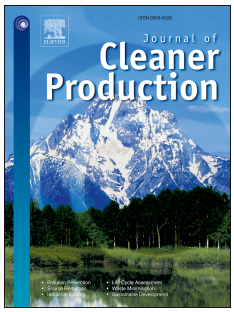

A Framework to Assess the Challenges to Food Safety Initiatives in an Emerging Economy

Sachin Kumar Mangla, Arijit Bhattacharya, Alok Kumar Yadav, Yogesh Kumar Sharma, Alessio Ishizaka, Sunil Luthra, Ratula Chakraborty

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A Framework to Assess the Challenges to Food Safety Initiatives in an Emerging Economy

Credit Author Statement

Sachin Kumar Mangla - Roles/Writing - original draft; Formal analysis; Investigation; Conceptualization; Methodology; Project administration.

Arijit Bhattacharya - Project administration; Conceptualization; Visualization; Writing - review & editing.

Alok Kumar Yadav - Roles/Writing - original draft; Data curation; Formal analysis; Conceptualization; Methodology.

Yogesh Kumar Sharma - Roles/Writing - original draft; Data curation; Formal analysis; Methodology.

Alessio Ishizaka - Visualization; Writing - review & editing.

Sunil Luthra - Conceptualization; Investigation; Writing - review & editing.

Ratula Chakraborty - Visualization; Writing - review & editing.

A Framework to Assess the Challenges to Food Safety Initiatives in an Emerging Economy

Sachin Kumar Mangla*
Plymouth Business School, University of Plymouth,
United Kingdom, PL4 8AA
Email: sachin.kumar@plymouth.ac.uk ; sachinmangl@gmail.com

Arijit Bhattacharya
Norwich Business School, University of East Anglia
Norwich NR4 7TJ, United Kingdom.
E-mail: A.Bhattacharya@uea.ac.uk

Alok Kumar Yadav
Graphic Era University, Dehradun-248002, Uttarakhand, India.
E-mail: alokwhy@gmail.com

Yogesh Kumar Sharma
Graphic Era University, Dehradun-248002, Uttarakhand, India.
E-mail: yogeshsharmame355@gmail.com

Alessio Ishizaka
NEOMA Business School, Mont-Saint-Aignan Cedex - France.
Email: Alessio.ISHIZAKA@neoma-bs.fr

Sunil Luthra
State Institute of Engineering & Technology (also known as Government Engineering College),
Nilokheri, India.
E-mail: sunilluthra1977@gmail.com

Ratula Chakraborty

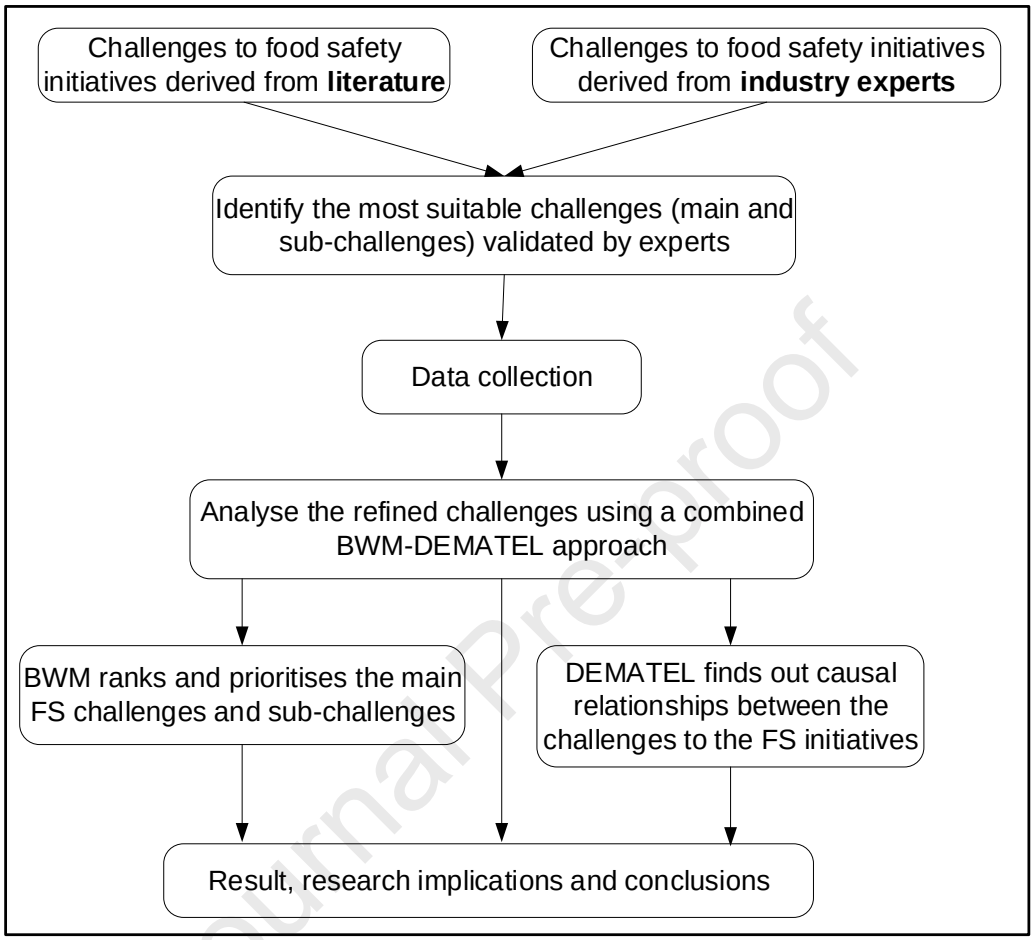
Norwich Business School, University of East Anglia

Norwich NR4 7TJ, United Kingdom.

E-mail: R.Chakraborty@uea.ac.uk

***Corresponding Author**

Graphical abstract



A Framework to Assess the Challenges to Food Safety Initiatives in an Emerging Economy

Abstract: Emerging economies, e.g. India, China and Brazil etc., face challenges to adopt food safety (FS) practices in their food supply chains. Considering food industry's operations and processes, this study identifies 25 challenges to the FS initiatives involving the opinions of practitioners from six major Indian food producers and academic experts. The challenges are grouped into five categories, viz. organisational, government and policy, global, knowledge and financial. We identify the best and worst challenges to the FS initiatives along with causality among them using combined Best Worst Method (BWM) and 'Decision Making Trial and Evaluation Laboratory' (DEMATEL) approaches. BWM prioritises these challenges, while DEMATEL identifies causal relationship maps for the prioritised challenges. The BWM results demonstrate that the government and policy related challenges are the key challenges followed by the organisational, global, knowledge and financial related challenges. The DEMATEL results exhibit the organisational, government and policy, and global related challenges as the cause group challenges. The knowledge and financial related challenges represent the effect group challenges. Mitigation of these challenges inherently necessitates stakeholders' involvement in the food supply chains. We identify constructs for food safety initiatives policy in the emerging economies to raise public awareness while encouraging greater collaboration and efficiency in food supply chains to help achieve the second Sustainable Development Goal (SDG) for securing food for everyone. The results of the study offer guidance and deeper insights to supply chain managers about synergy requirements between the government policymakers and key players of the industry in the emerging economies.

Keywords: Food safety; Supply chain management; Best Worst Method; DEMATEL; Emerging economy; Sustainability.

