



Modeling of Critical Food Supply Chain Drivers Using DEMATEL Method and Blockchain Technology

Santosh Patidar¹ · Vijay Kumar Sukhwani¹ ·
Apratul Chandra Shukla¹

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Abstract The main purpose of this paper is to identify the critical drivers of the food supply chain (FSC) in the Indian context and find cause–effect relationships among the identified drivers using a decision-making trial and evaluation laboratory (DEMATEL)-based method. After a review of the literature and discussion with food chain experts, fourteen drivers have been identified for this study. Critical drivers and their causal relationships are explored through the cause-and-effect diagram. Results of this study show that the drivers namely “Shift towards a sustainable food system in India” (D7), “Social requirements on food security and safety” (D13), and “Growing attention towards food SCM amidst pandemic Covid-19” (D1) are the top three critical and influential drivers. It has been observed that limited research studies are done to identify and analyze the FSC drivers specific in the Indian context. Recent advancements in Blockchain technology have paved the path for improving the performance of the food supply chain with appropriate Blockchain technology intervention. Blockchain technology (BT) can be a new driver in the FSCM. This paper proposes a conceptual framework for the implementation of Blockchain technology in the food supply chain. This paper attempts to draw the attention of policymakers to develop a new sound policy with the help of Blockchain technology to ensure food security.

Keywords Blockchain technology · Food safety · Food supply chain · Drivers

Introduction

Food waste is an important issue for the entire world in the twenty-first century, and food safety is a major global concern. The concept of FSC is widely popular in the last decades, due to multiple growth drivers of Indian agriculture sectors. In twenty-first century, more food is being produced and processed than ever before, and it is dispersed across longer distances than ever before. The world’s population is increasing at an exponential rate, and by 2050, it is predicted to reach 9.7 billion people [1]. Food production must increase by 70% by 2050, in addition to global population growth. India has the world’s second-largest population, and its population is projected to be close to 1.40 billion people in 2025. The demand for quality food is also increased. Food safety issues involving many countries are becoming more common because of globalization[2]. Perishable product transportation is the most difficult task in a long supply chain network [3]. With the expansion of agricultural commerce, the peril of tainted food from one country influencing customers in another has grown. Since the beginning of the COVID-19 crisis, over 20 nations have enacted bans on the export of agri-food goods [4]. COVID-19 has an impact on agriculture and the food chain around the world [5]. The global supply chain has been hampered by COVID-19 because of the imbalance between supply and demand. Utilizing cutting-edge techniques and technologies, it is possible to minimize the consequences of deadly viruses while controlling pandemic disruptions and maintaining supply [6]. Recently, the Russia–Ukraine war has also disturbed the global food supply chain and food security is being jeopardized around the world. According to the Food and Agriculture Organization (FAO), 26 countries purchase at least 50% of their wheat from Russia and Ukraine. Russia supplied 52.32 million tonnes (7.8%) of cereals to the world, while

✉ Santosh Patidar
santoshpatidar102@gmail.com

¹ Department of Mechanical Engineering, Ujjain Engineering College, Ujjain 456010, Madhya Pradesh, India

Ukraine contributed 69.82 million tonnes (11.3%). Ukraine is also a global supplier of sunflower oil. In 2020, Ukraine accounted for 52% of all sunflower oil and seed exports worldwide. Global wheat and cereal inventories are decreasing because of the Russia–Ukraine war [7]. Due to this most recent supply shock, prices have nearly doubled since a few months ago. A flexible supply chain can be improved the organization's performance [8]. The agricultural business in India, together with its linked industries, is unquestionably the largest source of livelihood in the country, particularly in rural areas. India has unique biodiversity, which ensures the huge availability of fruits and vegetables throughout the year [9]. Suppliers are critical to a company's success [10]. India is the world's second-largest fruit and vegetable grower and can fulfill the nation's requirements and export to other countries as well. Because of its huge potential for value addition, particularly in the food processing industry, the Indian food sector is poised for significant growth, increasing its contribution to global food commerce every year. This growing demand for chilled and frozen packed food is opening a new opportunity for the local market of developing countries like India. Radio Frequency Identification (RFID) technology can be used in SCM to gather and share data for tracking products in transit [11]. The Indian government has played a key role in the development and expansion of the country's agricultural sector. Joint venture in agribusiness improves productivity and reduces cost [12]. Owing to growing investments in the agricultural sector, in the coming years, the country's agriculture sector is likely to gain better momentum. To maintain this momentum, food supply chain has to be revamped in order to match this pace. The food supply chain is complex with perishable goods and several small stakeholders [13]. Many researchers have noteworthy contributions in this domain field, but still, there are gaps in the literature. All supply chain network stakeholders need to obtain a solid understanding of blockchain through insightful research because applications of blockchain technology in developing nations are still in their development [14]. The use of the latest technology is essential to facilitate the right quality of food. With this responsiveness, the latest technology like Blockchain needs to be incorporated into the FSC for tracking the consignment. This particular aspect is mostly untouched by researchers so far.

