



Identifying and ranking key technological capabilities in supply chain sustainability using ISM approach: case of food industry in Iran

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Received: 6 May 2022 / Accepted: 25 February 2023 / Published online: 14 March 2023
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Abstract

The food industry is one of the strategic industries in developing countries, such as Iran and plays a critical role in the economy, food security, and public health. The growing populations can only have food security when the food industry's supply chain is sustainable. Therefore, due to the sustainable food supply chain's great importance, having technological capabilities compared to others is considered a competitive advantage for the companies involved in the food industry, as it can distinguish them as pioneer actors. Although many technologies have been investigated and used in the sustainable supply chain recently, no study has focused on identifying and ranking key technological capabilities related to the food industry in sustainable supply chain management. Also, we have not found any study using the ISM-MICMAC method to identify, rank, and interdependence between key technology capabilities in supply chain sustainability. Accordingly, the present study sought to identify and rank key technological capabilities in the supply chain sustainability of food industry companies. In this study, after reviewing the relevant literature, eleven technological capabilities in supply chain sustainability were identified. Then using experts' opinions and Interpretive Structural Modelling (ISM), interdependence among the technological capabilities ranked. Finally, dependent and independent drivers were presented using the MICMAC analysis. The ISM analysis results indicated that *communication and information technology infrastructure* was the most significant driver for other technological capabilities in companies' supply chain sustainability. Moreover, *logistic optimization* is imperative for improving supply chain sustainability performance. Therefore, if *logistic optimization* is appropriately implemented, it can improve supply chain sustainability. The present study results can increase supply chain productivity and effectiveness in Iranian food industry companies.

Keywords Sustainable supply chain management · Technological capabilities · Interpretive structural model · MICMAC analysis · Food industry

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1 Introduction

The sustainable supply chain (SSC) concept has gained the attention of many experts and academics during the previous 20 years. Sustainability is a multifaceted and complex concept and has become a prevalent purpose among industrial experts and academics (Ghadimi et al., 2019). In general, sustainability refers to a method of sustaining society’s current needs that do not limit future generations from achieving their goals (Jalilian & Mirghafoori, 2019; Kibert et al., 2021; Yadav et al., 2022; Yakovleva, 2007). Sustainability is of critical significance in all industries and is even more important in the food industry. Ensuring the quality, safety, freshness, health, and sustainability in the household consumption basket’s essential foods has always been a priority, and companies spend huge costs on minimizing food wastage (Green, 2010; Kumar et al., 2022a, b; Y. K. Sharma et al., 2018; Yadav et al., 2022). Nowadays, consumers pay extra attention to the food’s safety, quality, and nutrition aside from its volume. Food safety is each consumer’s concern, and governments should pay close attention to the food industry companies’ methods and products (Beske et al., 2014; Kumar et al., 2022a, b; Yadav et al., 2022; Yakovleva, 2007), since one out of every ten individuals gets sick due to food poisoning, as the WHO reported (Duan et al., 2020a). In addition, according to the FAO report, the outbreak of COVID-19 and the Ukraine war has caused potentially worrying consequences for global nutrition and food security (FAO, 2022). Supply chains around the globe continue to face challenges from the COVID-19 epidemic, including delays and disruptions (Abbasi, Khalili, et al., 2022a, b, c). According to (Fig. 1), the prevalence of malnutrition (PoU) grew to almost 9% in 2020 from 8.0% in 2019. Also, it rose to nearly 9.8% in 2021, although at a slower pace. In 2021, about 702 or 828 million people worldwide (8.9 or 10.5% of the total population, respectively) encountered hunger. In its report’s continuation, FAO emphasizes that sustainability must be considered for food security to be achieved (Clapp et al., 2022; FAO, 2022). The

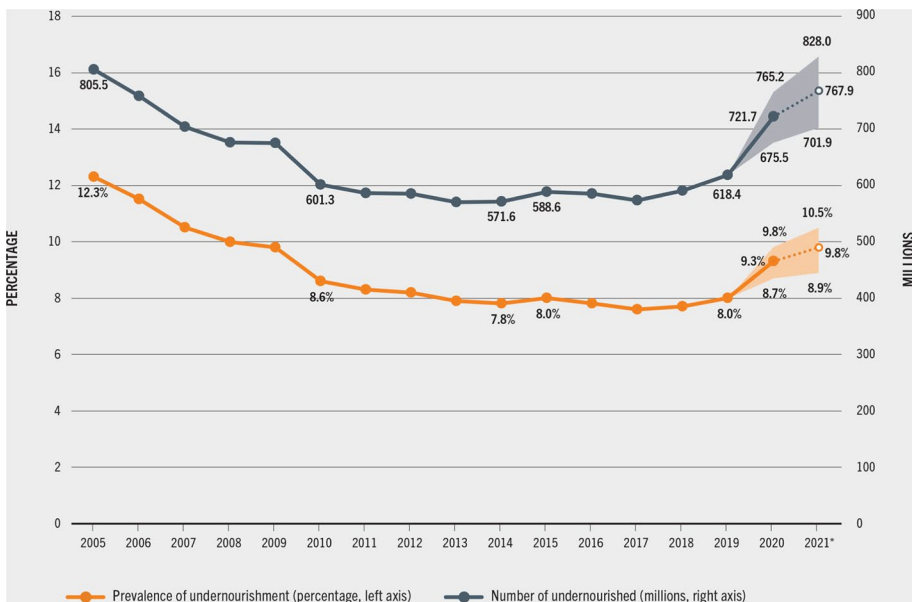


Fig. 1 The prevalence of malnutrition (FAO, 2022)

food systems ability to deliver nourishment and food safety over the long term without compromising the economic, social, and environmental foundations, which produce the safety of food for the next generations, is known as sustainability in the food safety context (Clapp et al., 2022; FAO, 2022).

Concentration on food safety is deeply associated with sustainable supply chain management (SSCM), as several firms are trying to address the issues associated with maintaining food safety and quality through SSCM (Beske et al., 2014). Aside from food safety and health, other issues such as ecological problems (deforestation) or social issues such as fair wages for farmers are reported by governmental or non-governmental organizations (NGOs) that raise various concerns in different countries and communities (Beske et al., 2014; Manteghi et al., 2021).

The food industry is considered the primary energy and resource consumer from the environmental view, and agriculture accounts for approximately 70% of freshwater extraction (Kumar et al., 2022a, b).

Given the lack of resources, population growth, and the food need increment, sustainability is imperative in food industries. The notion of ‘sustainability’ has made organizations focus on social responsibilities (such as maintaining resource diversity, consumer health), ecological goals (such as reducing greenhouse gas emissions and resource wastage), as well as economic goals (such as maximizing profits and increasing the demand for their products) (Jalilian & Mirghafoori, 2019; Manteghi et al., 2021).

Aside from the points mentioned above, the globalization and outsourcing of food systems, with the largest number of suppliers and involved companies, has made food systems more complex than before. Despite the fact that each supply chain member might affect the final product’s overall sustainability, further systematic efforts must be implemented for impressive success since the distance between the producers and customers in food supply chains poses a threat to conserving food quality and access to rapid food recalls (Cagliano et al., 2016; Duan et al., 2020b). In this regard, a survey (Commission, 2020) showed that half of the people believe that food manufacturers, shops, and retailers are the most crucial players in promoting a sustainable food supply system (Fig. 2).

In recent years, many technologies have been studied to handle the insecurity of food and increase the efficiency of food recalls (such as Radio Frequency Identification (RFID)

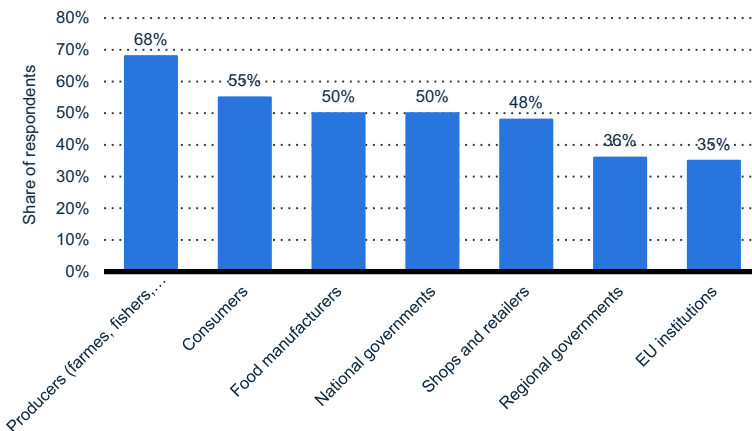


Fig. 2 Most crucial players in promoting a sustainable food system (Commission, 2020)

and Blockchain) (Duan et al., 2020a). Since the growing technological advancements are constantly decreasing the life cycle of products, particularly food products (Kim & Kara, 2012), organizations need to detect the required technologies and technological capabilities and exploit the most significant capabilities to promote their competitive advantage, and to become an important actor in a sustainable food supply system. This issue is because competitive markets and the company's sustainable performance have a close relationship with the use of key advanced technologies (Feng et al., 2020). To improve competitiveness, businesses use various methods to enhance their supply chain and organizational theories, which must become consistent with essential requirements (such as sustainability) to ensure their appropriate effectiveness (Gopal & Thakkar, 2016; Yadav et al., 2022). The intense commercial rivalry innovation in services, goods, and state rules (both national and multinational), including carbon taxation and environmentally friendly products, has compelled the industries to acknowledge and use sustainability as a competitive means (Gopal & Thakkar, 2016).

The points mentioned above reveal a significant research gap in the identification of technological capabilities and the execution of sustainable supply chains in the food industries. Thus, this study seeks to identify, recognize, and rank key technological capabilities of a sustainable supply chain in the food industry, given how essential they are to the economy and individual health. The present study results would have effects on companies' supply chain sustainability directly and indirectly. Moreover, the findings would help managers in this field improve their competitive advantage over their rivals, increase production and benefits, add further value to the food industry supply chain, and become important actors in a sustainable food supply system. To be more specific, the researcher aims to address the following queries:

1. What are the technological capabilities in the sustainability of companies' supply chains, particularly in food industries?
2. What are the interactions between technological capabilities and the sustainability of companies' supply chains?
3. Which technological capabilities are critical in companies with a sustainable food supply chain?
4. How is the order of these important technological capabilities in the supply chain sustainability of food industry companies?