1. Introduction

Food safety (FS) is regarded as one of the main concerns in food supply chains. Food safety related threats pose serious concerns to food systems while undermining public confidence in food safety (Liu et al., 2020). These threats can spread to multiple countries, such as the horsemeat scandal in Europe where the food contained undeclared horsemeat instead of beef

(Smith, 2017). Many prominent food safety scandals have involved selling rotten or contaminated foods, such as the rotten meat scandals in Brazil in 2017 (Vaqué, 2017) and in Kolkata in 2018 (Financial Express, 2018), and dioxin (a highly carcinogenic substance) contamination cases in mozzarella cheese in Italy (BBC News 2008a) and pork in Ireland (BBC News 2008b). In such cases, contaminants, food fraud and malicious tampering of FS records, etc., constitute threats to FS. Furthermore, FS problems seem to be on the rise despite increasing efficiency and integration in food supply chains. For instance, in the EU, food alerts and product recalls increased by 58% between 2013 and 2018 (Ralph, 2018).

Food safety addresses the world's growing food needs in an economically and environmentally sustainable way (He et al., 2019). Several interconnected issues in FS impact the quality of human life and nation's economic progress (Namany et al., 2020). FS initiatives help to ensure safe and fair distribution and consumption of food to society through food value chains. Food value chains include several intermediaries, viz., retailers, wholesalers, distributors, traders, processors, marketers and farmers or farm suppliers (Krishnan et al., 2020). Involvement of disparate activities like harvesting, production, processing, and distribution, make value chains increasingly complex and dynamic thereby decreasing chains' transparency (Sener et al., 2019).

The concept of FS is less advanced in emerging economies as compared to developed economies (Govindan, 2018). Stable demand and highly integrated supply chains mean that the availability of safe and secure food is comparatively easier to assure in developed nations compared with emerging economies like India (Basha and Lal, 2019). In such emerging economies, the unavailability of safe food can cause severe problems leading to undernourishment and ill-health, including the spread of diseases (He et al., 2019). For example, the World Health Organization (WHO, 2016) reports that approximately 4,000 people die every day from Bovine Tuberculosis in developing countries, and most diseases in humans occur due to contaminated food and improper food handling systems. Globally, one in seven children lacks access to sufficient safe food.

The production of safe foods involves economic and technological considerations interlinked through the entire food system in emerging economies (Maroušek, et al., 2019, 2020). FS initiatives could help address the scale of contaminated and wastage of food in developing economies (Zhang et al., 2018). In India, wastage of grains due to improper management of the food supply chain alone is worth $1 billion annually (Balaji and Arshinder, 2016). Food producers, though, are increasingly developing innovative capabilities by adopting technologies in supply chains to sustain competitive advantage

(Ahumada and Villalobos, 2009). Even so, from an organisational perspective, implementation of the FS initiatives pose several challenges due to lack of financial resources, transparency, government support and management commitment in the food sector (World Development Report, 2017). Kumar and Singh (2011) and Soni (2013) report progress towards better initiatives in the food industry with an emphasis on FS, and yet standards and measures still considerably lag behind those in developed economies. Therefore, it is crucial to identify and analyse a set of feasible and practical challenges to improve the efficiency and effectiveness of the FS initiatives in the context of an emerging economy (Maroušek, et al., 2019). In response to this critical need, this study seeks to address the following three key questions:

- What are the key challenges and obstacles to the FS initiatives in an emerging economy?
- How can these challenges be prioritised and rated as the most important and least important?
- How can these challenges be classified in terms of their causal relationships?

These research questions enunciate several interconnected objectives. The primary objective of this study is to identify the most important challenge for effective adoption of the FS initiatives in the food sector. Different business organisations might have different opinions regarding the FS challenges (Balaji and Arshinder, 2016). To provide different perspectives on these challenges, information and views are gathered from six major Indian food organisations. The second objective is to suggest an approach that facilitates analysis of these challenges for effective understanding and successful management of the FS initiatives in a food supply chain. To examine these challenges, we use an approach combining Best Worst Method (BWM) and the Decision-Making Trial and Evaluation Laboratory (DEMATEL) approaches. BWM helps to prioritise and rank challenges based on the best (most important) and worst (less important) challenges (Rezaei, 2015). DEMATEL examines and maps causal relationships between challenges (Cui et al., 2019).

The rest of this paper proceeds as follows. Section 2 presents a review of the relevant literature. Section 3 explains the solution methodology and research model adopted for the analysis. Section 4 provides an overview of the case organisations, analyses the datasets using the proposed integrated model, and discusses the results and implications for managers. Section 5 concludes the article and considers the scope for future research.

2. Literature Review

This section explores the literature relevant to food safety and its challenges. The articles exhibit the knowledge-base for the FS initiatives. The literature review demonstrates the barriers and challenges to adoption and implementation of the FS initiatives in food supply chains. We use a systematic literature review (SLR) approach (Marik et al., 2020). Using Scopus, Google and Google Scholar databases, we searched for articles within the domain of FS initiatives and its implementation in supply chains using various combinations of the keywords “food safety”, “food supply chain”, “food sustainability”, “challenges”, and “barriers”. We considered articles written in English and published in peer-reviewed journals and books and official reports (while excluding the conference proceedings). In addition, we used journal websites to cross search, including those relating to food and agricultural economics, production economics, operations management, public health policy, sustainable development, and environmental policy. We examined the collated publications through a forward snowball and backward snowball technique (Glock et al., 2017). The rest of this section summarises the key points and contentious issues arising from the literature review.

2.1 Food safety

FS is concerned with the adoption of certain practices across the food supply chains to keep food away from any contamination. Early research on food safety focused on increasing awareness about safety of food products (Kickbusch, 1997; Adams and Motarjemi, 1999), food handling and sanitation (Graham-Rowe et al., 2014). Recent research focuses on holistic approaches to create sustainable food systems through minimising food wastes (Young et al., 2017). Developing sustainable systems calls for identifying and attending to the different points in the food supply chain where wastage occurs (Käferstein and Moy, 1993; Balaji and Arshinder, 2016). Research identifies FS depending on three main components, viz. food availability, food access and food utilisation (King et al., 2017). Production and distribution systems play a key role for continuous food availability (Mishra and Jaiswal, 2012; Dania et al., 2018). Governments in various emerging economies, like India, focus on increasing the production of food grains through improved fertiliser, seeds and irrigation facilities (Devkota et al., 2020). Yet, the distribution system is the critical link and it needs an efficient food supply chain from farms to producers, distributors, retailers and then the end consumers (King et al., 2017). FS and wastage is also influenced by level of collaboration among stakeholders across value chains (Bustos and Moors, 2018; Dania et al., 2018).

Complex operations in food supply chains and concerns relating to growing resource scarcity are some of the impediments in FS (Kumar and Nigmatullin, 2011). Further, inappropriate monitoring of product transformations in internal supply chains can affect FS (Bosona and Gebresenbet, 2013).

2.2 Challenges to food safety

Gandhi and Zhou (2014) identify several hurdles to safe and secure food. These hurdles include new consumption patterns, urban population growth and increased demand for meat and dairy products. There is a need for stringent legislations and supportive regulatory environmental policies to improve the FS initiatives in the food industries (Zhang et al., 2018). Globalisation and market uncertainty also have significant influences on FS with a need to design policies that protect both the local and global level challenges in FS initiatives (Khandal, 2008; Sazvar et al., 2018).