Drivers influence the performance of the supply chain. It helps in achieving and maintaining a balance of responsiveness and efficiency of the supply chain. The performance of the food supply chain can be measured on the basis of the drivers that run it. Blockchain may be the new driver for FSC because this technology helps to develop an efficient and transparent FSC network. The following drivers are proposed by the authors namely "Growing attention towards food SCM amidst pandemic Covid-19" (D1), and "Rising demand for processed and frozen food in India due

to population growth" (D2). It has been observed that many authors have mentioned drivers to FSC, but very few studies have gone on to analyze them. Therefore, expert opinions are sought to get context-specific drivers and then, an evaluation of interdependence relationships among drivers is done to find the critical ones using a model. The direct relation matrix (DRM) sheet was presented to experts in the field of FSC to obtain their opinions on the degree of influence between pairwise drivers using the 5 linguistic terms. Finally, based on the data collected, the DEMATEL method is applied to analyze the relations among drivers. A DEMATEL technique is discussed in the next section. Considering the above gaps in the literature, the following objectives are set for this study:

- To identify and rank the drivers of the efficient food supply chain in developing countries like India;
- Determine the relationship and relative dominance of these identified drivers using the DEMATEL approach.
- Proposed Blockchain technology-based FSCM framework to transform food supply chain

The remaining part of the paper is structured into the following sections; a literature review presented in "Literature Review" section, Methodology used for investigating drivers and their rank using DEMATEL discussed in "Methodology used for Investigating Drivers and Their Rank Using DEMATEL" section. "DEMATEL Calculation Process" section describes the DEMATEL calculation process. Results and findings are presented in "Results and Discussion" section. A conclusion, management implications, and the study's future focus are included in the final section.

Literature Review

Post-harvest losses are much higher in India than in other developed countries. Reducing post-harvest losses can help to achieve sustainable development [15]. The maximum proportion of food waste occurs in the supply chain for fruits and vegetables because of poor quality. Safety and security are two aspects that are more crucial in cold supply chain management (CSCM) processes. The items may be consumed and result in food poisoning, which has a large societal and financial cost if safety and security risks are not identified [16]. This section of the paper focuses on the articles published in the domain of FSC, the applications of DEMATEL methodology, and an explanation of the identified critical drivers of FSC in the Indian context. This section also explains the application of blockchain technology to strengthen the food supply chain.

A review of numerous published national and international journal articles on FSC is done. The research articles

that were published between the years 2000 and 2022 are received. The online web of science databases was used to read the research articles. Fourteen drivers, which were identified from the existing articles and the opinions of the expert’s academicians, are listed in Table 1.

Blockchain Technology: Develop a Transparent Food Supply Chain Network

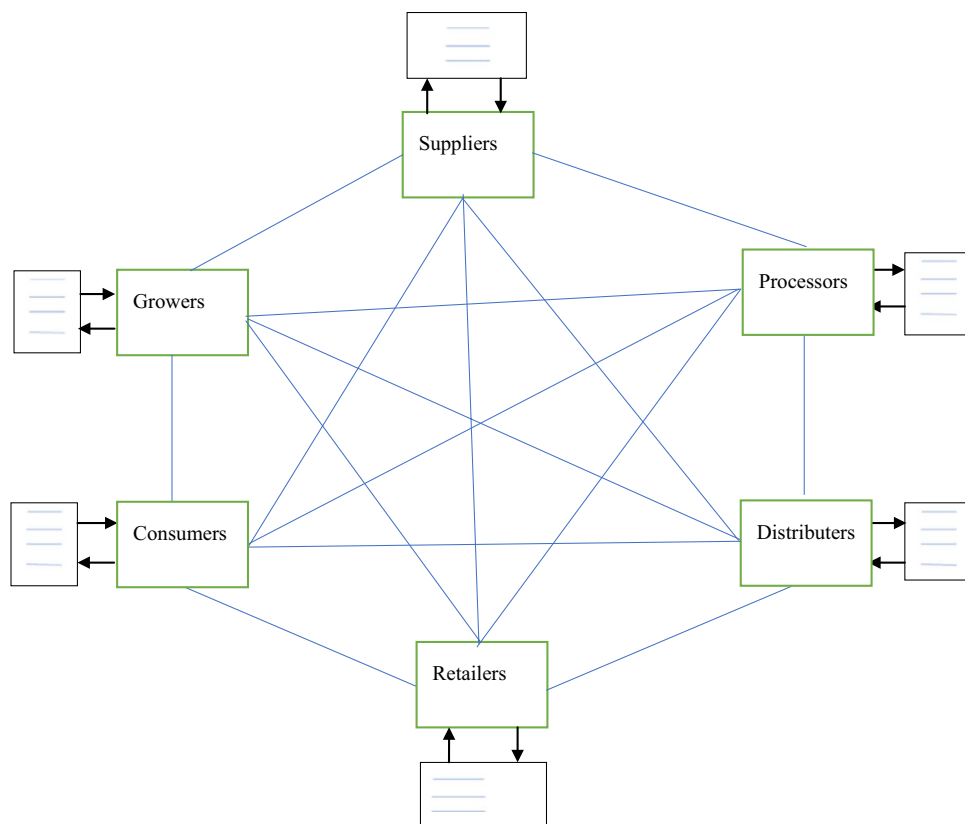
Blockchain technology, as one of the new technologies, is expected to have a substantial impact on FSC. This distributed ledger technology improves FSC transparency. This technology has the power to change the entire FSC network. Decentralized ledger technology unites the FSC entities in a network without the involvement of an intermediary. Figure 1 shows how decentralized ledger technology linked all