The study consists of the sections mentioned in the following. The literature review is provided in the second section. Then, the third section presents the research gap. The fourth section discusses the research methodology, including the structural-interpretative modeling and the MICMAC analysis. The fifth section shows the study results, including the identified technological capabilities and the analyses of the results. The sixth section discusses the results, and the seventh section draws the conclusion. Theoretical and managerial implications have been discussed in the eighth section, and limitations and future research are provided in the ninth section.

2 Literature review

The following section studies the research literature and discusses some of the essential theoretical frameworks and concepts of the research subject.

Numerous researchers have examined supply chain sustainability (SCS) and the influence of various factors on maintaining it in different countries and industries over recent years. For example, Kumar and Rahman (2017) categorized and modeled the factors in the acceptance of sustainability, and they provided practical strategies in the field of managing enablers. In the study of Sharma et al. (2018), the authors concentrated on improving security and safety as well as ranking the success factors in managing food supply chains sustainably. Gopal and Thakkar (2016) analyzed the Critical Success Factors (CSFs) in successfully implementing SSC strategies in India's automobile industry. They extracted the textual relationship between the CSFs using ISM to extend a hierarchy of CSFs to execute SSC strategies in India's automobile industry. Sustainability, especially in the food supply chain, can play a vital role during emergency situations. In this regard, Abbasi et al., (2022a, b, c) explained the pros and cons of different sustainability aspects in the context of the pandemic and the great lockdown by providing a mathematical model for sustainable end-of-life management. Also, To evaluate the sustainable performance of the supply chain Abbasi and Khalili et al., (2022a, b, c) developed an approach that could help companies to identify critical points between supply chain stakeholders during the COVID-19 outbreaks.

Feng et al. (2020) researched the impact of key technological capabilities in companies with advanced technology and their sustainable competitive advantage. They concluded that industries with advanced technologies could maintain their competitive advantage and become unbeatable in the complex environment if they keep innovating and conducting scientific research. Hong et al. (2018) investigated the connection between SSCM strategies and the performance of an organization, as well as the impact of SSCM on the dynamic capabilities of supply chains (SCs) and company performance (including economic, social, and ecological performance) using Structural Equation Modeling (SEM). In their study, the results indicated that SSCM strategies significantly affected the dynamic capabilities of the SC along with all three dimensions of performance. Furthermore, Beske et al. (2014) investigated dynamic capabilities execution in SSC and its achieving competitive advantage in the food industry. Their findings indicated that sustainability strategies and dynamic capabilities in the supply chain play a role in increasing the ability to track, detect, and meet customer needs. Moreover, Kyläheiko et al. (2011) investigated the relationship between technological capabilities, their suitability, innovative activities, and internationalization and proposed several hypotheses from a knowledge-oriented perspective. They concluded that technological capabilities leave a significant and positive impact on internationalization and innovation strategies.

Sugathan et al. (2015) studied Green Supply Chain Management (GSCM) concerning environment-compatible information technology strategies. Their results indicated that GSCM had a positive and direct effect on the ecological and technological performance of the studied companies. Also, Khan et al. (2016) introduced information sharing in SSCM and investigated whether sharing information could decrease the costs of SSC. They concluded that sharing information leads to better annual profits as well as reduced consumer prices. Singh et al. (2019) determined and examined the key factors of the application of Information Communication Technology (ICT) for sustainable SMEs Indian food industry development sector. They identified the "Encouragement to the ICT service provider" as an essential factor and "Effective and comprehensive food supply chains using information communication technology" as one of the influential factors.

Tseng et al. (2019a, b) investigated the improvement of sustainable supply chain capabilities (SSCC) by using social networks to make decisions. Their results present that the top seven factors that most influence SSCC are crucial for enhancing SSCC. In addition, companies' SSCC can be upgraded to bring in new clients, maintain current clients

delighted and faithful, and improve incomes. Agyabeng-Mensah et al. (2020) investigated the impact of logistic optimization, green warehousing, social standards, and values on SCS and economic performance. Moreover, Rajesh (2017) conducted a study on supply chain resilience and investigated the concepts of firms' resilience and technological capabilities. The study results indicated that proper reinforcement of these key capabilities results in more resilience and flexibility in the supply chain. However, the literature review found no study investigating and modeling technological capabilities in SCS. Such studies would create tremendous value for countries such as Iran and significant industries such as the food industry to emphasize the long-term SCS approach.

A number of new studies in the SSCM area, arranged by the year of publication, are shown in Table 1. Numerous studies have been done to determine different SSCM enablers and barriers [4, 9, 11, 12, 15, 16, 19, 22, 23, 25, 26, 30], depicted in Table 1. A few articles have tried to discover the SSCM drivers and use modeling tools [3, 21, 31] to analyze interactions among the drivers. Moreover, some studies have concentrated on generic SCs instead of particular industries' SCs [8, 5, 18, 20, 24, 21, 29]. Also, many articles have investigated dynamic capabilities or specific capabilities [1, 2, 5, 7, 8, 13, 14, 17, 28]. Accordingly, it can be argued that no effort has yet been made to identify, analyze, and prioritize key technological capabilities (TCs) in SSCM related to the food industry, and this is pioneer research of its sort. To this end, ISM and MICMAC methods were used to create a hierarchal sketch of all TCs by identifying their interrelationships. ISM's ability to segregate complicated relationships between system components into hierarchical structures attracted attention from various disciplines. Using a systematic approach, ISM contributes to understanding the direct or indirect relationships between various elements separately and provides precious insights (Usmani et al., 2022). In addition, none of those studies used ISM and MICMAC as a method to identify, rank, and reveal interdependence among different TCs. This study tries to address this gap in the SSCM field.

2.1 Sustainability

Since Brundtland published *Our Common Future* in 1987, most scholars have accepted the definition of sustainability, relying on the three key areas of ecological, social, and economic, guaranteeing evolution in the future (Abbasi, Khalili, et al., 2022a, 2022b, 2022c; Dalal-Clayton & Bass, 2000; Sánchez-Flores et al., 2020; Yadav et al., 2022). However, the Council of Supply Chain Management Experts (CSCMP) updated the sustainability concept in 2013 to a business effort to adapt to sustainable development efforts while accounting for the stakeholders' needs and the company's social responsibility (Sánchez-Flores et al., 2020).

According to what was noted, sustainable development promotes the quality of life in communities while protecting our natural resources because of its vital function in economic and ecological prosperity, and this turned it into a necessity at the global level (Vishwakarma et al., 2022). Moreover, increased international pressures have led organizations to adopt sustainable strategies to boost the supply chain's productivity and competitive advantage (Jalilian & Mirghafoori, 2019; Sánchez-Flores et al., 2020).

2.2 Sustainable supply chain management (SSCM)

Supply chain management (SCM) was defined as the rapid and dependable provision of raw resources and final products. Accordingly, efficient performance and persistent current

Table 1 Recent literature in the area of SSCM

No.	Authors	Contribution	Focused area	Tools/techniques used
1	Beske et al. (2014)	Determining SSCM procedures enable businesses to keep control of their SC and gain a competitive advantage by enacting dynamic capabilities	Food industry	Literature review
2	Lee et al., (2014)	Established how GSCM procedures and technological innovation affect manufacturing companies	Manufacturing companies in Malaysia	(SEM)
3	Sugathan et al. (2015)	Determined the driving factors and performance results connected with implementing GSCM	Manufacturing companies in Malaysia	Input-Process-Output (IPO) Theory
4	Hosseinnia and Ramezani (2016)	Studied the social, customer-oriented, human resources, and environmental factors that affect sustainable entrepreneurship in the Iranian food industry's small- and medium-sized enterprises	Food industry	Questionnaires procedure and SPSS analysis
5	Khan et al. (2016)	Analyzed the effects of information sharing in a two-dimensional supply chain (social and environmental)	Sustainable Supply Chain (SSC)	Mathematical Model
6	Gopal and Thakkar (2016)	Studied the crucial success factors in adopting SSC practices	Automobile industry	ISM
7	Rajesh (2017)	Identified technological capabilities assist supply chain resilience	Electronics manufacturing industry	Total Interpretive Structural Modelling (TISM)
8	Hong et al. (2018)	Studied how supply chain (SC) dynamic capabilities and company performance were impacted by SSCM techniques	Enterprises	SEM
9	Kumar and Rahman (2017)	Modeled, categorized, and prioritized the distinct enablers of sustainability adoption	Indian automobile SSC	ISM and fuzzy analytic hierarchy process (AHP)
10	Vitorino Filho and Mooni, (2018)	Studied how technological capabilities contribute to supply chains' competitive advantage	Campinas technology hub	Mann-Whitney U technique

Table 1 (continued)

No.	Authors	Contribution	Focused area	Tools/techniques used
11	Sharma et al. (2018)	Determined and categorized success factors (SFs) pertinent in order to make Sustainable Food Supply Chain Management (SFSCM) secure and safe	SFSCM	Multi criteria decision making (MCDM) tool, and fuzzy AHP
12	Shankar et al. (2018)	Categorized and identified various important success factors necessary for the installation of the traceability system	Food Logistics System (FLS)	Exploratory Factor Analysis (EFA), and TISM
13	Singh et al. (2019)	Applications of information and communication technology for SMEs' sustainable development	Food industry	Grey- DEMATEL
14	Tseng et al. (2019a, 2019b)	Research using social media in decision-making to improve the sustainability of the SC	Textile and Apparel (T&A) sector	FSE-DEMATEL
15	Raut et al. (2019)	The relationships between the main impediments to sustainable development have been developed	T&A sector	MCDM, and ISM
16	Majumdar and Sinha (2019)	Examined the key impediments to GSCM	T&A sector	ISM
17	Feng et al. (2020)	Analyzed the influence of the key technological capabilities on the enterprises' sustainable competitive advantage	High-tech industry	AHP
18	Agyabeng-Mensah et al. (2020)	Examined the impact of green warehousing, social values and ethics, and logistics optimization on SCS and economic performance	Manufacturing companies in Ghana	Smart PLS3
19	Parashar et al. (2020)	Identified the main enablers that are essential for reducing inefficiencies along the whole food supply chain (FSC)	FSC Food wastage	ISM, and MICMAC Analysis
20	Kumar et al. (2020)	Recognized key technology and sustainability methods in the FSC	Agri-food system	fuzzy Best–Worst Method