In emerging economies, poverty is linked to malnourishment, and government initiatives may help support people living below poverty levels. For instance, the Indian Government has adopted a Public Food Distribution (PFD) programme and Targeted Public Distribution System (TPDS) for ensuring access to food grain as a safety net (Balaji and Arshinder, 2016). However, due to the lack of transparency, irregular supply, low quality of grain (wheat and rice), misuse of political power and weak monitoring, some 40% of grain is reported as wasted under the PFD and TPDS programmes (Umali-Deininger and Deininger, 2001).

Low levels of education, weak social networks, low household income, unemployment, and low social capital appear as the prime reasons for lower FS and insecurity in economies (Lund et al., 2010; King et al., 2017). Government action is critical through legislation, regulations and collaboration with food organisations (Hodge, 2007; Grant Thornton, 2014). Ensuring FS and security in emerging economies is a challenging task due to population growth, urbanisation and environmental threats (Poulsen et al., 2015). The fastest growing emerging economies, such as India and China, face particular challenges due to the increasing demand for meat and dairy products, changing consumption patterns and changing market conditions (Gandhi and Zhou, 2014). The efficiency of a food supply chain depends greatly on a country's infrastructure, including social media and transportation and scientific support facilities, all of which requires substantial government investment and commitment to resourcing (Bustos and Moors, 2018).

Taking stock of the issues arising in the literature, we identify 24 specific challenges to FS initiatives. Based on their simplified meaning and considering the experts' views, we

categorise these challenges into five groups: (i) organisational related challenges (O), (ii) government and policy related challenges (GP), (iii) global related challenges (G), (iv) knowledge related challenges (K) and (v) financial related challenges (F). Table 1 summarises only the challenges identified from the literature. Later, the experts are asked if these challenges to FS are sufficient for the purpose of this study. In the end, the experts suggested to add one more challenge to the challenges identified from the extant literature. The details on the collated data and experts' agreement on identified challenges are provided in section 5.1 and section 5.2 respectively.

Table 1: Description of challenges to the food safety initiatives

S. No.	Challenges	References
(i) Organisational related challenges (O)		
1	Corporate social responsibility (O_1)	Vellema et al., 2006; Grant Thornton, 2014; Gardas et al., 2019.
2	Lack of skilled manpower and expertise of human resources (O_2)	Grant Thornton, 2014; World Development Report, 2017; Ali et al., 2019.
3	Lack of technological advancement and process innovation (O_3)	Grant Thornton, 2014; Vlachos, 2015; Vlajic et al., 2018.
4	Lack of management support and commitment (O_4)	Grant Thornton, 2014; Balaji and Ashinder, 2016.
5	Poor information system network (O_5)	Bosona and Gebresenbet, 2013; Masiero, 2015; Wu, 2015; Balaji and Arshinder, 2016; Verdouw et al., 2016.
6	Lack of communication and collaboration among organisational members (O_6)	Balaji and Arshinder, 2016; Bustos and Moors, 2018; Dania et al., 2018; Sener et al., 2019.
(ii) Government and policy related challenges (GP)		
7	Lack of supportive legislative framework (GP_1)	Hodge, 2007; Zhang et al., 2018.
8	Governance issues (GP_2)	World Development Report, 2017; Govindan et al., 2018; Ali et al., 2019.
9	Urbanisation related problems (GP_3)	King et al., 2017; Anser et al., 2020.
10	Lack of co-ordination (between government and food organisations) (GP_4)	Grant Thornton, 2014; World Development Report, 2017; Bustos and Moors, 2018; Dania et al., 2018.
11	Poor support to adequate infrastructure and facilities (transportation, cold storage, equipment) (GP_5)	Grant Thornton, 2014; Young et al., 2017; Govindan, 2018.

12	Lack of food safety standard and certifications (GP_6)	Unnevehr, 2000, 2015; Zhang et al., 2018.
(iii) Global related challenges (G)		
13	Uncertainty of climate change (G_1)	Govindan, 2018; Sazvar et al., 2018
14	Problems of increased demand for meat and dairy product (G_2)	Balaji and Arshinder, 2016
15	Poverty and inequity (G_3)	Rao 2006; Marucheck et al., 2011; Unnevehr, 2015
16	Population growth (G_4)	Staniškis, 2012; Govindan, 2018
17	Changing market scenario (G_5)	Marucheck et al., 2011; Grant Thornton, 2014; Ali et al., 2017
(iv) Knowledge related challenges (K)		
18	Lack of farmer knowledge and interest (K_1)	Balaji and Arshinder, 2016; Basha and Lal, 2019
19	Fear of new food (Food Xenophobia) (K_2)	Verbeke and Poquiviqui López, 2005
20	Changes in consumption pattern (K_3)	Staniškis, 2012; Grant Thornton, 2014; Govindan, 2018
21	Lack of consumer awareness and knowledge (K_4)	WHO, 1999; Vellema et al., 2006, Graham-Rowe et al. 2014; Young et al., 2017; Basha and Lal, 2019
(v) Financial related challenges (F)		
22	Lack of farmers' capital (F_1)	Bustos and Moors, 2018
23	Higher inspection costs (F_2)	Sazvar et al., 2018
24	Lack of supply chain investment (F_3)	Wang et al., 2012; Grant Thornton, 2014; Balaji and Arshinder, 2016

2.3 Knowledge gaps on food safety

Several knowledge gaps emerge from the review of the extant literature relevant to food safety and its supply chains. We highlight the following five gaps as particularly pertinent:

- Studies identifying and analysing the challenges to the FS in emerging economies are scant. Most studies focus on the understanding of production and distribution system, food availability and development of policies at a broad level (Balaji and Arshinder, 2016; Zhang et al., 2018).
- FS practices are quite immature in emerging economies when compared with developed economies (Mangla et al., 2019; Namany et al., 2020). Therefore, another research gap is in identification of constructs for food safety initiatives policy in the

emerging economies to raise public awareness while encouraging greater collaboration and efficiency in food supply chains.

- Far less is understood about the priority amongst the challenges (i.e. most and less desirable) (Turi et al., 2014) and analysing their causal relationships for driving forward successful FS initiatives in an emerging economy context.
- Very limited research findings are available exploring the views of food businesses on the FS initiatives investigating feasible FS challenges and pragmatic prioritisation process.
- Considering the economic, social and rising population challenges faced by the emerging economies, another research gap is to explore how food managers can develop policies to achieve the second Sustainable Development Goal (SDG), which is to secure food for everyone.

This article contributes to the extant literature by addressing these research gaps and identifying the best and worst challenges to the FS initiatives along with causality among them using a combined BWM and DEMATEL approach. To the best of our knowledge, this research is a novel contribution in identifying and analysing feasible challenges to successful FS initiatives within an emerging economy perspective considering numerous operations and processes of the food industry.

3. Research Methodology

This study employs a qualitative case-based research methodology (Eisenhardt, 1989). It uses the data from six food business organisations in India. A case study approach has been adopted in this research as the approach helps in (i) revealing the real-life occurrence of the considered phenomena, and (ii) understanding relevant problematic issues during face-to-face interactions with managers (Yin, 2009; Subramanian et al., 2014). The approach is intended to provide meaningful implications on the challenges to the FS initiatives in India. A construct validity test is performed by examining disparate datasets with respect to each variable (i.e. each challenge) to elucidate the credibility of this case-study approach (Govindan et al., 2017). Figure 1 illustrates the research methodology.