parties in the FSC network. It encourages trust and openness in a cooperative environment through a variety of features. The decentralized nature of its operation means that it is not controlled by a single party. An agreement refers to a decision made by all stakeholders on how to complete a transaction. Any transaction can be traced using this unique feature and capability. The distributed ledger is updated whenever a transaction is made so that all nodes can see it. The unique features of this technology make it a more reliable and trusted technology. Traditional databases can be changed or modified, but in blockchain technology, data are secured through distributed ledger techniques, and once created data cannot be changed or modified. Smart contracts are implemented through this technology. The contract logic programs need to be developed for specific mutual contracts between two or more food supply chain parties. Some certain terms

Table 1 Drivers of food supply chain identified from the literature

Sr. no	Drivers	Description	Literature
D1	Growing attention toward food SCM in amidst pandemic Covid-19	Inadequate product tracing and tracking is a fundamental hindrance to a successful food supply chain	Proposed
D2	Rising demand for processed and frozen food in India due to population growth	Because of lack of infrastructure and a poor logistics system, it is difficult to convey goods to reach consumers	Proposed
D3	Growing economy of India	There are very few farmer training centers in India, and there are no established institutions that execute this duty	[17]
D4	Shift from unorganized to organized food market in India	Large investment firms are not taking an interest to invest in food industries	[17]
D5	Growing awareness toward nutritious food	Lack of use of advanced technology in logistics systems results in disruptions	[17]
D6	Stringent measures of Indian regularity authority like FSSAI	The key difficulty is the uneven distribution of cold storage facilities throughout the country. Lack of planning in infra-structures development is evident	[17]
D7	Shift toward a sustainable food system in India	For improving coordination and communication across the food cold chain, there is a need to build integrated well designed information systems. If SC partners are not aware to fully utilize the ICT capability it may affect the responsiveness adversely	[18]
D8	Growing attention toward multi-purpose food cold storage	The improper collaboration and planning between the various point of SC can lead to many inconsistencies at different levels like technological failures, labor issues, sales team forecasts, inventory management, etc.	[18]
D9	More emphasis on food parks and integrated cold chain development	The present skill gaps in this industry are the result of fast development in food chain management processes, and operations with the latest technology change	[19]
D10	Eat right India initiative	The operating cost of Indian cold storage is very high. The cost of installation is significantly higher due to the expense of importing equipment	[20]
D11	Continuing growth in the production of agriculture products	Many poor people are not much aware of food quality. They consume toxic food and get sick	[21]
D12	Monetary and tax benefits through government financial schemes	Indian food supply chain is highly complex and it consists of many stakeholders	[22]
D13	Social requirements on food security and safety	Lack of standardization impedes the efficiency of the food supply chain	[23]
D14	Increasing private sector investments	To protect social and ethical values in the food supply chain, government rules and policies are essential	[24]

Fig. 1 Distributed ledger technology-based FSC



and conditions exist while establishing the smart contract. The concept of FSC is widely popular in the last decades, due to multiple growth drivers of Indian agriculture sectors. These drivers create multiple opportunities for investors and food processing industries. It is essential to identify and analyze these critical drivers. Every country wants to export more for economic development. Investors are looking for opportunities where they can invest and expand their businesses. Therefore, it is utmost important to highlight and bring in the notice to the investors, what are the lucrative opportunities in India. Investors should know the current investment opportunities in the country.

This paper attempts to identify the critical drivers of FSC, especially in the Indian context. Ranking of critical drivers based on their impact potential may help investors and financial stakeholders to execute their business. Hence, the present study aims to identify the drivers of implementing FSC. Further, it identifies the most influential drivers. DEMATEL (decision-making trial and evaluation laboratory) method is used to rank and identify the most effective drivers for implementing FSC. A DEMATEL is one of the powerful decision-making techniques to help decision-makers for established the ranking among multiple criteria [25]. A DEMATEL method is extensively applied in several management domains to handle intricate problems. The steps involved in DEMATEL are discussed

in "Methodology used for Investigating Drivers and Their Rank Using DEMATEL" section [26].

Methodology used for Investigating Drivers and Their Rank Using DEMATEL

DEMATEL was applied to all 14 identified drivers. DEMATEL is a decision-making tool commonly used for modeling relationships between variables. DEMATEL method is used to find the causal connection among the factors and divide these factors into two quadrants, one for the cause group and one for the effect group [27]. This method involves the following four steps:

Step First (Formation of DRM)

There are n driver and m food chain specialists who have expressed their judgments on the relationships and degree of correlation between the variables using the linguistic scale. Five levels of influence are presented in Table 2.

After collecting all of the expert's responses, the average matrix ($n \times n$) K is created.