Table 1 (continued)

No.	Authors	Contribution	Focused area	Tools/techniques used
21	Karmaker et al. (2021)	Examined the factors influencing SSCs to address SC disruptions in the COVID-19 pandemic	COVID-19 pandemic	fuzzy-TISM
22	Menon and Ravi (2021a, 2021b)	Identified and investigated significant obstacles to sustainability implementation	Electronics industry	Grey-DEMATEL
23	Menon and Ravi (2021b)	Studied the elements that act as enablers of sustainability	Electronics industry	Grey-DEMATEL
24	Kumar et al. (2022a, b)	Investigated the key emergent themes in sustainable FSC	Agriculture food	Bibliometric analysis, and Thematic analysis
25	Vishwakarma et al. (2022)	Identified the barriers that prevent sustainable implementation throughout the various SCM phases	T&A sector	ISM, and fuzzy MICMAC, and DEMATEL
26	Yadav et al., (2022)	Identified different obstacles in the networks of the FSC	Agriculture food	literature review
27	R. Sharma et al. (2022)	Identified significant Collaborative Sustainable Practices in the multi-tier FSC	FSC	TISM, and Fuzzy MICMAC
28	S. Kumar et al. (2022a, b)	Designed a conceptual framework to lessen the effects of implementing thirteen major obstacles against BLC-IoT in FSC	FSC	ISM, and DEMATEL
29	Abbasi et al. (2022a, b, c)	Provided a mathematical model that describes the interactions between the economic and environmental aspects of the green closed-loop supply chain network	COVID-19 pandemic	Weighted Sum Method (WSM)
30	Agrawal et al.(2022)	The key success variables for the adoption of sustainable GSCM methods were examined	Brass manufacturing industry	AHP, (TOPSIS), and DEMATEL
31	(Abbasi, Khalili, et al. 2022a, b, c)	Measured the SSC performance during the Coronavirus outbreak	COVID-19 pandemic	AHP

Table 1 (continued)

No. Authors	Contribution	Focused area	Tools/techniques used
32	Identified, analyzed, and prioritized key technological capabilities (TCs) in SSCM	Food industry	ISM, and MICMAC Analysis

of the products and information along the chain used to be a daily challenge. Besides, the companies were scrutinizing for different methods to lower their wastage, not for social or ecological purposes, but economic purposes (Ramezaninia et al., 2022; Sánchez-Flores et al., 2020).

Still, it appears that SCM is among the main tools to manage expenses and boost economic performance in light of nowadays cut-throat market. Additionally, companies must change their supply chain models to address issues, such as environmental conservation, workforce advantage, corporate transparency, and safety concerns. Companies need to focus on creating environmentally friendly supply chains rather than merely concentrating on financial efficiency (Hong et al., 2018). SCM facilitates the client base integration, network of distribution, companies' internal activities, and supply base. Accordingly, the SCM functions significantly impact organizational and sustainable performance and how the companies' external stakeholders perceive them (Bastas & Liyanage, 2018). Eventually, the consensus between the researchers indicates that a combination of all three sustainability pillars is required in SCM and the design of sustainable supply chains to solve sustainable development problems (Abbasi et al., 2021; Bastas & Liyanage, 2018; Sánchez-Flores et al., 2020; Vishwakarma et al., 2022).

Seuring and Müller (2008) define SSCM as the management of materials, information, and money flow, and the collaboration between companies along the supply chain while taking into account the objectives of the economic, environmental, and social elements of sustainable development, which are drawn from the needs of clients and stakeholder groups. Moreover, Bentahar and Benzidia (2018) define SSC in their study as "The integration of economic, social, and ecological aspects of managing inter-organizational and intra-organizational currents using creative and cooperative methods to create sustainable value." Jalilian and Mirghafoori (2019) define a sustainable supply chain as a method to obtain a competitive advantage.

Kumar et al., (2022a, b) and Vishwakarma et al. (2022) believe that the incorporation of sustainability strategies into SCM is known as a sustainable supply chain. In addition, the application of SSCM has the potential to manage economic, social, and environmental issues, and the adoption of SSCM provides a competitive edge to the company, developing a circular economy, reducing the price of a product, improving relationships between customers and suppliers, and so forth (Vishwakarma et al., 2022).

2.3 Food industries

The food industry is one the oldest industries in Iran that has been historically run by the private sector and thus entails more competition than the other main public industries of the country. The industries active in this field have equipped themselves with the world's latest technologies to compete. The latest statistics published by the Statistics Center of Iran regarding the active industrial workshops in the country indicate that food industry workshops amount to over 12% of the total added value of the entire industrial sector. These statistics also reveal that food industries in Iran take up 17% of the employment in the industry sector, which will undoubtedly increase this share by considering the agricultural chains, food transportation, distribution, and market (Statistical Centre of Iran, 2016). These figures indicate that the food industry is entirely competitive (Cagliano et al., 2016). Moreover, the Iranian population is predicted to grow to 103 million people by 2030 and over 105 million people by 2060 (World Population Prospects, 2019). According to Kumar et al., (2022a, b), it is anticipated that there will be 9.7 billion people on the planet. This

prediction includes the planned growth of a middle class demanding more diverse and high-quality products that need more, different, and expensive resources. This population will need above 60% of the global food resources (Global Commission on the Economy and Climate, 2014) and will consume a maximum of 45% of global energy and 30% of the global demand for water merely for farming (Cagliano et al., 2016). However, more food is produced than consumed amount. Previous studies indicate that one-third of the annual food produced in the world is spoiled or wasted (Cagliano et al., 2016; Yadav et al., 2022). Around 1.3 billion tons of waste are produced annually by the food supply chain (FSC) (Kumar et al., 2022a, b). However, despite the profound relationship between the food industry with humans and the earth, there is ample evidence suggesting that many of our current food production systems harm the earth and its dwellers and have aroused public concerns regarding the sustainability of food systems. Such concerns are aroused due to their increased negative impacts on the environment. For example, food systems generally amount to 15–28% of developed countries' total greenhouse gas emissions (Cagliano et al., 2016; Kumar et al., 2022a, b; Yakovleva, 2007). Moreover, the food industry activities are considered a key factor in climate changes and global warming that threaten the overall stability of food, including negative impacts on food production, food price, food consumption, access to food, and supply chain infrastructures (Cagliano et al., 2016; Kumar et al., 2022a, b; Yadav et al., 2022). However, a natural characteristic of food is that its quality keeps changing over time, turning food safety and quality into a challenge. External environmental factors (e.g., temperature and transportation) can threaten the quality and freshness of food products. Processed food with high durability is produced using many ingredients and may have an utterly complex production process. The production of complex foods also means dealing with challenges such as the failure of the product and the need for further attention to ingredients quality and the production procedure (Duan et al., 2020a). The managers, industries, and practitioners involved in the agro-food supply chain are forced to employ the latest instruments, techniques, and methodologies to model current FSC problems and redesign the network of FSC correspondingly. This is because strict government regulations, growing sustainability concerns, food security concerns, and traceability issues are all becoming widespread (Yadav et al., 2022).

According to the United Nations Environment Programme (UNEP), there is an extreme strain on food systems to adapt to environmental changes, including harmful emissions from human activity and water use, population expansion, illnesses, and changes in the temperature and ecosystem (Kumar et al., 2022a, b). Without sustainable food supply chain management, sustainable development is not conceivable. Additionally, recognition of sustainability across the broader system of actors, stakeholders, and customers in FSCs is crucial. (Kumar et al., 2022a, b).

The food industry sustainability strategy (FFIS), prepared by the Environmental Department of Britain Government, Food and Rural Affairs (DEFRA), exhibits that the food industry plays a significant role in sustainable development since it is the key employer, important water and energy consumer, and a remarkable waste producer. FFIS highlights the fundamental areas that must be considered as an element of sustainable consumption and production strategy in food production and distribution, including (1) Ecological issues (e.g., energy consumption and climate change, wastage, water, and food transportation), (2) Social subjects (e.g., nutrition and healthiness, food safety, equal opportunities, health and safety, and ethical trade), and (3) Economic subjects (e.g., scientific innovations, labor force skills, and retail crimes) (Yakovleva, 2007). This report develops strategies and indices for the sustainable development of the food and beverage industry in the UK in the four main areas: social development that acknowledges people's needs, efficient environmental

safeguards, careful usage of natural resources, and continuing high levels of economic growth and employment (Yakovleva, 2007).

2.4 Technological capabilities

Samarnbutr (2012) argues that self-awareness is companies' most crucial success factor, and they can only thrive if they identify their existing capabilities comprehensively. They would not achieve successful development without knowing the extent of their capabilities. In other words, the technical capabilities and advanced technologies—which include a set of complementary knowledge and skills that can be used in business procedures such as product development, production, and after-sales services—are essential sources for the companies to obtain a competitive advantage over rival companies. A competitive advantage is essential for businesses in the competitive market, and the main technological capabilities (TCs) are considered among the practical tools for the company's development in high-technology industries (Wang et al., 2006). More concretely, TCs are the basis of outstanding performance and competitive advantage in the technologically competitive marketplace (Vitorino Filho & Moori, 2018; Wang et al., 2006). Thus, companies need to identify their competitive power and improve it constantly to acquire a specific market share and achieve sustainable development (Feng et al., 2020; Wang et al., 2006).

