to learn the other guides and standards better. This issue is especially well seen in the SCOR supply chain standard. The supply chain is the

core of construction operations and a lack of knowledge about it causes many problems in the advancement of this industry.

Diversifying financing tools and using feasibility tools in projects play an important role in reducing risks in financing and related risks. Many development projects in the construction industry's supply chain need to be appropriately performed in the field of evaluation and cost and income estimates and this issue causes the supply chain to face serious risks. Using scenario analysis methods to create a flexible approach can increase the stability of financial decisions. The use of new financial tools in the capital markets is one of the things that can reduce some of the financing problems of the construction supply chain due to the acceptance of investors and

shareholders. This issue can also reveal different aspects of financial risks.

Changing people's tastes and attitudes is a social risk related to an agile and anti-fragile supply chain. The expansion of social networks, the free flow of information and generational changes and effectiveness due to internal problems are serious threats. In this context, paying attention to the trends and drivers influential on consumer behaviour in the future, examining the changes in customers' buying behaviour and translating customers' wishes and co-creating with them play unique roles in the production and improvement of construction quality in managing this risk. The scenario planning tool is suitable for discovering different scenarios about social tastes and tendencies. After identifying possible scenarios, the appropriate policy can be made based on the most likely scenario.

Discussion and Conclusion

Most previous research about supply chain risk has focused on specific aspects of risk and many elements need to be addressed. However, this research, focusing on the SAAL supply chain approach (a combination of existing approaches), has tried to examine the issue of supply chain risk comprehensively in chaotic context. This was the first time that this risky situation was investigated in the supply chain in the construction industry. This review is a preliminary review for further research that will be published in future articles. With the help of this survey, the foundation of the next research was provided. For this reason, the current research sought to identify and prioritise the risks facing the SAAL supply chain in the chaotic context of Iran. For this purpose, background review and expert interviews extracted SAAL supply chain risks. So, this issue caused many challenges. Because many managers did not understand the current situation in Iran. Therefore, many coping strategies fail. Understanding the current situation took a lot of research time.

The result of this review was 63 risks that were classified into 14 main categories: environmental, economic, social and cultural, modularisation - integration, political, legal, market. production/manufacturing process, supply, operational, informational, financial. Then, the risks of the main categories were screened with the fuzzy Delphi

method. Among these risks, 18 with a diffuse number above the threshold of 0.6 were selected for the final analysis (Table 5). Each supply chain category has specific risks. Identifying risks and agreeing between them was one of the time-consuming tasks. Next, the risks related to each supply chain approach were prioritised using the best-worst fuzzy hierarchical technique.

Results show that the risk of exchange rate fluctuations has an average weight of 0.0880 and the purchasing power of people has an average weight of 0.0852 from the risks of a sustainable approach in the first and second priority, respectively. Financing problems with a weight of 0.0791 from the lean approach in the third place, economic burden with a weight of 0.0759 from the sustainable approach in the fourth place and the increase in the price of materials and resources with a weight of 0.0733 rank fifth. These risks show that considering the economic issues governing Iran, financial issues are critical and the focus should be on them. Sanctions, economic speculators, embezzlers, spending low economic budgets for construction issues, low salaries of employees compared to the inflation line, the growth of inflation, the ever-increasing migration of efficient and literate human resources and inefficient management of the country have caused the emergence of such problems in the country.

Limitations of the Study

This was the first time that risks of the SAAL supply chain, especially in the construction industry. Because so far no research has been done regarding the risks of the SAAL supply chain. There was very little information in this regard. So, this issue caused many challenges. Because many managers did not understand the current situation in Iran, understanding this situation took a lot of research time. Many human capitals have migrated from the country. The lack of educated and intelligent people to conduct research and interviews was much felt.

This research has only identified and prioritised SAAL supply chain risks. Also, this research has been conducted in the construction industry in Karaj and the relationships between the risks of the SAAL supply chain have not been investigated and only the weight of these risks has been determined. At the same time, generalising its results to other areas of the construction industry, such as road and dam building and even cities of other provinces

in the same area, should be done cautiously. Another area for improvement is the need for more awareness among activists in this field of the need to use supply chain management in the construction industry.

Supply chain risk is one of the topics that has attracted significant attention. Despite several literature, there is not much research in the context of collapsing and the third world economies, particularly countries like Iran, which has been at the forefront of several issues and there is scope for study. I recommend it is going to be reviewed in the next research capture of the various aspects of supply chain risk and its implications on the economy.

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