Table 2 Five levels of influence

Define (driver influence over another driver)	Corresponding number
“No influence”	0
“Low influence”	1
“Medium influence”	2
“High influence”	3
“Very high influence”	4

Step Second (Normalized DRM)

Dividing the DRM K by S , the $n \times n$ normalized X is generated, where S is derived as follows:

$$S = \max \left(\sum_{j=1}^n K_{ij}, \sum_{i=1}^n K_{ij} \right), (X) = \frac{K}{S} \tag{1}$$

and $X = [x_{ij}] n \times n$ where $0 \leq x_{ij} \leq 1$

Step Third (Total Relation Matrix)

It can calculate by the given equation:

$$T = X(I - X)^{-1} \tag{2}$$

I is denoted the $n \times n$ identity matrix.

Step Fourth: (Cause-and-Effect Values)

The total relation matrix (TRM) is created by adding the sums of the i th row and j th column. The i th row depicts causal influence, while the j th column depicts effect influence. R_i and C_j are calculated in this step. DEMATEL approach for FSC is introduced as illustrated in Fig.2.

We have invited only Indian experts to participate in this research study. For this investigation, twenty experts were taken into account. Eleven experts are faculty in a prominent research and academic institution in India, and each has more than ten years of experience. There are five experts in the field of food processing. These experts have between five and ten years of managerial experience. Four professionals, managers with 0–5 years of experience, are from the logistics and cold storage industries. Table 3 shows the experts’ profiles.

Figure 3 shows that 45% of experts hold a bachelor’s degree, and 55% are highly qualified, holding a doctorate.

DEMATEL Calculation Process

This section provides an outline of the DEMATEL calculation process.

Step 1 In this first step, the DRM X is obtained. The expert’s opinion was taken, and it is illustrated in Table 4.

Table 3 Experts’ profile

	Frequency (%)
<i>Work experience (in years)</i>	
0–5	20
5–10	25
More than 10	55
<i>Qualification</i>	
Doctorate	55
Bachelors or professional degree	45
<i>Types of organization</i>	
Food processing unit	25
Storage, logistics and distribution	20
Academic institute	55

Fig.2 Flowchart of work done to identify and analyze the drivers to FSC in the Indian context

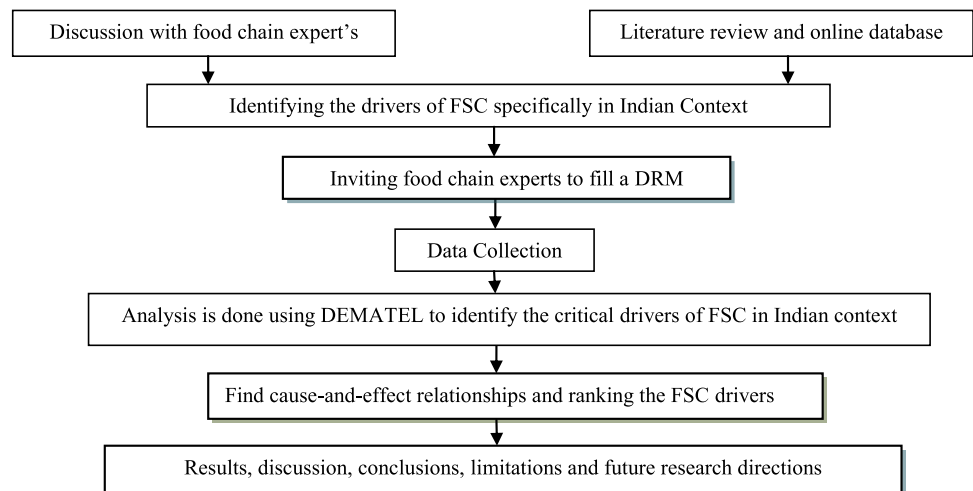
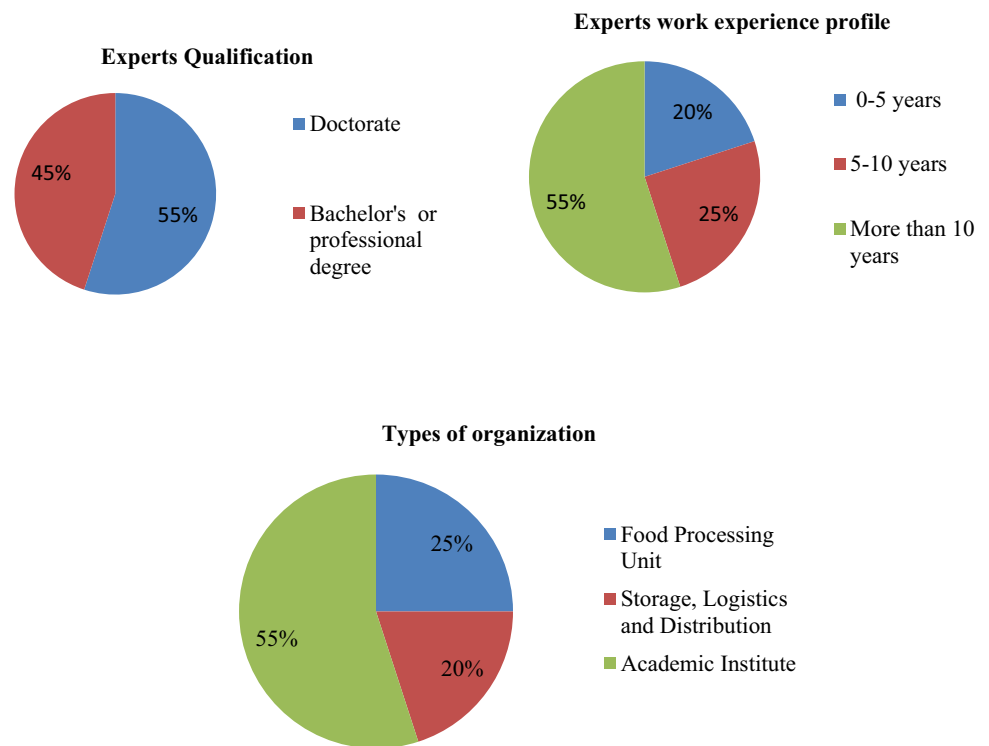