It is pretty challenging to define technological capability, and one cannot easily find a proper definition for it. Many terms have been used to explain this concept. Some authors have used similar terms in their works and articles. For example, Dahlman and Westphal (1982) and Sanjaya Lall (1992) use the term “technological effort,” and scholars such as Bell et al. (1985) use the term “technological capacity,” by which they mean the firm's capacity to maximize technological information aiming to protect the company's innovation and competitiveness in the market. Nevertheless, in short, the term “Technological Capability” is more comprehensive than all of the other terms suggested so far (Dutrénit, 2011; Samarnbutr, 2012).

Mansfield (1984) states that TCs indicate the collected technical knowledge that the company can use while developing new products and services or enhancing ones that already exist. TCs include the technological expertise of individuals and teams, the processes and procedures, and other technological assets (such as information and production systems and machinery) that collectively contribute to the technological potentials required for the company's mission (Kyläheiko et al., 2011). A further definition of TC is the ability to use technological knowledge in production, investment, and innovation in an efficient manner (Dutrénit et al., 2019). Additionally, TC can be considered a core ability that enables businesses to create and market goods and services priced by their target market and manage client relationships efficiently (Wang et al., 2006).

In his study, Latip (2012) defined TC as the business's ability to utilize a wide variety of notable and diverse assets, including technical resources, skills, and knowledge (e.g., information technology software and hardware (IT) and machinery), and provide goods and compete in the market. According to Latip, this definition is consistent with Lall's (1992) definition of TC, suggesting that technological knowledge varies between companies and is not fairly distributed, is not easily imitable, and is easily transmitted across the firm. Researchers such as Wang et al., 2006 believe that key TC can increase efficiency and distinguish the firm by improving product innovation and processes. Further, organizations that benefit from significant technological competencies can become more distinguished through innovative products in response to the fast changes in market needs since they

ensure the benefits of efficiency using pioneering innovation activities. Therefore, these companies can create a more significant competitive advantage over their rivals, allowing them to obtain a higher return than the average investment return.

More precisely, many researchers have investigated the competitive advantage of TCs. In their article, Vitorino Filho and Moori (2018) studied the role of technological innovation capabilities in relation to strategic supply chain management and competitive advantage. According to the qualitative and quantitative data results, technologies and TCs can cause strategic SCM to gain a competitive advantage. Moreover, according to (Ortega, 2010; Shan & Jolly, 2013; Wang et al., 2006; Wu et al., 2022) TCs have a positive influence on firms' performance.

Salisu and Abu Bakar (2020) research shows a favorable and significant relationship between TC and SMEs' performance ($\beta=0.603$; $t=8.043$; $p=0.000$). According to statistical outcomes, TC is a strategic SME's capability that significantly enhances performance in the nowadays dynamic and cut-throat marketplace.

In addition, the contribution of TC is significant not only as a competitive advantage for the companies but for the general enhancing the supply chain and the cooperation between the companies (Latip, 2012; Yousefi & Mohamadpour Tosarkani, 2022). Also, in Kumar et al., (2022a, 2022b) research, they mentioned that technology, as the key enabler of sustainability in the FSC, boosts waste prevention, cooling technologies, information flow, digitization, tracking, data analysis, forecasting, monitoring, life extension, and value enhancement. As a result, organizations must focus their attention on investing in advanced equipment and facilities to reinforce the operational aspect of their business, increase supply chain efficiency, and better support inter-firm relations.

The literature review indicates that supply chain design is currently considered a complex task, and SCM results reveal both upstream and downstream concerns for supply and demand due to the importance of the ecological aspect of sustainability (Lamba & Thareja, 2021).

3 Research gap

Researchers believe that technologies and TCs need precise analysis because TCs improve competitive advantage and SCM (Salisu & Abu Bakar, 2020; Vitorino Filho & Moori, 2018). Actually, it is of great demand to investigate TCs so that by applying key TCs, firms can improve their competitive edge and become the main actors in the sustainable food supply system. Despite the abundant literature on SSC, no study has been found that used the ISM-MICMAC method to identify, rank, and reveal interdependence among key TCs in SSC.

According to the above discussion, there is a lack of research on sustainability in the food industry and TCs. To close this gap, the present study investigates and identifies TCs of the SCS in the food industry of Iran, considering the competitive advantage that TCs create for companies in the SC of the food industry. Firms need to detect the required TCs and exploit the more significant capabilities to become decisive actors in a sustainable food supply system.

ISM method was implemented to investigate the relationship between TCs in this research as it is the most widely used method to determine the causal connections between factors and create the main elements. In the following, MICMAC analysis was used to obtain each TC's driving and dependency power. The structural model, created by

effectively merging the ISM and MICMAC analysis methodologies, gives information on the relative relevance of the TCs and the strength of their relationships. This research helps the literature on SSCM in the food industry sector. This article fills research gaps by focusing on identifying and ranking key TCs in SCS, which is considered the innovation of this research.

4 Research methodology

The present study detected and ranked the key TCs in the SCS of Iranian companies operating in the field of the food industry. To this end, after reviewing and identifying the TCs from the literature, the ISM approach was implemented to determine the connection among the capabilities. The following section presents an introduction to the ISM method and its stages.

4.1 Interpretive structural modeling (ISM)

The interpretative-structural modeling (ISM) method introduced by Warfield in 1974 is an efficacious approach to examining various factors in a complex system (Usmani et al., 2022; Zhou et al., 2019) and is used to identify and develop the relationship between specific variables (D. Kumar & Rahman, 2017). ISM is a technique used to convert raw and unstructured data into meaningful interpretations based on the experts' opinions (Beloor et al., 2022). ISM is interpretative because it provides the possibility to disintegrate a turbulent system into a multi-level structural model using group judgment and experts' opinions and can improve the performance of management by identifying drivers (Usmani et al., 2022; Zhou et al., 2019). The ISM method is considered a group learning process in the first degree; However, it can also be used as an individual's learning process (Raut et al., 2017; Zhou et al., 2019). In other words, ISM is an interactive learning procedure in which a group of various elements with direct relationships is arranged in an organized and comprehensive model. Moreover, researchers use the ISM method to understand the direct and indirect connections among different variables in diverse industries (Lamba & Thareja, 2021; Raut et al., 2017; Thennal VenkatesaNarayanan et al., 2021; Usmani et al., 2022). The ISM process turns unspecified mental and weak systems models into obvious and specific models which are helpful for various goals. Furthermore, ISM can serve as a means for organizing and directing the complexity of connections among variables (Raut et al., 2017).

It has been confirmed that the ISM approach can be used as a systematic method to improve the performance of SSCM in various industries as an effective management tool (Zhou et al., 2019). Accordingly, numerous researchers have utilized the MICMAC-ISM method to handle various supply chain sustainability issues. For instance, Narayanan et al. (2018) used ISM and MICMAC to rank the obstacles to implementing the sustainable method in plastic production industries in India. Also, Beloor et al. (2022) used ISM and MICMAC to identify the association between numerous sustainable manufacturing facilitators.

Kumar and Rahman (2017) used MICMAC and ISM to model and rank SSC enablers in their study. Lamba and Thareja (2021) also used ISM to rank the obstacles that influence the execution of GSCM. Additionally, in identifying the key success factors (CSFs) of SSCM practices in the Indian oil and gas industry, Raut et al. (2017) used

the ISM method to establish interrelationships between independent variables, which contributed to the understanding of the relative relations between CSFs and determined their interdependence during the implementation of sustainability. Majumdar and Sinha (2019) used ISM to identify the contextual connections among the twelve main barriers to managing the green textile and apparel supply chain in Southeast Asian nations. Menon and Ravi (2021a) used ISM to establish the hierarchical structure and interrelationship among significant barriers preventing the Indian electronics industry from implementing sustainability. They used MICMAC analysis to recognize the driver variables and dependent variables.

As mentioned, the ISM approach demonstrates a higher ability to understand better management methods in SSCM (Zhou et al., 2019). Since this method helps illustrate the interaction and overall structure of the components, the present study uses the ISM-MICMAC hybrid method to frame the structure of the relationships between TCs. The ISM method is prioritized over other similar methods because of its ability to absorb real problems' dynamic complexities.

4.2 Steps of ISM methodology

As Fig. 3 illustrates, the ISM implementation stages are as follows (Beloor et al., 2022; D. Kumar & Rahman, 2017; Narayanan et al., 2018; Raut et al., 2017; Usmani et al., 2022; Zhou et al., 2019):

Stage 1: The TCs, which play a part in the SCS of companies operating in food industries, are recognized and documented.

Stage 2: The contextual relationships between each pair of the TCs specified in stage 1 are determined and collected based on the experts' opinions.

Stage 3: The Structural Self-Interaction Matrix (SSIM) is formulated and evaluated based on the professionals' judgment demonstrating the pairwise relationships among the TCs.

Stage 4: Computation of the reachability matrix. The primitive reachability matrix is obtained from the SSIM matrix by turning the qualitative opinions into binary codes. The ultimate reachability matrix is derived considering the ISM transience; a fundamental assumption in the ISM technique states that if the stimulus "X" corresponds to "Y" and the stimulus "Y" corresponds to "Z," then "X" corresponds to "Z." SSIM demonstrates direct relationships. In contrast, the reachability matrix shows direct and indirect connections between the mentioned factors.

Stage 5: The reachability matrix developed at stage 4 (the final reachability matrix) can be split into a number of levels based on each factor's reachability and antecedent set. The reachability set for an individual factor contains itself and the other combinations facilitating its achievement. The rules for dividing the levels were mentioned in the result analysis section, and the final level of each factor was acquired.

Stage 6: The hierarchical model based on the ISM is formed using the divided levels, and then a hierarchical model of the TCs in the SCS of the companies performing in the food industries is designed and prepared.

Stage 7: The ISM model developed at stage six was assessed to examine the conceptual inconsistencies and make the required changes. Each constituent factor's driving and dependency power were then calculated and analyzed.