After consultation with industrial experts and a critical review of literature, the challenges (main and sub-challenges) to the FS initiatives are identified. These challenges are subsequently analysed using a combined BWM and DEMATEL decision-making approach through experts' feedback. The BWM and DEMATEL methods are combined as fewer numbers of pair-wise comparisons are required with BWM as compared with other Multiple-

Criteria Decision Making (MCDM) methods, e.g. Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) (Cui et al., 2019; López and Ishizaka, 2019).

DEMATEL's advantage over AHP and Interpretive Structural Modelling (ISM) is that it helps to uncover the interdependencies among the variables by knowing the strength of relations and classifying them into cause and effect groups (Lopez and Ishizaka, 2017). The combined BWM-DEMATEL approach is a systematic method for studying decision making based on the opinions of a group of independent experts. The combined approach offers a scientific means to prioritise and rank the challenges to the FS initiatives and establish the causal relations among and between the challenges by classifying the challenges into cause and effect groups. The following sub-sections explain further details about the proposed method.

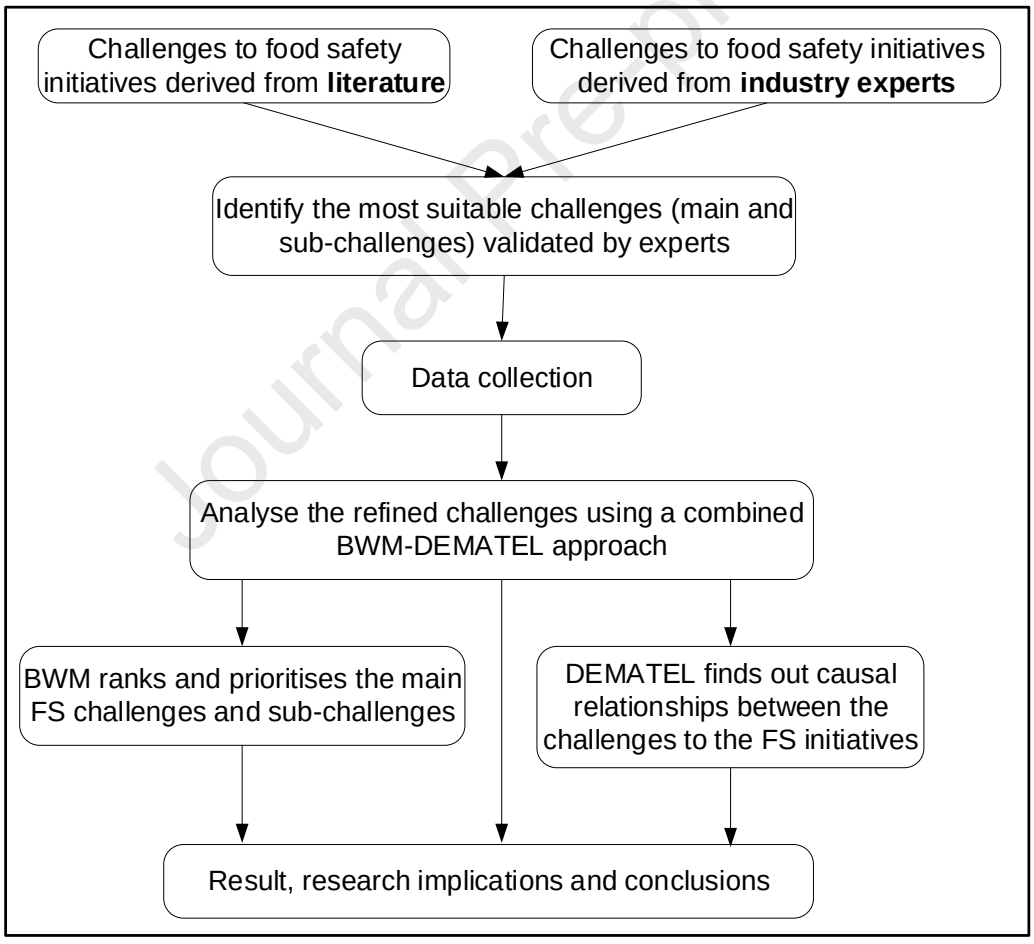


Figure 1: The research methodology

3.1 Best Worst Method (BWM)

Most of the MCDM techniques suffer from a lack of consistency in experts' judgment during pair-wise comparisons (Yadav et al., 2018). The BWM method does not have this inconsistency problem. The method is widely used to analyse different decision-making problems on supply chain management and sustainability (Rezaei, 2015; Ahmadi et al., 2017), supplier selection (Rezaei et al., 2015) and project portfolio selection (Jeng and Huang, 2015) etc. The method uses the following six-step procedure (Rezaei, 2016; van de Kaa et al., 2020):

Step 1: A set of *n* challenges to the FS initiatives {c_1, c_2 …., c_n} are identified from the literature review and experts' opinions.

Step 2: The best (e.g. most important and most desirable) and worst (e.g. less important and less desirable) challenges are identified through experts' opinions. Next, pair-wise comparison between the FS challenges are developed.

Step 3: After selecting the best and worst challenges, the preference of the best challenge to the other challenges is determined using a number between 1 and 9. The best-to-others (BO) vector is: $A_B = (a_{B1}, a_{B2}, ..., a_{Bn})$, where, a_{Bj} is the preference of the best challenge B over criteria j, with $a_{BB} = 1$.

Step 4: Determine the preference of all FS challenges over the worst challenge using a number between 1 and 9. The vector others-to-worst (OW) is $A_W = (a_{1W}, a_{2W} \dots, a_{nW}{}^T)$, where, a_{jW} shows the preference of the FS challenge *j* over the worst criterion, W with $a_{WW} = 1$.

Step 5: Calculate the optimal weights (W_1*, W_2*, W_3*, W_n*) of the FS challenges. Determine the optimal weights such that the maximum absolute differences $|W_B - a_{Bj} W_j|$ and $|W_j - a_{jW} W_W|$ for all *j* are minimised as follows:

$$\text{Min max } \{|W_B - a_{Bj} W_j|, |W_j - a_{jW} W_W|\} \text{ such that}$$

$$\sum_j W_j = 1$$

$$W_j >= 0, \text{ for all j.}$$

To solve this problem, it is converted into the following linear programming problem:

$$\text{Min} \xi^L$$

Such that,

$$|W_B - a_{Bj} W_j| \leq \xi^L, \text{ for all j}$$

$$|W_j - a_{jW} W_W| \leq \xi^L, \text{ for all j}$$

$$\sum_{j} Wj = 1$$

W_j >= 0, for all j.

Solving this linear model, we obtain optimal weights (w 1*, w 2*…, w n*) and the optimal value ξ^L.

Step 6: The next step is to check the consistency level of the comparisons. Consistency of the comparison depends on the value of ξ^L – see Table 2 for the consistency index values. A value closer to 0 indicates higher consistency. All the values below 1 for ξ^L indicate consistent comparisons (Rezaei et al., 2015).

Table 2: Consistency index

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency index (max ξ)	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

3.2 DEMATEL

DEMATEL is a tool for analysis of a structured model (Gabus and Fontela, 1972). The tool is capable of analysing the complex decision problems and defining relationships between the factors using graphical illustrations (Mangla et al., 2016). The 5-step procedure of the DEMATEL method (Gandhi et al., 2016) is as follows:

Step 1: The challenges to the FS initiatives are identified from the literature review and experts' inputs.