Fig. 3 Experts' profile



Each expert provided his opinions on 14*14 linguistic DRM for determining relationships and degree of correlation between the variables using a linguistic scale. The average of all responses is utilized to form comprise the average direct relation matrix.

The remaining phases of DEMATEL methodology are solved using the methods described in "Methodology used for Investigating Drivers and Their Rank Using DEMATEL" section. Equation (1) is used in the second step to obtain 14*14 normalized DRM "X" by dividing the DRM "X" by S ($S=45$). Finally, the total relation matrix (TRM) is obtained, while the sum of the total influence matrix T_c and the ranking of drivers are calculated. Table 5 also shows the importance vector ($R_i + C_j$) and relative vector ($R_i - C_j$). Table 6 shows the cause-and-effect group.

Results and Discussion

The fast-growing economy of India is creating potential opportunities for investors. Many factors are strengthening the food supply chain market of India. In this study, the interrelationship between the identified fourteen drivers is explored by using the DEMATEL approach. The findings are presented in Fig. 4. There are two groups: one is the cause drivers group and the second is the effect drivers group. Classifications of these two groups are based on drivers relationships with other drivers. The following is an explanation of the research procedure and findings from the

causal diagram (Fig. 4). After analyzing the data through a systematic step by step calculation process, five drivers have appeared in the cause group namely "Shift towards a sustainable food system in India" (D7), "Social requirements on food security and safety" (D13), "Growing attention towards food SCM amidst pandemic Covid-19" (D1), "Rising demand for processed and frozen food in India due to population growth." (D2), "Growing economy of India" (D3), Driver D7 has been a ranked 1 in the cause group. It is pointed out that government policy and regulation support are very important for the sustainable development of SC infrastructure. In India, there are many states and central regulatory authorities which handle the entire food management system. Agriculture produce is important for all human beings, and it plays a vital role in maintaining the socio-economic life of India. It is further observed that drivers thirteen, one, two, and three are also in the cause group and significantly influence the system. Similarly, Nine drivers have appeared in the effect group namely "More emphasis on food parks and integrated cold chain development"(D9), "Eat right India initiative" (D10), "Increasing private sector investments" (D14), "Monetary and tax benefits through government financial schemes"(D12), "Growing awareness towards nutritious food" (D5), "Stringent measures of Indian regularity authority like FSSAI" (D6), "Shift from unorganized to organized food market in India"(D4), "Continuing growth in the production of agriculture products" (D11) and "Growing attention towards multi-purpose food cold storage" (D8). The drivers that come in the effect group are

Table 4 Direct relation matrix (average)

Sr. no	Drivers	“D1”	“D2”	“D3”	“D4”	“D5”	“D6”	“D7”	“D8”	“D9”	“D10”	“D11”	“D12”	“D13”	“D14”
D1	Growing attention toward food SCM amidst pandemic Covid-19	0	3	4	0	4	0	0	2	3	4	1	1	3	2
D2	Rising demand for processed and frozen food in India due to population growth	3	0	4	4	3	3	3	4	4	3	3	3	2	3
D3	Growing economy of India	4	3	0	4	3	3	2	4	3	4	4	3	4	4
D4	Shift from unorganized to organized food market in India	0	4	3	0	2	4	2	4	3	3	2	4	2	3
D5	Growing awareness toward nutritious food	4	3	3	2	0	3	3	4	4	4	4	2	2	4
D6	Stringent measures of Indian regularity authority like FSSAI	0	3	4	4	3	0	3	2	3	2	3	2	1	2
D7	Shift toward a sustainable food system in India	0	3	2	2	3	3	0	3	3	3	2	2	2	3
D8	Growing attention toward multi-purpose food cold storage	2	4	4	4	4	3	3	0	3	4	4	2	1	4
D9	More emphasis on food parks and integrated cold chain development	2	3	3	3	4	3	3	4	0	2	4	3	3	4
D10	Eat right India initiative	3	3	4	3	4	2	3	4	2	0	4	1	1	2
D11	Continuing growth in the production of agriculture product	1	3	3	2	4	3	2	4	4	3	0	4	3	1
D12	Monetary and tax benefits through government financial schemes	1	3	3	4	2	2	2	3	3	1	3	0	2	3
D13	Social requirements on food security and safety	3	1	4	2	3	2	3	2	4	1	3	2	0	1
D14	Increasing private sector investments	2	4	3	4	4	2	3	4	4	3	1	4	1	0