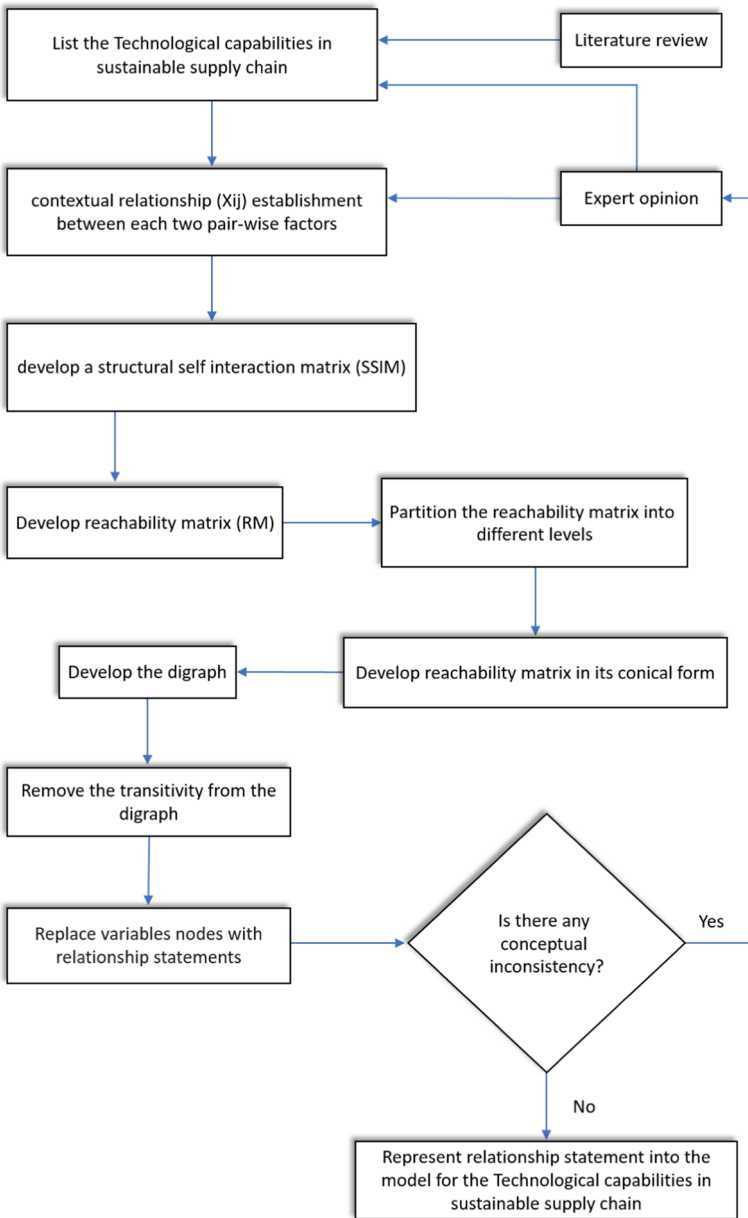


Fig. 3 ISM's steps- modified from (Narayanan et al., 2018; Raut et al., 2017)

5 Results

5.1 Identification of TCs in SCS

This stage is one of the essential stages of the present research. At this stage, the TCs in SCS was first extracted by reviewing the literature, including articles, research journals, books, and published reports. Two filters (the characteristics of SCS and suppliers considering the three sustainability dimensions simultaneously) were considered to collect these capabilities. Hence, 11 criteria were obtained for the SCS approach as follows (eleven identified TCs are summarized in Table 2):

5.1.1 TC1: Big data

Big data and predictive analytics capability are critical for managing supply chain functions and have become a competitive necessity for the SCM (Hazen et al., 2016; Roßmann et al., 2018; Tseng et al., 2019a, b; Waller & Fawcett, 2013). Big data can include information published on companies' websites, addressing growth in sales and business activities or strategies to adopt technologies, innovation, research, and development. Furthermore, the power of big data is analyzing the prediction of future events using the statistical knowledge obtained from the existing information. Predictive analyses significantly affect and enhance the supply chain networks' performance (Tseng et al., 2019a, 2019b).

5.1.2 TC2: Social media

The study by Tseng et al., (2019a, 2019b) suggests that social media are an online communication platform that allows users to create online social relations with others to share their information, thoughts, emotions, messages, and other forms of content, such as text, images, and videos, and creates bonds in real life. Social media help companies advertise their brands, supply their products to customers, and strengthen mental leadership and awareness through these external connections. In addition to the above, dependent partners in the sustainable supply chain can benefit from close coordination and collaboration with social media.

5.1.3 TC3: Information and communication technology infrastructure

Information and communication technology are defined as a set of techniques and elements that enable the use of computers, software, and computer networks, processing, storing, managing, and transmitting the information (Pérez-López et al., 2018). Information and communication technology applications help organizations create an efficient information communication system to better access and use resources and preserve the environment (Singh et al., 2019).

5.1.4 TC4: Logistic optimization

Logistic optimization indicates the optimization of velocity, pathway, burden, and transportation features as well as using alternative energies (instead of fossil fuels) and reverse logistics that significantly improve profit margins and control the company's greenhouse

Table 2 Eleven TCs of the SCS that identified through a comprehensive literature review

No	Technological capabilities	References
TC1	Big data	(Hazen et al., 2016; Roßmann et al., 2018; Tseng et al., 2019a, b; Waller & Fawcett, 2013)
TC2	Social media	(Tseng et al., 2019a, b)
TC3	Information and communication technology infrastructure	(Bourlakis & Bourlakis, 2006; Pérez-López et al., 2018; Singh et al., 2019)
TC4	Logistic optimization	(Agyabeng-Mensah et al., 2020; Ali et al., 2020; Tseng et al., 2019a, b; Turrisi et al., 2013; Yadav et al., 2022)
TC5	Radio Frequency Identification technology (RFID)	(Gaukler, 2010; Vlachos, 2014)
TC6	Internet of Things	(Manavalan & Jayakrishna, 2019)
TC7	Supply Chain Management Information Systems	(de Camargo Fiorini & Jabbour, 2017)
TC8	Blockchain technology	(Treiblmaier, 2019; Yadav et al., 2022)
TC9	Technological innovation	(Tseng et al., 2019a, b; Falcone et al., 2019; Lim et al., 2017)
TC10	Supply chain innovations	(Artisomchyk & Zhivitskaya, 2015)
TC11	Smart packaging	(Chen et al., 2020; Sharma et al., 2018)

gas emissions (Tseng et al., 2019a, b). Moreover, Turrisi et al. (2013) suggest that logistics significantly impact the environment, and reusing materials can decrease the negative impacts. In this regard, Abbasi et al. (2022b) mentioned that reducing CO₂ emissions has become one of the primary goals of supply chain design as a result of environmental protection, client awareness, and carbon policies. According to the research of Yadav et al. (2022), by strategically placing supply chain nodes, the food logistics network can be designed to effectively address some of the issues that the agricultural food supply chain faces by selecting more sustainable methods at all stages of the food distribution process, enhancing the route of the food distribution, and more effectively reconstructing the food logistics chain network.

5.1.5 TC5: Radio Frequency Identification technology

RFID is a recognition technique that utilizes electromagnetic waves to transfer data from a label to a receiver electronic gadget (Gaukler, 2010; Vlachos, 2014). The application of this technology has expanded in all operation management fields over recent years. RFID programs are now part of retail operations, which includes the stages of inventory control and logistic, configuration and production management, identification, fraud protection, and security (Gaukler, 2010). The execution of RFID methods significantly affects the enactment of the supply chain in terms of the supplier, inventory, distribution, planning, sales, and prediction. Furthermore, RFID can also improve distribution systems' performance, such as the shipped products and distribution goods by 33.8% and stockpile availability by 45.6% (Vlachos, 2014).

5.1.6 TC6: Internet of Things

The Internet of Things (IoT) was first used to define interconnected devices using RFID technologies. IoT has been created from the strong advent of wireless technologies, sensors, and various devices connecting to the internet. These devices are informed about their surroundings using sensors transmitting a large volume of data daily. These devices can be used easily and detect each other via the internet. In a simpler sense, the IoT can be implemented in all human life levels worldwide. Thus, IoT can be described as a tangible, robust, and scalable technology that uses the internet to facilitate the digital transformation of the interconnected world and transmits all relevant information in real-time along the value chain (Manavalan & Jayakrishna, 2019).

5.1.7 TC7: Supply chain management information systems

According to de Camargo Fiorini and Jabbour (2017), an information system (IS) using organizational practices provides planning and sustainability of information. ISs, directly or indirectly, have positive effects on an organization's environmental, operational, financial, and/or social performance.

5.1.8 TC8: Blockchain technology

Blockchain technology enables the recording of immutable data and simplifies viewing shared data along the supply chain. "It is a digital, decentralized, and distributed ledger in which transactions are recorded and added in the order of their time, aiming to create

permanent and nonexclusive records” (Treiblmaier, 2019). Blockchain technology has the ability to enhance SCM and sustainability significantly. By enhancing traceability and transparency in sustainable supply chains, this technology can encourage ethical sourcing and guarantee conformity to environmental regulations. Furthermore, A collection of social and environmental parameters can be tracked using Blockchain technology, which is the key to increasing sustainability (Yousefi & Mohamadpour Tosarkani, 2022).

5.1.9 TC9: Technological innovation

Innovation refers to using technology to improve efficiency through the interpretation of shared knowledge regarding buyer behaviors and social trends (Tseng et al., 2019a, b). Also, innovation is accompanied by developing new solutions and ideas and introducing technological organizational or administrative changes in the procedures (Lim et al., 2017). According to the definition of OECD, technological innovation is divided into the aspects of process and product innovation (Yu et al., 2017).

5.1.10 TC10: Supply chain innovations

Supply chain innovations integrate the advancement in relevant information and technologies using the latest approaches of logistics and marketing to enhance operational effectiveness and reinforce services’ efficacy (Artsiomchyk & Zhivitskaya, 2015).

5.1.11 TC11: Smart packaging

Smart packaging is a vast notion, including active and intelligent packaging that can monitor the internal and external changes in the product (intelligent) and send more responses (activity) to the supply chain by connecting to an external (electrical or optical) interface (Chen et al., 2020). Moreover, Sharma et al. (2018) imply that packaging is among the essential factors of success in effectively implementing a food sustainable supply chain.