Step 2: Compute the direct-relation matrix. Each expert is requested to estimate the strength of relations between any two FS challenges using a scale with values 0, 1, 2 and 3 (i.e. no influence, low influence, high influence and very high influence, respectively) in Matrix **A** (n × n), where each element of x_{ij} denotes the degree to which the criterion *i* affects the criterion *j*, and *n* is the number of factors. For each respondent, an n×n non-negative matrix is established as $A^k = [x^k_{ij}]$ (where k is the number of respondents with $1 \leq k \leq H$,). Thus, X^1, X^2, X^3 . . . , X^H are the matrices from H respondents. To incorporate all opinions from H respondents, the average matrix $A = [a_{ij}]$ is constructed as follows:

$$a_{ij} = \frac{1}{H}\sum_{K=1}^{H} x_{ij}^k. \quad (1)$$

Step 3: Determine the normalised direct-relation matrix (D). The average matrix (**A**) is transformed into a normalised direct relation matrix as in Eq. (2):

$$D=\mathbf{A}\times S, \quad (2)$$

where, $S = \min\left[\frac{1}{\max \sum_{j=1}^{n} |m_{ij}|}, \frac{1}{\max \sum_{i=1}^{n} |m_{ij}|}\right]$. (3)

Step 4: The normalised direct-relation matrix is converted into total relation matrix (**T**) as in Eq. (3):

$$\mathbf{T} = \mathrm{D}(\mathbf{I} - \mathrm{D})^{-1} \quad (4)$$

'**I**' is the identity matrix. After calculating the total relation matrix (**T**), the sum of row and the sum of column of total relation matrix r_i and r_j are calculated. r_i shows the total effects of the FS challenges, both direct and indirect ways as received by i_{th} challenge on other challenge. r_j reveals the total effects both direct and indirect ways as received by j_{th} challenge from other challenge. (r_i+c_j) is known as prominence, which indicates the importance between each challenge. (r_i-c_j) is the relation group which is divided into two groups known as cause and effect groups with respect to positive and negative values of (r_i-c_j).

Step 5: Estimate threshold value for digraph. Estimating the threshold value allows decision makers to screen out some negligible effects from the total relation matrix. The effects greater than the threshold value are selected and plotted in digraph. The threshold value is computed through the average of the elements in matrix **T**. The digraph is obtained by plotting the values of (r+c, r-c).

4. Case Study

Six Indian food business organisations, anonymously labelled as X1 through X6, are identified for a detailed case analysis. The following Table 3 outlines the organisation profiles.

Table 3: Organisation profiles

	Brief description of the organisations
Business organisation #X1	The company was established in 1906. They have annual turnover of US$8.5 billion with 26,000 employees. The organisation produces top quality food for consumption in India and the world. The organisation is dedicated to doing business in a sustainable manner. The organisation is carbon efficient, water efficient and solid waste recycling positive. The company desires to adopt food processing practices in a way to achieve zero wastage in their food production and distribution system.

Business organisation #X2	X2 Ltd. was established as a producer in India in 1961. Their annual turnover is US$1.4 billion. The company is ISO 22,000 certified and well known in the realm of chocolate and dairy products. The number of people engaged in their supply chain is approximately 320,000 including farmers, suppliers and transporters. Currently, the company has eight factories across India. For reducing usage of water, the organisation has adopted a 3R methodology (i.e. reduce, reuse and recycle). The organisation is interested to analyse the challenges to FS to improve their efficiency and prepare for future strategy.
Business organisation #X3	X3 Ltd. was established in 2006. They have about 200,000 employees with an annual turnover of US$0.75 billion. The company is committed to make better India to best India. The organisation manufactures a range of grocery products including diary, confectionary and daily usage products. The organisation currently faces several problematic issues in their supply chain due to low technology innovation and political imbalance. Therefore, the organisation is conscious of the need to examine the challenges to FS with an aim to enhance their production capacity and efficiency without compromising the food quality.
Business organisation #X4	X4 Ltd. is a large producer and supplier of organic foods in India. It exports several organic products like rice, pulses, diary, vegetables, spices and animal feed to 46 countries. The organisation is committed to giving consumers the best quality food products in food sector. Due to its high-quality food, the market value for this organisation has increased in developed countries but it is still not well established in the Indian market because of price sensitive consumers. Therefore, the organisation has taken part in this research with a view to enhancing their production and efficiency for the Indian consumers.

Business organisation #X5	X5 Ltd. was established in 1990. The annual turnover of this organisation is approximately US$ 10 billion. The organisation is involved in flexible packaging technology, mushrooms, fruits and vegetables. The organisation has well established business in developed countries, across Europe, USA, Canada and Australia. The prime objectives of this organisation are to follow environmental, social, economic practices for sustainable business development.
Business organisation #X6	X6 Ltd. was established in 1994. The annual turnover of this organisation is approximately US$ 5 billion. The organisation produces mainly breakfast and dietary product items. 'More production with fewer resources' is the goal of the organisation. However, they are facing some challenges to compete in local and global market. To understand new generation customer and market dynamics in the food sector, this organisation has decided to participate in this research.

4.1 Data Collection

For the purpose of data collection, a total of 14 experts were identified. Among them, 12 are from food industries (two from each organisation) consisting of two assistant general managers, two financial managers, three manufacturing heads, one marketing representative, and two operational level managers having more than ten years of experience. The remaining two are from academia having more than 15 years of experience in teaching and linked to food industries for research and consultancy. All these experts were capable to take decisions in their relevant field. Several group discussion sessions and meetings were arranged with the experts and their responses had been recorded. The collected responses based on the majority of the experts' agreements were considered for analysis in this research. Prior to data collection, the prime objectives of the study, i.e. analysis of challenges that influence directly or indirectly on the FS initiatives in food industries, were explained to the experts. The data is collated and used in two parts of this work as explained below.

4.2 Part I: Most suitable challenges to the FS initiatives

Initially, 24 sub-challenges to the FS initiatives were recognised on the outcome of the literature review. Experts were asked to provide their responses and validate the challenges identification process. Experts were asked to amend, through either addition or deletion of the challenges to the list. After a long discussion with the expert panel, it was decided to amend the initial list. Consequently, one new challenge was added, given as 'unorganised mercantile structure'. In this way, a total of 25 challenges to the FS initiatives were finalised (Table A.2). These 25 challenges were again categorised into 5 main challenges (i.e. organisational related challenges, government and policy related challenges, global related challenges, knowledge related challenges, and financial related challenges) based on their meaning through experts' feedback.

4.3 Part II: Analysing challenges using BWM-DEMATEL

The identified 25 challenges were analysed using the combined BWM-DEMATEL approach. The following sub-sections provide details of the analysis procedure.

4.3.1 Most desirable and least desirable challenges

After selecting the 25 most suitable challenges under the five categories of the challenges (hereinafter referred to as the main challenges), experts were asked to select the most desirable and least desirable challenges. Based on their feedback, government and policy related challenges (GP) represented the most desirable (best) challenge while financial related challenges (F) represented as the least desirable (worst) challenge respectively. Next to this, experts were asked for their preference on best to other and other to worst challenges. In this regard, pair-wise comparisons were formulated as shown in Tables 4a and 4b. Similarly, the other comparisons for the best to other and other to the worst challenges for sub challenges were found (listed in Appendix A).