Table 5 Total relation matrix, $R_i + C_j$ and $R_i - C_j$ for the drivers

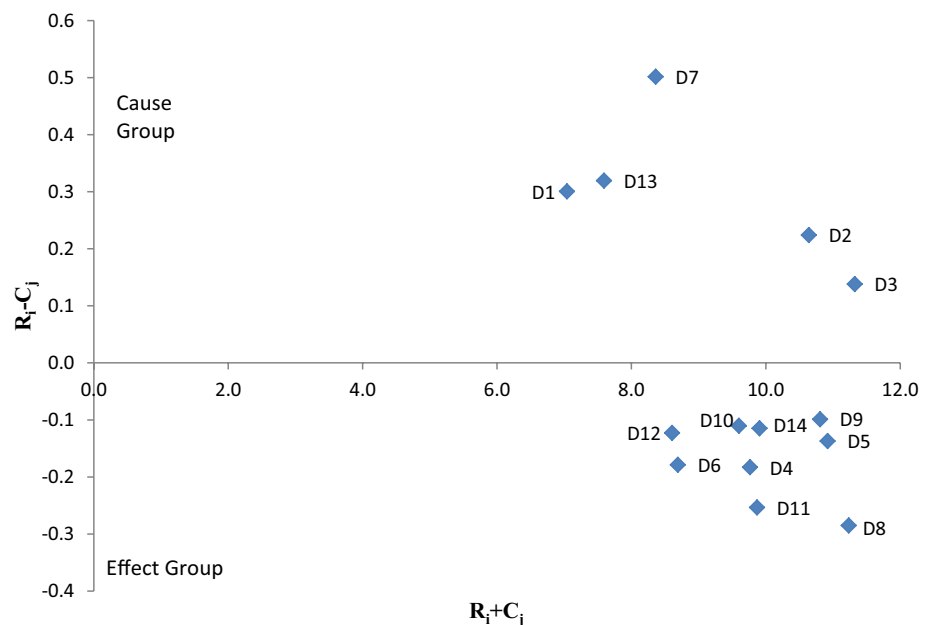
Drivers	R_i	C_j	$R_i + C_j$	$R_i - C_j$	Rank
D1	3.671	3.371	7.042	0.301	14
D2	5.433	5.209	10.641	0.224	5
D3	5.731	5.592	11.323	0.138	1
D4	4.740	5.026	9.766	-0.285	8
D5	5.410	5.509	10.919	-0.099	4
D6	4.277	4.414	8.692	-0.137	10
D7	4.123	4.238	8.361	-0.115	12
D8	5.491	5.744	11.235	-0.253	2
D9	5.312	5.495	10.807	-0.183	3
D10	4.744	4.855	9.599	-0.110	9
D11	4.845	5.024	9.869	-0.179	7
D12	4.241	4.364	8.606	-0.123	11
D13	4.047	3.545	7.592	0.502	13
D14	5.113	4.794	9.907	0.319	6

highly influenced by cause group drivers. Thus, by improving cause group drivers, effect group drivers are improved simultaneously. The cause group drivers need more attention than the effect group drivers. In this study, “Shift towards a sustainable food system in India” (D7), “Social requirements on food security and safety” (D13), “Growing attention towards food SCM amidst pandemic Covid-19” (D1) are the top three drivers that need the most attention. The most significant causal driver “Shift towards a sustainable food system in India” (D7) has the highest ($R_i - C_j$) value (0.502), which means D7 should require more attention for the effective management of the FSC. Meanwhile, Table 4 shows that the influence impact degree of (D7) is 4.123 (R). From this study, it can be concluded that the D7 is the major driver and requires the most attention in the food supply chain management system. “Social requirements on food security and safety” (D13) has a significant impact on other drivers with the second highest ($R_i - C_j$) value of 0.319. This driver can be considered an important driver and need to pay high attention. Moreover, D13 has the 2nd ($R_i - C_j$) value among all the drivers, which means this driver influences the other drivers in a significant way. Similarly, “Growing attention towards food SCM amid pandemic Covid-19” (D1) (0.301) “Rising demand for processed and frozen food in India due to population growth.” (D2) (0.224), and “Growing economy of India” (D3) (0.138), have positive ($R_i - C_j$) values, which means these drivers also have a significant impact on other drivers.

The negative value of ($R_i - C_j$) indicates that the drivers are in the effect group and are mostly influenced by others. In this study, nine drivers appeared in the effect group. Effect group drivers namely “Growing attention towards multi-purpose food cold storage” (D8) have the highest ($R_i - C_j$) value (-0.285) among all drivers, which means it is significantly

Table 6 Cause and effect group

Cause group drivers	$(R_i - C_j)$ Positive	
D7	0.502	Cause
D13	0.319	Cause
D1	0.301	Cause
D2	0.224	Cause
D3	0.138	Cause
Effect group drivers	$(R_i - C_j)$ Negative	
D9	-0.099	Effect
D10	-0.110	Effect
D14	-0.115	Effect
D12	-0.123	Effect
D5	-0.137	Effect
D6	-0.179	Effect
D4	-0.183	Effect
D11	-0.253	Effect
D8	-0.285	Effect

Fig. 4 Cause and effect diagram

influenced by other drivers. “Continuing growth in the production of agriculture products” (D11) has the second highest $(R_i - C_j)$ value (-0.253). Similarly, D4, D6, D5, D12 and B14 have moderate $(R_i - C_j)$ values (-0.183), (-0.179), (-0.137), (-0.123) and (-0.115), respectively. It shows that these drivers are moderate influence by other drivers. D10 and D9 have very low $(R_i - C_j)$ values (-0.110) and (-0.099), respectively. It indicates that these drivers are mildly affected by other drivers.