5.2 The second stage: using the ISM

5.2.1 Structural self-interaction matrix (SSIM)

The ISM, founded on specialists and group discussions, creates mutual relationships between the components that have poor relationships. It is inferred from the literature that most of the authors have used 5–15 industrial experts for this purpose (D. Kumar & Rahman, 2017). In this study, five managers of the Iranian FSC and two academic experts took part in a brainstorming meeting to identify the contextual relationship between the eleven identified TCs in the SCS of food industry companies. All the managers participating in brainstorming meetings had been present in the initial investigations of the study. Five industrial manager experts were recognized via connections acquired during the initial explorations, and two experts (who had over 10 years of teaching experience in SCM) were selected from the university. Thus, the brainstorming session had an appropriate sampling approach. Appropriate measures were taken for all group members to reduce

decision-making bias and develop a clear understanding of the results. All seven experts were asked to make pairwise comparisons by responding, “Do you think factor i directly impacts factor j or vice versa?” (D. Kumar & Rahman, 2017; Zhou et al., 2019); Still, different judgments might be made in the pairwise comparison of the two factors. Therefore, based on the regulation, “The minority is subordinate to the majority,” if three or more experts agree, the final contextual relationship between the factors mentioned in each group is determined (Zhou et al., 2019).

Standard ISM uses four symbols to receive experts’ responses regarding the comparison of variables and demonstrate the hierarchical structure and the relations among systems factors. The standard ISM VAXO scale is described below (D. Kumar & Rahman, 2017; Lamba & Thareja, 2021; Thennal VenkatesaNarayanan et al., 2021; Zhou et al., 2019):

- V =capability i will assist in achieving capability j .
- A =capability j will assist in achieving capability i .
- X =both capabilities, i and j , assist in helping achieve each other.
- O =capabilities i and j are unrelated.

Table 3 demonstrates the SSIM for the 11 TCs of the SCS of food industry companies.

5.2.2 Reachability matrix

At this stage, SSIM is used to obtain the reachability matrix. At first, the initial reachability matrix (IRM) is obtained by transforming the value of each SSIM cell into binary values. The following rules are implemented to achieve the IRM to replace V , A , X , and O in the SSIM table (D. Kumar & Rahman, 2017; Lamba & Thareja, 2021; Thennal VenkatesaNarayanan et al., 2021; Zhou et al., 2019):

- If the (i, j) entry in the SSIM is V , then in IRM, the (i, j) entry becomes 1, and the (j, i) entry becomes 0.
- If the (i, j) entry in the SSIM is A , then in IRM, the (i, j) entry becomes 0, and the (j, i) entry becomes 1.

Table 3 The SSIM of TC’s

$(i \downarrow j \rightarrow)$	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	TC10	TC11
TC1		O	A	O	O	A	V	X	O	O	O
TC2			A	O	O	O	O	O	V	O	O
TC3				O	O	V	V	O	O	V	O
TC4					O	O	A	O	O	A	A
TC5						V	V	A	O	O	O
TC6							V	A	O	A	V
TC7								A	A	X	A
TC8									V	A	V
TC9										A	V
TC10											O
TC11											

Table 4 The initial reachability matrix of TC's

$(i \setminus j \rightarrow)$	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	TC10	TC11
TC1	1	0	0	0	0	0	1	1	0	0	0
TC2	0	1	0	0	0	0	0	0	1	0	0
TC3	1	1	1	0	0	1	1	0	0	1	0
TC4	0	0	0	1	0	0	0	0	0	0	0
TC5	0	0	0	0	1	1	1	0	0	0	0
TC6	1	0	0	0	0	1	1	0	0	0	1
TC7	0	0	0	1	0	0	1	0	0	1	0
TC8	1	0	0	0	1	1	1	1	1	1	1
TC9	0	0	0	0	0	0	1	0	1	1	1
TC10	1	0	0	0	0	0	1	1	0	0	0
TC11	0	1	0	0	0	0	0	0	1	0	0

If the (i, j) entry in the SSIM is X, then in IRM, the entries in both the cells (i, j) and (j, i) become 1.
 If the (i, j) entry in the SSIM is O, then in IRM, the entries in both the cells (i, j) and (j, i) become 0.

Table 4 demonstrates the initial reachability matrix (IRM). The final reachability matrix (FRM) is attained by transient combination at the next step. Transience is a connection among three factors, indicating that if there is a relationship between the X and Y variables and Y and Z variables, then X and Z must have a relation, necessarily. (i.e., $i > j$ and $j > k$, then $i > k$) (D. Kumar & Rahman, 2017; Lamba & Thareja, 2021; Thennal VenkatesaNarayanan et al., 2021). Consider transitions makes it possible to evaluate the indirect effect of variables on one another, thus directing the relationship between variables (Thennal VenkatesaNarayanan et al., 2021). Table 5 shows the FRM, in which "1*" depicts the incorporated transitivity link between the variables.

Table 5 The final reachability matrix

$(i \setminus j \rightarrow)$	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	TC10	TC11	
No	1	2	3	4	5	6	7	8	9	10	11	
TC1	1	1	0	0	1*	1*	1*	1	1	1*	1*	1*
TC2	2	1*	1	0	1*	1*	1*	1*	1	1*	1*	1*
TC3	3	1	1	1	1*	1*	1	1	1*	1*	1	1*
TC4	4	0	0	0	1	0	0	0	0	0	0	0
TC5	5	1*	0	0	1*	1	1	1	1*	1*	1*	1*
TC6	6	1	0	0	1*	1*	1	1	1*	1*	1*	1
TC7	7	1*	0	0	1	1*	1*	1	1*	1*	1	1*
TC8	8	1	0	0	1*	1	1	1	1	1	1	1
TC9	9	1*	0	0	1*	1*	1*	1	1*	1	1	1
TC10	10	1	0	0	1*	1*	1*	1	1	1*	1*	1*
TC11	11	1*	1*	0	1*	1*	1*	1*	1*	1	1*	1*

Table 6 Iteration level 01

Code	No	RS	AS	IS	Level
TC1	1	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	1, 4, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	
TC2	2	2, 3	1, 2, 4, 5, 6, 7, 8, 9, 10, 11	2	
TC3	3	3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	3	
TC4	4	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11	4	4	1
TC5	5	1,2, 3, 5, 6, 7, 8, 9, 10, 11	1, 4, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	
TC6	6	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	1, 4, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	
TC7	7	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	1, 4, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	
TC8	8	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	1, 4, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	
TC9	9	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	1, 4, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	
TC10	10	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	1, 4, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	
TC11	11	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	1, 4, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	

Table 7 Iteration level 02

Code	No	RS	AS	IS	Level
TC1	1	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	2
TC2	2	2, 3	1, 2, 5, 6, 7, 8, 9, 10, 11	2	
TC3	3	3	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	3	
TC5	5	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	2
TC6	6	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	2
TC7	7	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	2
TC8	8	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	2
TC9	9	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	2
TC10	10	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	2
TC11	11	1, 2, 3, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	1, 5, 6, 7, 8, 9, 10, 11	2

5.2.3 Partition of reachability matrix

The FRM is categorized to obtain the levels of each variable (Thennal Venkatesa Narayanan et al., 2021). Classification of the levels in FRM is carried out using the antecedent set (AS) and reachability set (RS). Antecedent and reachability capability sets are described as it comes:

RS: Variable itself and all other variables it may help achieve (consists of the set of impacting variables).

AS: Variable itself and all other variables that help achieve it (consists of the set of impacted variables).

By taking into account shared variables in AS and RS, the Intersection Set (IS) is created. The iteration variable, which is the same in RS and IS, is mentioned. This

Table 8 Iteration level 03

Code	No	RS	AS	IS	Level
TC2	2	2, 3	2	2	3
TC3	3	3	2, 3	3	

Table 9 Iteration level 04

Code	NO	RS	AS	IS	Level
TC3	3	3	3	3	4

variable is placed at the top of the ISM hierarchical levels, and it must be interpreted that this element cannot influence the other elements above it (Thennal Venkatesa Narayanan et al., 2021). These iterations continued until all the elements were classified into the various ISM hierarchical levels. The recognized levels boost to make the final digraph and the ISM model (Raut et al., 2017). Tables 6, 7, 8 and 9 demonstrate the classification of the identified levels.

5.2.4 Developing a conical matrix

The variables in the columns and rows of the reachability matrix are classified founded on the iterating level to create a conical matrix (D. Kumar & Rahman, 2017; Thennal Venkatesa Narayanan et al., 2021).

After creating the conical matrix, the variables' driving power and dependence power are calculated to detect how they affect and are affected. Table 10 demonstrates the conical matrix that specifies the dependence and driving power of the variables (capabilities). According to Table 10, TC2 and TC3 have the highest driving power among the other studied capabilities. Therefore, they significantly affect other capabilities, including TC4. The highest dependence power was observed for TC4, which means the other studied capabilities easily influence it.

5.2.5 Development of digraph

After the various levels of studied variables (capabilities) were determined, the FRM conical form was used to create a structural model by building an initially directed graph (initial digraph). The studied capabilities are demonstrated by the direct and indirect bonds and nodes, presented with directed lines. Level I capabilities (TC4) are shown at the top of the digraph, and level II capabilities (TC1, TC5, TC6, TC7, TC8, TC9, TC10, and TC11) are placed at the next level of the diagram. Accordingly, the other capabilities fill the remaining levels of the digraph. Figure 4 shows the digraph built in the present study. The solid arrows in this digraph indicate the direct influence of a capability on the other capabilities, while the dashed arrows show the indirect impacts resulting from transience in FRM. Thus, the digraph can be simplified by removing transient relationships. The hierarchical relationship between the capabilities is obtained from the final digraph.