Table 4a: Pair-wise comparison between best to others (BO)

"Best to others" challenges (BO)	**Organisational related (O)**	**Government and policy related (GP)**	**Global related (G)**	**Knowledge related (K)**	**Financial related (F)**
Best challenge (GP)	2	1	3	5	7

Table 4b: Pair-wise comparison between others to worst (OW) challenges

Others to	**Organisational**	**Government**	**Global**	**Knowledge**	**Financial**

worst challenges (OW)	related (O)	and policy related (GP)	related (G)	related (K)	related (F)
Worst challenge (F)					
O					4
GP					7
G					3
K					2
F					1

After identifying all pair-wise comparisons, the optimal weights and optimal value ξ^{L} for main and sub challenges were computed using Eq. (2). After solving the linear programming problem, the value of optimal weights $w_1^*, w_2^*, w_3^*, w_4^*, w_5^*$ and ξ^{L} for the main challenge and each sub challenge were obtained – see Tables 5 and 6.

Table 5: Optimal weights of the main challenges

Main challenges	Weights	ξ^{L}
O	0.229	0.0513
GP	0.458	
G	0.155	
K	0.092	
F	0.065	

ξ^{L} value 0.0513 indicates a high consistency. It shows the reliability of MCDM problems. According to the weights GP has obtained the first priority with a value of 0.458. Consequently, the ranking of remaining main challenges is: O> G> K> F.

Table 6: Optimal weights, relative weight, and relative rank, global weights and global rank of the sub challenge

Main challenges	Sub challenges	Relative preference weights	Relative ranking	Global preference weights	Global ranking
O	O1	0.391	1	0.0895	2
	O2	0.171	2	0.0391	9
	O3	0.152	3	0.0348	10
	O4	0.110	5	0.0251	14
	O5	0.132	4	0.0302	12
	O6	0.044	6	0.0100	23
GP	GP1	0.287	1	0.1314	1
	GP2	0.191	2	0.0874	3
	GP3	0.062	6	0.0283	13

	GP4	0.117	5	0.0535	7
	GP5	0.179	3	0.0819	4
	GP6	0.164	4	0.0751	5
G	G1	0.160	3	0.0248	16
	G2	0.162	2	0.0251	15
	G3	0.455	1	0.0705	6
	G4	0.135	4	0.0209	17
	G5	0.088	5	0.0136	21
K	K1	0.075	4	0.0069	24
	K2	0.195	2	0.0179	18
	K3	0.170	3	0.0156	20
	K4	0.560	1	0.0515	8
F	F1	0.066	4	0.0042	25
	F2	0.260	2	0.0169	19
	F3	0.506	1	0.0328	11
	F4	0.168	3	0.0109	22

4.3.2 Causal relations using DEMATEL

After determining the most important and less important challenges to the FS initiatives, the most suitable challenges were analysed to identify their causal relationships. Based on the DEMATEL method, the experts were asked to frame the direct relation matrix using a pre-defined scale with values 0, 1, 2 and 3. Next to this, average direct relation matrix was formed by taking average of inputs provided by the experts. The average direct relation matrix for the main challenges to the FS initiatives is illustrated in Table 7.

Table 7: Average direct-relation matrix for the main challenges to the FS initiatives

Main challenges	O	GP	G	K	F
O	0.00	1.00	1.25	1.84	1.90
GP	1.90	0.00	1.30	1.89	1.94
G	1.40	0.87	0.00	0.46	1.00
K	1.00	1.11	0.17	0.00	1.24
F	0.87	1.00	0.85	1.00	0.00

The average direct relation matrix is transformed into normalised direct-relation matrix using Eq. (2) – see Table 8.

Table 8: Normalised direct-relation matrix for the main challenges to the FS initiatives

Main challenges	O	GP	G	K	F
O	0.00	0.14	0.18	0.26	0.27
GP	0.27	0.00	0.18	0.27	0.28
G	0.20	0.12	0.00	0.07	0.14

K	0.14	0.16	0.02	0.00	0.18
F	0.12	0.14	0.12	0.14	0.00

The normalised matrix was transformed into total relation matrix (**T**) by using Eq. (3) (Table 9). The sum of rows and columns in matrix (**T**) was calculated to identify the cause and effect relationship between the challenges. The datasets (r +c) (known as 'prominence') and (r-c) (known as 'relation') of the considered challenges were computed (Table 7). Prominence represents the importance of the challenges. Similarly, relation represents the categorisation of the challenges into the cause and effect groups.

The challenges in categories O, GP and G belong to the cause groups. The challenges in categories K and F belong to the effect group using their respective (r-c) score. By mapping the (r + c) and (r - c) datasets, a causal relationship diagram of the main challenges to the FS initiatives is drawn and represented in Figure 2. Table 9 shows the total relation and direct-indirect influence matrix of the main challenges to FS.

Table 9: Total relation and direct–indirect influence matrix (T) of main challenges to FS

Main challenges	**O**	**GP**	**G**	**K**	**F**	**Sum = r_i**	**r +c**	**r – c**	**Cause/Effect**
O	0.36	*0.43*	*0.42*	*0.59*	*0.65*	2.46	4.64	0.28	Cause
GP	*0.65*	0.36	*0.47*	*0.67*	*0.74*	2.89	4.69	1.09	Cause
G	*0.43*	0.32	0.20	0.34	*0.44*	1.73	3.32	0.14	Cause
K	0.37	0.34	0.21	0.27	*0.45*	1.65	3.91	-0.61	Effect
F	0.37	0.34	0.29	0.39	0.30	1.69	4.27	-0.89	Effect
Sum = c_j	2.18	1.80	1.59	2.26	2.58	**Threshold value=0.41**			

In addition, the threshold value was computed by considering the average of all the elements in the matrix T, which is 0.41. Hsieh et al. (2016) and Liu et al. (2017) have reported that value of θ may be chosen subjectively. In our study, the idea to use mean value of indirect influence matrix was discussed and found to be more suitable to get a decipherable causal digraph. Table 9 shows in italics the values higher than this threshold value. These are used to draw the digraphs (impact relationship map) of the main challenges, as illustrated in Appendix B.

Further, the average, normalised, total relation matrix and causal impact relationship diagram for the sub challenges have also been drawn (see Appendix B).

4.4 Results and discussion of key findings

The BWM analysis prioritises the main FS challenges and sub challenges. The DEMATEL analysis divides the main challenges into 'cause' and 'effect' groups. An analysis of the values of r+c of Table 8 shows that the government and policy related challenges (GP), such as the lack of supportive policies, corruption, etc., critically affect the imperative challenges for the FS initiatives in the food industry. The main challenges with categories O, GP and G belong to the 'cause' group, while the categories K and F come under the 'effect' group (Table 8). The 'cause' group challenges need higher managerial attention in improving the FS initiatives success rate. A focus on the 'cause' group challenges will automatically improve the remaining two 'effect' groups i.e. knowledge and financial related challenges. The BWM analysis in Table 4 ranks the key challenges as: GP (government and policy related) > O (organisational related) > G (global related) > K (knowledge related) > F (financial related).