An efficient food supply chain ensures that the perishable items reach the consumers in the shortest time while

maintaining product volume, quality, and safety. This research has identified critical drivers, which positively support the implementation of the food supply chain in India. Much attention needs to be paid to the above-mentioned drivers. The finding of this study also suggests great investment opportunities in India, due to the high demand for quality and hygienic food. The various drivers are strengthening the existing FSC, but still, India needs to work to reduce food waste. Efficient food management can reduce food waste and feed more.

Conclusions Limitations and Future Research Directions

India has a big opportunity to become a food basket for the world. India's population is diverse, with various religious groups, each with its food preferences and culture. Indian horticulture gains popularity in the world over the last couple of years, despite that India's share in the global market is less than 2%. Agriculture exports slightly increase, owing to government initiatives and the development of food chain infrastructure. For instance, wheat exports from India reached a record high in March 2022; India exported a record 7.85 million tonnes, rising 275% from the previous year. The private sectors and government sectors have also taken proactive initiatives toward the development of food chain management. In this study, DEMATEL method to find the critical drivers specific to India is used. The following drivers found to be critical:-

- “*Shift towards a sustainable food system in India*” (D7) is the most critical driver. It has been pointed out that the Government of India is focusing on comprehensive policy regarding food item quality, storage, transportation, cold chain, etc. To accomplish the 2030 Sustainable Development Goals, India is working hard to transition to a sustainable food system (SDGs).
- “*Social requirements on food security and safety*” (D13) is the second most critical driver. Equitable distribution of food items is a social responsibility of the system. A strong and efficient supply chain guarantees that fresh, hygienic, and high-quality food is delivered on time. During the second wave of Covid-19, the Indian government supplied free food grains to around 80 million individuals to help the needy.
- “*Growing attention towards food SCM amidst pandemic Covid-19*” (D1) is the third most critical driver. The Government of India has simplified the rules and regulations for interested foreign investors. This resulted in foreign investment, which has significantly increased in the last couple of years.
- “*Rising demand for processed and frozen food in India due to population growth.*” (D2) is a cause group driver and affects all other drivers, because the demand for processed food has risen significantly as a result of population growth. The continuously rising population and urbanization have generated an ever-increasing demand for quality and hygiene food.
- “*Growing economy of India*” (D3) is a cause group driver. India is the fastest-growing economy in the world. In 2022, India's GDP is predicted to grow at the fastest rate, at 6.7 percent. As the value of exports rises and the economy expands. Owing to initiatives taken by the

Indian government to make doing business simpler, India is the preferred choice for future investment.

The key limitation of this study is that only a small number of experts were available for giving their opinion. However, if a large pool of experts from varied backgrounds contributes to the study, the results could be more close to the real situation. In the future, obtained results can be further validated using other MCDM techniques like fuzzy DEMATEL, Total interpretive structured modeling (TISM), Analytic network process (ANP), Grey relational analysis, etc., Assuming that other MCDM techniques may provide more insights into the criticality of drivers. These findings will be helpful to policymakers and experts in the food industry in developing strategies for their businesses.

Blockchain Technology: a New Driver in Food Supply Chain

Blockchain is a network-based, decentralized, digitally distributed public ledger that brings all participants together on a single platform to share data in the form of digitally signed transactions [28]. The nodes are linked together, so that they may exchange real-time data and assist with supply chain management. Many researchers have suggested the possible application of blockchain technology [29]. Blockchain's potential was previously emphasized in many research studies to improve transparency, trust, efficiency, and cost reduction [30]. Blockchain technology builds a unified system in which all forms of transactions are digitized in the same way, enhancing accessibility and readability. In this competitive environment, integrating blockchain technology into the food industry faces various challenges. Implementation of blockchain in FSC might be a big game-changer. One must keep track of everything on a ledger in a traditional supply chain, which is quite difficult. Blockchain is a digitally distributed public ledger with real-time data that is transparent and easily accessible to all stakeholders. To create an immutable chain of data, all data are stored in blocks, with each block's header carrying the hash of the previous block.

A traditional supply chain has the following drawbacks: (i) Lack of transparency and traceability. (ii) No information about the product's origin. (iii) At any point in the process, food safety cannot be assured. (iv) Throughout the supply chain, a ledger is used for the recording of the transaction, which can easily be modified and changed. Comparison of traditional FSC and Blockchain technology-based FSC is presented in Table 7.

Blockchain technology can address the aforementioned concerns by acting as a public ledger via distributed networks and overcoming information maintenance issues such as verification and validation. Blockchain technology ensures security, maintains digital records, restricts the entry

of a third-party middleman in transactions, lowers transaction costs, and improves supply chain performance.