Table 10 Conical matrix

$(i \setminus j) \rightarrow$	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	TC10	TC11	Dr.P	Rank
TC1	1	0	0	1	1	1	1	1	1	1	1	9	3
TC2	1	1	0	1	1	1	1	1	1	1	1	10	2
TC3	1	1	1	1	1	1	1	1	1	1	1	11	1
TC4	0	0	0	1	0	0	0	0	0	0	0	1	4
TC5	1	0	0	1	1	1	1	1	1	1	1	9	3
TC6	1	0	0	1	1	1	1	1	1	1	1	9	3
TC7	1	0	0	1	1	1	1	1	1	1	1	9	3
TC8	1	0	0	1	1	1	1	1	1	1	1	9	3
TC9	1	0	0	1	1	1	1	1	1	1	1	9	3
TC10	1	0	0	1	1	1	1	1	1	1	1	9	3
TC11	1	0	0	1	1	1	1	1	1	1	1	9	3
De.P	10	2	1	11	10	10	10	10	10	10	10		
Rank	2	3	4	1	2	2	2	2	2	2	2		

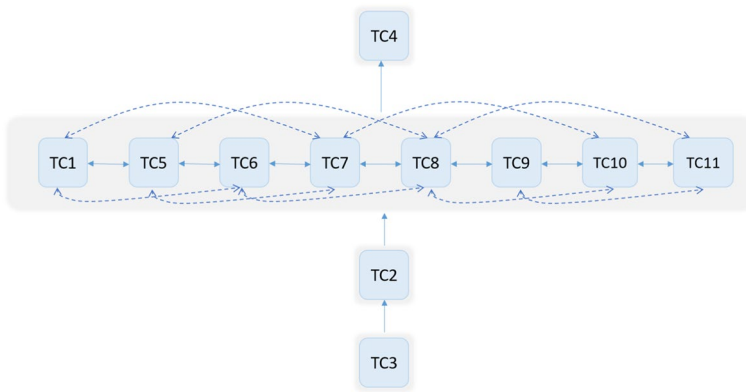


Fig. 4 Final digraph depicting relationship among the TC's

5.2.6 Formation of the ISM model

The ISM model is developed from the final digraph by replacing the serial number of the capability nodes with the capability statements. As mentioned, the transient is eliminated from the digraph and converted to ISM to better understand communication. Hence, the reachability of each capability to other capabilities can be comprehended from the structural model. Figure 5 presents the ISM modeling of TCs.

5.2.7 MICMAC analysis

The matriced' impacts croises-multiplication applique' and classment—abbreviated as MICMAC—was used in this research to examine the TCs in the SCS of food industry companies. The MICMAC analysis aims to classify studied variables into various groups according to their dependence to one another and their driving power. The FRM was used

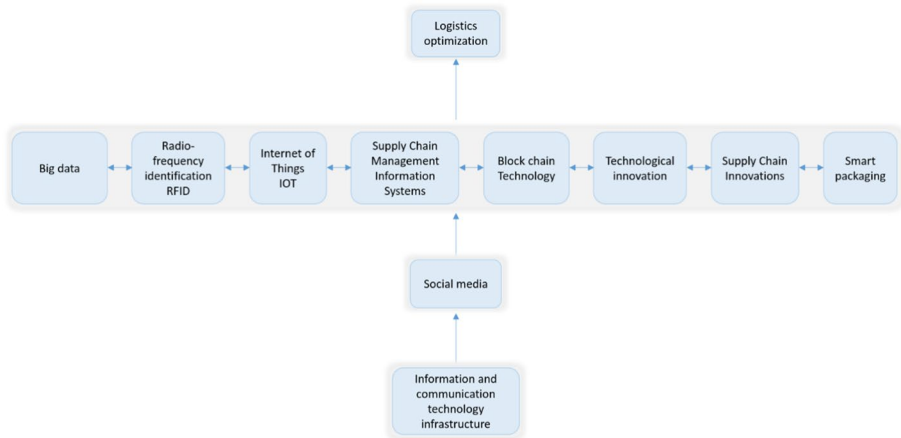


Fig. 5 ISM model

to calculate each technological capability's dependence and driving power. According to the MICMAC analysis, the studied variables (the identified TCs) were classified into four sectors/clusters mentioned in the following:

Cluster I capabilities are known as “Autonomous capabilities” with poor driving and dependence power. In this research, no capability is recognized as an autonomous capability.

Since cluster II capabilities have poor driving power and strong dependence power, they are referred to as “Dependent capabilities.” In the present study, social media (TC2) and information and communication technology infrastructure (TC3) were dependent capabilities.

Cluster III capabilities are known as “Driving or independent capabilities” since they have strong driving power and weak dependence power. Logistics optimization (TC4) was identified as an independent capability in the present study.

Cluster IV capabilities are known as “Linkage capabilities.” These capabilities have strong driving and dependence power and are essential capabilities in the system, and any change in them impacts the whole system. Seven capabilities were identified as linkage capabilities in the present study (Lamba & Thareja, 2021; Narayanan et al., 2018; Raut et al., 2017; Thennal Venkatesa Narayanan et al., 2021; Zhou et al., 2019).

These four clusters are illustrated in Fig. 6 by drawing the average driver line and average dependence line. In general, the dependence and driving power chart can demonstrate the characteristics of the TCs identified in SCS (Zhou et al., 2019).

6 Results and discussions

The TCs in SCS demonstrate significant challenges given the complex nature of their utilization methods, stakeholders, suppliers, and the pressure of costs. The company's chief manager and decision-makers should understand the importance of using TCs in the sustainability of the supply chain and the tools and techniques to implement them.

In the present research, ISM and MICMAC analysis were utilized to clarify the significance and interdependence of the TCs. The driving and dependence powers obtained from

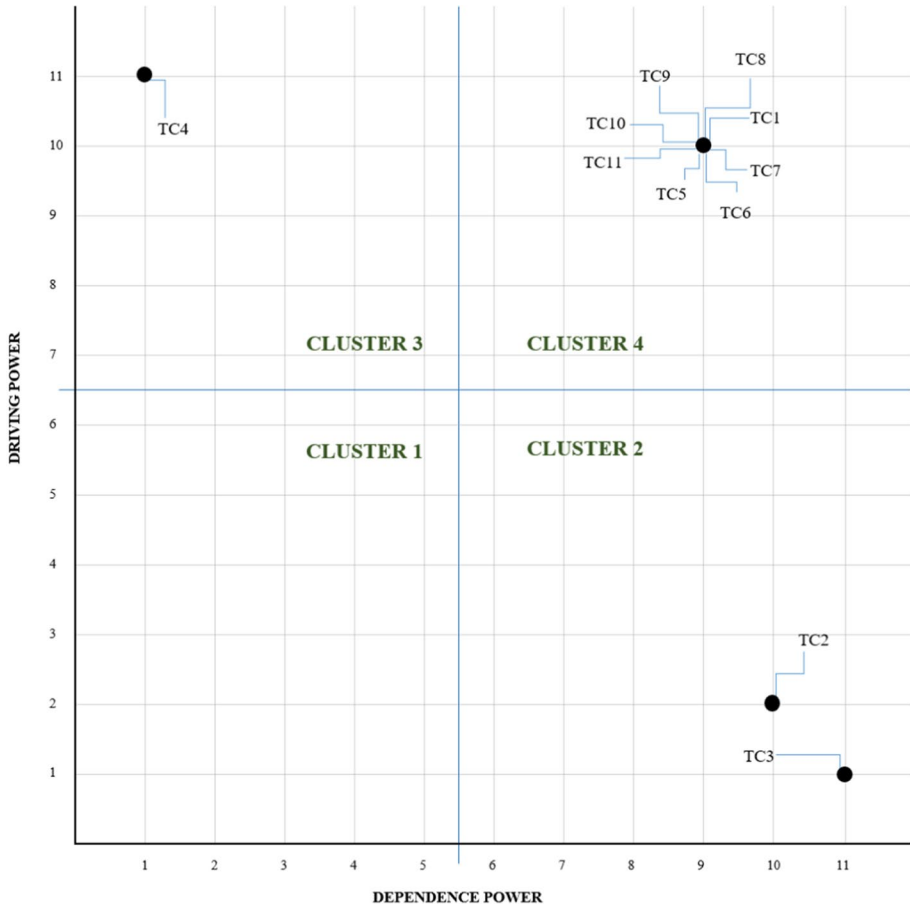


Fig. 6 Driving and dependence power diagram using MICMAC analysis

the ISM are the two criteria used to prioritize TCs. The ISM model was developed using eleven TCs in the SCS of food industry companies based on a complete literature review and expert opinions. Moreover, the SSIM was developed, and the relationships between all the capabilities were analyzed using the ISM model and MICMAC analysis. Then, the eleven TCs were iterated into four levels, and the ISM structure was developed (Fig. 5). The superior TC in the ISM (i.e., TC4) had the least role than the other ten TCs. TC4 is the least efficient in the SSC of companies in the food industry and thus requires the least attention. Figure 5 demonstrates that TC2 at the third level and TC3 at the fourth level are pretty important to achieve level-two capabilities and, in turn, help achieve TC4 capability as well. It can be inferred from the ISM model demonstrated in Fig. 5 that TC3 is an essential driver for other TCs in the SCS of food industry companies. The ISM hierarchy also indicates that TC1, TC5, TC6, TC7, TC8, TC9, TC10, and TC11 capabilities depend on TC2 and TC3. Moreover, TC4 depends on TC1, TC5, TC6, TC7, TC8, TC9, TC10, and TC11.

The independent and dependent drivers of the TCs in the SCS of companies in the food industry can be identified from the MICMAC analysis demonstrated in Fig. 6. Identifying

dependent and independent drivers using the MICMAC analysis helps better understand sustainability drivers in the food industry's supply chain. No capability was observed in the first cluster with low driving and dependence power. Dependent capabilities are depicted in the second cluster with weak driving power and strong dependence power. TC2 is influenced by the TC3 level, which helps the SCS of food industry companies. Driving capabilities are in the third group and have a high driving power and low dependence power. TC4 (logistics optimization capability) is the primary driver in the SCS of food industry companies; this capability needs more attention than the other capabilities. Moreover, the capabilities in the fourth cluster (TC1, TC5, TC6, TC7, TC8, TC9, TC10, and TC11) have a high driving and dependence power.