The DEMATEL analysis places the 'GP' challenge in the 'cause' group. This means that it influences the other challenges in achieving food safety (Table 8). The 'GP' challenge has the highest (r–c) value of 1.09, which implies that GP has very high impact on the entire system but receives comparatively less influence in return due to its relatively low (r+c) score (equal to 4.69). This is indicative of the government playing a key role in effective adoption of the FS initiatives in developing economies like India (Zhang et al., 2018). The government and policy related main challenges contain six sub-challenges, i.e. GP1, GP2, GP3, GP4, GP5 and GP6. The prioritised order of these sub-challenges is found from BWM as: GP1 (0.287) > GP2 (0.191) > GP5 (0.179) > GP6 (0.164) > GP4 (0.117) > GP3 (0.062). The DEMATEL analysis determines that challenges GP1, GP2 and GP5 belong to the 'cause' group while remaining three challenges GP3, GP4 and GP6 fall under the 'effect' group. The analysis suggests that food industry managers should focus on developing supportive legislative frameworks, managing governance issues and improving infrastructure and facilities. The other challenges of this category will help in achieving the goals of the FS initiatives through enhanced food quality, reduced waste and cost benefits.

The organisational related challenges (O) receive the second highest rank (from the BWM analysis) among the five main challenges with a value of 0.229 (Table 4). The DEMATEL analysis indicates that this main challenge belongs to the 'cause' group. The challenge 'O' also obtains the second highest factor in the (r-c) column, with a score of 0.28. This exhibits a rational power to influence other challenges due to its high influential impact index (r) value, which is equal to 2.46 (Table 8). This main challenge has six sub-challenges, i.e. O1, O2, O3,

O4, O5 and O6. Table 5 shows the prioritised order of these six sub-challenges as: O1 (corporate social responsibility) > O2 (lack of skilled manpower and expertise of HR) > O3 (lack of technological advancement and process innovation) > O5 (poor information system network) > O4 (lack of management support and commitment) > O6 (lack of communication and collaboration among organisational members). Among these six challenges, O1, O2 and O4 belong to the 'cause' group while other three, viz. O3, O5 and O6, belong to the 'effect' group.

The above analysis indicates that the food industry managers should follow corporate social responsibilities to achieve business sustainability (Grant Thornton, 2014). The managers should seek to develop workforce skills and increase HR expertise to improve the effectiveness of the FS initiatives, such as process innovation at strategic business levels. Management support and commitment is a crucial factor in adopting the FS initiatives. This factor is important to ensure quality of the food through application of the advanced technologies, e.g. Internet of Things and/or digitalisation (Verdouw et al., 2016), and innovation-led lean and sustainable practices (Bhattacharya and Dey, 2020; Ghobadian et al., 2020).

The global related challenge (G) has obtained the third rank with a value of 0.155 (Table 4). Table 8 shows that the challenge 'G' is placed in the 'cause' group. DEMATEL has ranked this challenge third with a (r-c) score of 0.14. The impact factor (r) of this challenge, which is 1.73, indicates its influence on the overall system in enhancing the success of the FS initiatives. This challenge has five sub-challenges. The BWM analysis ranks these sub-challenges as: G3 (poverty and inequity) > G2 (problems of increased demand for meat and dairy) > G1 (uncertainty of climate change) > G4 (population growth) > G5 (Changing Market Scenario). The challenges G1, G2 and G3 belong to the 'cause' group and remaining challenges G4 and G5 fall under the 'effect' group.

The BWM analysis of Table 4 shows the rank of the knowledge related challenges (K) as fourth with a value of 0.092. Table 8 shows that this challenge belongs to the 'effect' group with a negative value (-0.61) of (r-c). This means that this challenge can be easily influenced by other challenges. This corroborates with the real-life situations where adequacy of awareness and knowledge among various stakeholders, such as consumers, farmers and suppliers, are viewed as significant in establishing successful FS initiatives. This main challenge has four sub-challenges, K1, K2, K3, and K4. Table 5 illustrates their prioritised order as: K4 (lack of consumer awareness and education) > K2 (fear of new food) > K3

(changes in consumption pattern) > K1 (lack of farmer knowledge and interest). The challenges K1 and K4 form the 'cause' group while the challenges K2 and K3 belong to the 'effect' group. It is found that the consumer awareness and understanding is significant in reducing food waste and improving consumption patterns and preferences for food products. Farmer knowledge and interest are critical to accomplishing the objectives of the FS initiatives in a developing country like India (Bustos and Moors, 2018). There is also a shift recognised in the consumption behaviour of consumers in relation to 'Food Xenophobia' (i.e. fear/avoidance of new food).

The BWM analysis of Table 4 ranks the financial related challenges (F) fifth with a value of 0.065. This challenge belongs to the effect group with the least negative value of (r-c), which is -0.89. This means that this challenge will receive the highest impact as compared with the other challenges. In reality, lack of financial resources is a decisive factor for the FS initiatives, which corroborates to this analysis. This challenge has four sub-challenges. These are prioritised in Table 5 as follows: F3 (lack of supply chain investment) > F2 (higher inspection costs) > F4 (unorganised mercantile structure) > F1 (lack of farmer capital). The challenges F1, F3 and F4 form the 'cause' group while the challenge F2 forms the 'effect' group. The need for funds and investment to change improve the food industry is a key factor (Balaji and Arshinder, 2016). For example, to develop the Mega Food Park scheme, the Government of India invested INR 0.5 billion but faced difficulty in paying the remaining balance of nearly INR 1 billion (Grant Thornton, 2014). The lack of farmers' capital and unorganised mercantile structure are also crucial causal challenges in the FS initiatives which have a considerable influence on food production, food waste (Krishnan et al. 2020) and the price structure of the food products. We note that the three financial related 'cause' group factors, viz. F3 (lack of supply chain investment), F4 (unorganised mercantile structure) and F1 (lack of farmer capital) have an impact on the 'effect' group variable F2 (higher inspection costs). This means that the inspection costs will increase when the mercantile structure is unorganised, supply chain investment is poor and capital availability to the farmers is insufficient. However, if the 'cause' group challenges are addressed in the above order, the 'effect' group challenges improve.

To stabilise the higher inspection costs (i.e. the 'effect' group challenge), the results point to the need for policy planners, government bodies and managers of food organisations to work collectively to address this need. This is important for developing dedicated quality laboratories and performing suitable inspection tests at a reasonable cost.

4.5 Research implications

This study can help government and non-government bodies, policy planners, strategic decision makers and managers involved in implementing the FS initiatives. The outcomes of this study have the following implications.

4.5.1 Provision of efficient information network and business intelligence for transparency

With the emergence of global markets, online marketing and consumer demand for healthy and tasty food, the entire process of food marketing has changed. Improved communication among all the intermediaries of the food supply chain is essential. An efficient information communication channel and network is required for sharing the necessary food product related information among the horizontal and vertical members of the supply chain. In addition, improved business intelligence can assist all parts of the food supply chain to make better and more integrated and transparent decisions while facilitating new business opportunities and reducing costs for improving efficiency. Business intelligence solutions help managers to work more flexibly. Thus, we suggest managers adopt modern information technologies and business intelligence techniques, such as electronic seals and RFID, for food traceability and higher safety to improve food safety. We encourage food policymakers to employ GPS techniques to improve transparency and reduce food wastage during transportation.