Many stakeholders are involved in FSC, including growers, suppliers, processors, distributors, retailers, and consumers. FSC begins at the farm and ends at the fork of the consumer. The three things are (i) product flow, (ii) information flow, and (iii) money flow in the complete supply chain. These flows are interconnected. All flow and related data are documented in the traditional supply chain-using ledger.

It is very difficult and time-consuming to trace the transaction in traditional FSC. While all flow-related data may be displayed in one click with the blockchain-based FSC. As a result, the entire process is easy and transparent. Any parties, at any moment, will have their transaction details updated in the form of a digital code. Figure 5 shows how Blockchain can transform FSC. Food supply chains have faced numerous challenges, including poor traceability management systems, low transparency, and incompetence [31]. Technology-based FSC can solve problems across the FSC network. The chain comprises a ledger from the beginning until the generation

of new blocks. Each block contains details of all transactions, because of the hash value; each block has a reference to the one before it. An interconnected Blockchain network helps in transaction and user verification [32].

ITC Limited is an Indian multi-industry corporation headquartered in Kolkata. It has a big fast moving consumer goods (FMCG) market in India. The company has an extensive value chain for fresh potatoes and chips. The company recently launched Technico-ITC Connects, a blockchain-based digital platform, to enhance end-to-end product traceability. To achieve complete transparency throughout its potato supply chain, Technico is adopting traceability technology based on blockchain. Technico-ITC, a blockchain-based digital platform, has built the company’s image in the markets [33].

Table 7 Traditional FSC versus blockchain technology-based FSC

Traditional food Supply chain	Blockchain technology-based food supply chain	Overcome the drawbacks of traditional FSC using Blockchain technology
Based on centralized systems	Based on a decentralized distributed system	Decentralized, digitally distributed public ledger that brings all participants together on a single platform to share data in the form of digitally signed transactions
Lacks of traceability	Provenance Tracking	The usage of smart contracts on the blockchain allows for asset traceability
Lack of transparency	Transparent Procurement	Digital smart mutual contracts enhance transparency
Data tempering	Transacting Immutably	Maintain immutable real-time data
Security threats	Structured data with high security	Which provides using cryptography techniques

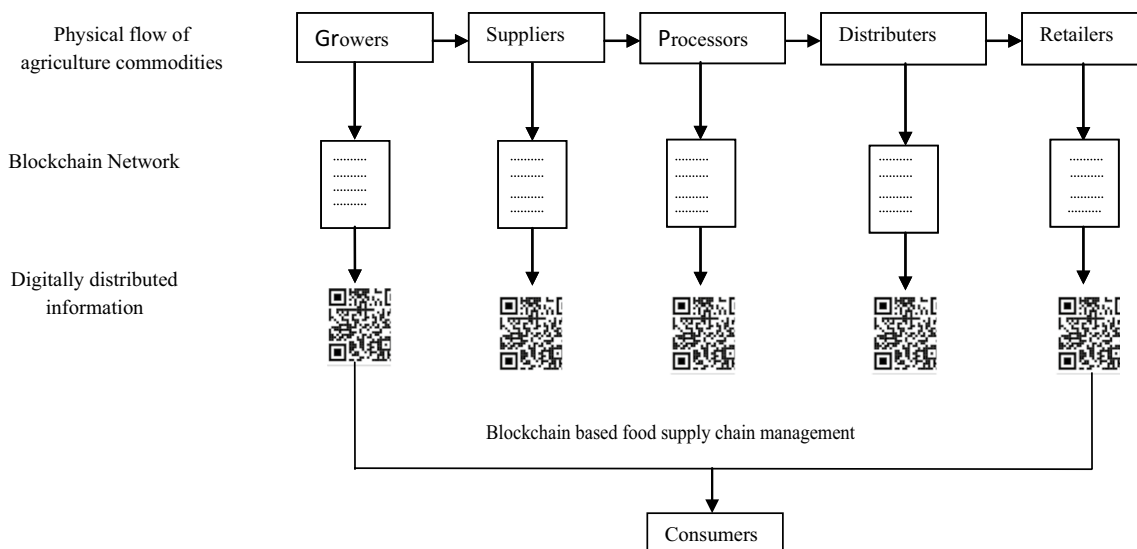


Fig. 5 Transforming food supply chain using Blockchain technology (proposed conceptual framework)

Theoretical and Managerial Implications

To maintain food security, developing countries like India must reduce food loss at every stage of the food supply chain and reinforce it. The results of this study can help managers and professionals in the food business create effective FSC networks. It is difficult to maintain and monitor the complete supply chain network because of the length and complexity of the Indian FSC network. Therefore, it is crucial for managers and practitioners to concentrate on the critical drivers that will enable effective management of the food supply chain. Following points motivate the practitioners to strengthen the food supply chain:

- 1 This study encourages practitioners to use blockchain technology into the FSC to create a successful food management system.
- 2 The use of blockchain technology can improve food traceability and assist management in tracking down the food supply.
- 3 The study also provides a theoretical framework for choosing crucial FSC drivers in the Indian environment, assisting investors in comprehending the present and long-term opportunities in a developing country like India.
- 4 Organic farming is a sustainable future farming. Organic farming produces pesticide and residue-free agriculture products, which contribute to improving the health of the soil as well as the health of consumers.
- 5 The findings of this research can be used to help develop new, efficient food policies that will support food security.

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