Accordingly, from Figs. 5 and 6, it is clear that TC1, TC5, TC6, TC7, TC8, TC9, TC10, and TC11 significantly influence the other variables. These TCs are unstable and can change if the driving variables change. Also, any change in these TCs can have an impact not only on other TCs but also on themselves. These factors were considered as the linkage variables in the MICMAC analysis. Linkage variables significantly influence dependent variables (TC3 and TC2). This result means that the TCs at each stage leads to the SCS in food industries.

Implementing TCs in SSCM can enable firms to maintain sustainability in pioneering positions, increase their share of the market, and improve the company's profitability. According to our results, TC3 was revealed to be a capability that contributes to the achievement of other TCs and is a significant driver for other TCs in the SCS of food industry companies. This result confirms the previous studies on the benefits of using information technology by researchers such as (Bourlakis & Bourlakis, 2006; Hong et al., 2018; Singh et al., 2019; Sugathan et al., 2015; Theodorou & Florou, 2008), suggesting that IT is a strategically important element in creating a competitive advantage.

According to Bourlakis and Bourlakis (2006), managers must first be aware of the efficiency and the prominent strategic roles of information technology as a medium in integrating retail logistics operations and pay efforts to carry out proper information technology operations that must be conducted alongside their logistic operations. Secondly, retail managers must constantly evaluate the company's IT infrastructure and figure out whether the existing IT infrastructure is complex enough to be integrated with the company's logistic goals.

In their study, Singh et al. (2019) state that information communication applications help improve the cooperation between various stakeholders and increase the performance of food supply for green and sustainable development. According to the present study results, TC2 capability is influenced by the TC3 capability level, which supports the results of Tseng et al., (2019a, 2019b), indicating that social media is influential in SSC. The increasing importance of social media has led managers to pay more attention to SSC capabilities in the decision-making process since a company can take advantage of social media in its decision-making process, which will not be possible without a well-developed technological infrastructure.

According to the model formulated based on ISM, TC4 is a crucial capability to enhance the sustainability performance of the FSC. This finding regarding TC4 is consistent with the results of Agyabeng-Mensah et al. (2020). Effective logistic optimization implementation as a green measure needs cooperation along the supply chain to acquire the desired sustainability results. Thus, logistic optimization with a shared effort between the supply chain members leads to a considerable decrease in greenhouse emissions, reduces the damaging impacts of companies on the environment, and increases the community's health and well-being. Agyabeng-Mensah et al. (2020) prove that the execution of green warehousing

and logistic optimization ensures employee safety and the community's safety, preserving the environment from degradation and ensuring market size growth, sales, profitability, and capital return. Moreover, green warehousing and logistic optimization improve the SSC. Furthermore, according to Ali et al. (2020), an efficient and suitable logistic network design increases the returned products' economic advantages, improves customer satisfaction, increases market share, reduces costs, and increases adding value to the logistic network. Therefore, logistic network configuration is considered an essential issue in logistics and SCM, significantly affecting the overall supply chain performance. Logistic optimization (TC4) was mentioned in the study of Tseng et al., (2019a, b) as a criterion with the highest driving and dependence powers. However, the present study concluded that TC4 had a high driving power and low dependence power. Also, the results of Tseng indicate that logistic optimization is a decisive driver of SSCM performance. Moreover, the results of Tseng et al. (2019a, b) indicated that logistic optimization is a determined driver of SSCM performance.

This research emphasizes the importance of understanding the role of TCs in the supply chain and the company's performance. The result of the study is aligned with the findings of Rajesh (2017), which indicates that TCs can also improve competitive advantage in dynamic supply chains. Moreover, this study's results can inspire companies since implementing the most important TCs in supply chain sustainability can improve company performance.

7 Conclusions

SCS has become a necessary topic of conversation between experts and managers over recent years. Furthermore, given the intense competition in the supply chain, quick changes in customer demand patterns, and pressures imposed by the government and other stakeholder groups to increase food safety and security, the food industry in developing countries such as Iran has been urged to rise their attention to adopting sustainable strategies. Sustainability has become the competitive advantage of each company's supply chain and contributes to achieving economic advantages and increasing the brand image. However, the essential issue is whether the companies can technically develop these strategies and implement them in reality.

The present study was conducted to identify, recognize, and determine the TCs that directly or indirectly impact the SCS of food industry companies. This case study demonstrates the applicability of the ISM method to model and rank TCs in the SCS of the Iranian food industries. Food industries are willing to adopt sustainability strategies in their supply chains since it impacts the competition in the global market. The developed hierarchical model helps managers comprehend the nature of TCs and their mutual impacts to make management decisions accordingly to improve SSCM strategies. Table 2 demonstrates the eleven TCs identified through a comprehensive review of the SCS literature.

This study used the ISM model to provide accurate insight into the identified TCs. The identified TCs in this study have been ranked using the ISM model. Moreover, the MIC-MAC analysis analyzes the capabilities based on their interactions (driving/dependence), which help decide which TC contributes to the realization of the other. The results of the present study help food industries realize which TCs to invest in, which TCs to take advantage of, and which TC should be used first and why?

After implementing the ISM model, it was observed that there were effective relationships between the TCs that helped accelerate sustainability in the supply chain. Furthermore, the proposed ISM model reveals that some TCs have a low dependence power and are placed at a lower level in the ISM diagram. In the ISM model, TC3 was revealed at the bottom.

As a general conclusion, results indicate that logistics optimization capability (TC4) is the key capability that can lead to a high level of sustainability in the supply chain if appropriately implemented. Accordingly, framing the key TCs and introducing them to the managers is essential to increase the SCS in Iran's food industries.

8 Theoretical and managerial implications

The present study provides some theoretical and empirical concepts to contribute to applying TCs in the SCS of food industry companies. This section discusses the theoretical concepts of SCS of food industry companies and mentions the management concepts for practical industries.

8.1 Implications to practice and managerial insights

The present study helps managers, industry stakeholders, and policymakers to identify and evaluate the TCs in the SCS of food industries and make the best decisions to adopt TCs. The ISM technique provides an interactive learning process. The relationships among TCs are presented in a structural model, which would help managers understand and make the right decisions at different decision-making levels.

The presented ISM model helps policymakers understand the various TCs and their interdependence for implementing SSCM strategies in the Iranian food industry. Nowadays, managers seek to understand the priorities in various TCs and methods of adopting SSCM strategies toward sustainable development. This is important since understanding these concepts enables the managers to focus on a limited number of essential and strategic TCs while considering the impact of other TCs on themselves and each other as well as preventing the possibility of error and heavy economic expenses. Moreover, the hierarchical model and the results obtained from the MICMAC analysis demonstrate how the driving power variables are related from various aspects and interact to sustain the food industry supply chain.

TCs with a high driving power and low dependence power, such as logistic optimization (TC4), are more strategic, while the capabilities with high dependence power and low driving power, such as (TC2) and (TC3), are performance-oriented and result-oriented. Accordingly, better results can be attained by constantly improving driving or independent TCs. Promoting these driving factors is imperative for the sustainable performance improvement of food industries since they increase the health and safety of food products in this chain. Furthermore, the successful execution of the SSC leads to a competitive advantage over the other companies.

The present study focused on the food industry, an industry with many consumers and a high level of competitiveness. The approach adopted in this study can be used in other high-consumer industries, such as cosmetics, pharmaceuticals, chemicals, and others.

8.2 Implications to theoretical knowledge

This study examines the TCs in the SCS of food industry companies, helps improve the theoretical knowledge in this field, and provides a better insight into develop the SCS in this industry. Our study complements previous research examining the relationship between TCs and firm sustainability performance and supports the previous studies that have identified various effects of TCs and SCS. It also emphasizes the importance of identifying the key TCs to improve food security and the ecological aspects of SCS. The application of the ISM approach would help industrial managers demonstrate the complex relationships between the TCs in the decision-making process and can present the details of these capabilities based on the hierarchy described at several levels. The present findings support that identifying and investigating relationships among TCs in the food industries' SCS is critical. Managers must be aware of the structural relationships between TCs in the food industry companies' supply chain sustainability to achieve sustainable performance.

9 Limitations and directions for future research

Identifying TCs helps achieve sustainability in the food industry supply chain. Many studies have recently been conducted on the SCS of food industries, such as RFID, smart packaging, and others. However, few studies have investigated the key TCs in the SCS of companies through a literature review and a systemic analytical approach. To enrich the literature, we seek to investigate the SCS of food industry companies by identifying the critical TCs and providing guidance on performance improvement.

This study can be a beneficial guide for sustainable development experts and chief managers in Iranian food industries, help them realize a comprehensive vision based on the TCs for long-term advantages, and intrigue the interest of researchers for further studies in this regard.

Despite the theoretical and empirical innovations mentioned in this study, it is necessary to acknowledge the research limitations to conduct future research. The TCs in this study were obtained from research journals, and this issue might have resulted in a lack of comprehensive attention to other TCs. Furthermore, there is the possibility that more effective TCs are not considered and classified.

The research perspective of this work is based on the SCS of food industry companies and their key TCs, and the more complex interrelationship as well as the exact interaction between various stakeholders require further qualitative research using the game-based theory. The present study mainly focused on the Iranian food industries, so the results will be helpful for food industries in Iran. However, the findings may not be generalizable to other countries, which is the most critical limitation of the present study. Furthermore, the final ranking of the TCs might deviate due to the industry type and its various competitive environments, firm sizes, and the history of its presence in the market. In addition, despite the advantages of the ISM-based method, the disadvantages of the ISM method's drawbacks limit the present study as well. The study model has been designed based on the judgment of a group of food industry supply chain experts, which might be biased and influence the final results' accuracy. Although the present study has used the insights of academic and industrial experts, which ensures that the results are significantly helpful,

future researchers can validate this model using structural equation modeling (SEM), AHP, and fuzzy approaches.

Data availability The data supporting this study's findings are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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