4.5.2 Role of government regularity structure and frameworks

The role of government is prominent in developing an efficient FS concept within a country. In this regard, a suitable government regulatory structure and framework can help to obtain governmental support and infrastructure development (e.g. for transport and reliable energy), better co-ordination between central and state governments, and a shared commitment to increasing the effectiveness of food industries as well as developing a sustainable eco-system perspective. Government supportive legislative frameworks can help in enabling open market conditions, training and development programs for farmers, encouraging cooperatives, rural property clarification, assistance in risk management, investing in infrastructural development etc. Any safety standards that are developed would have some costs associated with it. Imposing strict standards require higher resources resulting in higher costs. Ultimately, it is consumers who will pay for this cost in terms of taxes and food prices.

Hence, efficient governing mechanisms and regulatory standards need to be deployed to capitalise on economic gains and accomplish sustainability in the food sector.

4.5.3 Role of reduced branding cost of the product

Consumers are sensitive to pricing structures especially in a developing economy context like India. Thus, if an organisation does not have a clear value oriented strategy, it risks losing customer loyalty and satisfaction levels. In this regard, the managers in the food sector should seek to reduce brand costs and stabilise pricing structures of products in meeting the higher demands of safe and secure food. The food industry generally makes huge investments in branding products. Managers should ensure that their branded products are of consistent superior quality and protect customers against fraud for the sake of preserving their reputation.

4.5.4 Provision of funding and allocation of resources and organised payment system

From a managerial perspective, major funding and investment is required to change and upgrade the current scenario in the industry. This is likely to require innovation, adopting new technologies, new processes, new machines and equipment, and new skills and better training throughout the supply chain to enhance FS. Food manufacturers also require adequate funds to invest in their food quality research and development activities to achieve effective adoption of the FS initiatives. In addition, well organised payment and incentive mechanisms are crucial to reduce costs and improve employee efficiency in meeting the objectives of the FS initiatives.

4.5.5 Behavioural change and knowledge of consumers regarding food wastage

One third of edible food is wasted annually due to inefficiencies in supply chain operations. Lack of adequate knowledge and resources make it difficult for the food processing industry to implement lean-focused sustainable process innovations with an objective of producing healthy and sustainable food. Consumers need to change their behaviour to reduce food waste and drive changes. With a cultural change towards reducing food waste there is likely to be more impetus in the food industry which will ensure effective FS initiatives. Therefore, the managers should take measures to enhance consumers' food related knowledge in accomplishing the goals of FS in India. Periodic workforce training and stakeholders' awareness will be appropriate to provide safe food with higher customer satisfactions. To

ensure safe food, benefits could flow from enhancing consumer education and awareness to promote behavioural change in using, storing and donating food.

5. Conclusions

The food industry plays a major role in a nation's economic progress, health and sustainable development. In India, 60% of the population depends on agri-food. Hence, improving the efficiency and sustainability of the food sector will benefit to the population. Food producers find difficulties to adopt efficient FS initiatives due to prevailing food safety challenges.

In this study, we have identified 25 key challenges in five categories considering the extant literature and experts' opinions. These challenges are prioritised and ranked using a novel combined decision-making approach based on BWM and DEMATEL techniques. BWM is used to rank challenges while DEMATEL is used to find the casual interactive relations between and among the food safety challenges. The results elucidate the prioritised order of the main challenges. The government and policy related challenges are ranked first, followed by organisational related challenges, global related challenges, knowledge related challenges and financial related challenges. We find that the organisational related challenges, government and policy related challenges, and global related factors are clustered as the 'cause' group, while the challenges related to knowledge and financial are clustered as the 'effect' group.

The causal analysis indicates that the food industry managers should focus on the 'cause' group challenges as these affect the challenges of the 'effect' group. We have also examined the priority order and the causal relations for each of the sub-challenges providing further insight into the priorities for those involved in implementing the FS initiatives in an emerging economy context.

This study relates to one emerging economy. However, the outcomes of this study have implications for other emerging economies. Future research would benefit from a cross-country study using questionnaire-based survey and structural equation modelling. Our focus here has been on collating opinions from major food production companies. This study can be extended to consider other enterprises participating in the supply chain. For example, it may be pertinent to replicate a similar study in small- and medium-sized enterprises' food supply chains. We are conscious that individuals' opinions on the FS challenges are inherently subjective. Thus, a future study may consider the opinions as widely as possible from different stakeholders and decision makers in the food supply chain. Future studies may also consider sensitivity analyses to identify the variation of one FS challenge over the others.

Another opportunity would be to introduce fuzzy set or grey set theory to consider the subjectivity of the information. Some statistical methods, e.g. design of experiment, may be used to find correlations in the causal relationships. Future research may consider other MCDM approaches depending on the nature of information available.

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Appendix A: BWM Analysis

The pair-wise comparisons for sub challenges are shown in Table A.1.1 and Table A.1.2 for organisation-related challenges, in Table A.2.1 and Table A.2.2 for government and policy related challenges, in Table A.3.1 and Table A.3.2 for global related challenges, in Table A.4.1 and Table A4.2 for knowledge related challenges, and in Table A.5.1 and Table A.5.2 for financial related challenges.

Table A.1.1: Pair-wise comparison between best to others (BO) of Organisational sub challenges

BO	**O1**	**O2**	**O3**	**O4**	**O5**	**O6**
Best challenge (O1)	1	2	4	3	5	7

Table A.1.2: Pair-wise comparison between others to worst (OW) of organisational sub-challenges

OW	**O1**	**O2**	**O3**	**O4**	**O5**	**O6**
Worst challenge (O6)						
O1	7					
O2	3					
O3	2					
O4	4					
O5	5					
O6	1					

Table A.2.1: Pair-wise comparison between best to others (BO) for government and policy related challenges

BO	**GP1**	**GP2**	**GP3**	**GP4**	**GP5**	**GP6**
Best challenge (GP1)	1	2	8	3	5	4

Table A.2.2: Pair-wise comparison between others to worst (OW) for government and policy related challenges

OW	**GP1**	**GP2**	**GP3**	**GP4**	**GP5**	**GP6**

Worst challenge (GP3)	
GP1	8
GP2	5
GP3	1
GP4	4
GP5	3
GP6	2

Table A.3.1: Pair-wise comparison between best to others (BO) for global related challenges

BO	**G1**	**G2**	**G3**	**G4**	**G5**
Best challenge (G3)	4	5	1	3	7

Table A.3.2: Pair-wise comparison between others to worst (OW) for global related challenges

OW	**G1**	**G2**	**G3**	**G4**	**G5**
Worst challenge (G5)					
G1	2				
G2	4				
G3	7				
G4	3				
G5	1				

Table A.4.1: Pair-wise comparison between best to others (BO) for knowledge related challenges

BO	**K1**	**K2**	**K3**	**K4**
Best challenge (K4)	8	3	4	1

Table A.4.2: Pair-wise comparison between others to worst (OW) for knowledge related challenges

OW	**K1**	**K2**	**K3**	**K4**
Worst challenge (K1)				
K1	1			
K2	2			
K3	3			
K4	8			

Table A.5.1: Pair-wise comparison between best to others (BO) for financial related challenges

BO	F1	F2	F3	F4
Best challenge (F3)	7	3	1	2

Table A.5.2: Pair-wise comparison between others to worst (OW) for financial related challenges

OW	F1	F2	F3	F4
Worst challenge (F1)				
F1	1			
F2	5			
F3	7			
F4	3			

Appendix B: DEMATEL Analysis

The causal digraph and relationship diagram for the main challenges are shown in Figure 2a and Figure 2b.

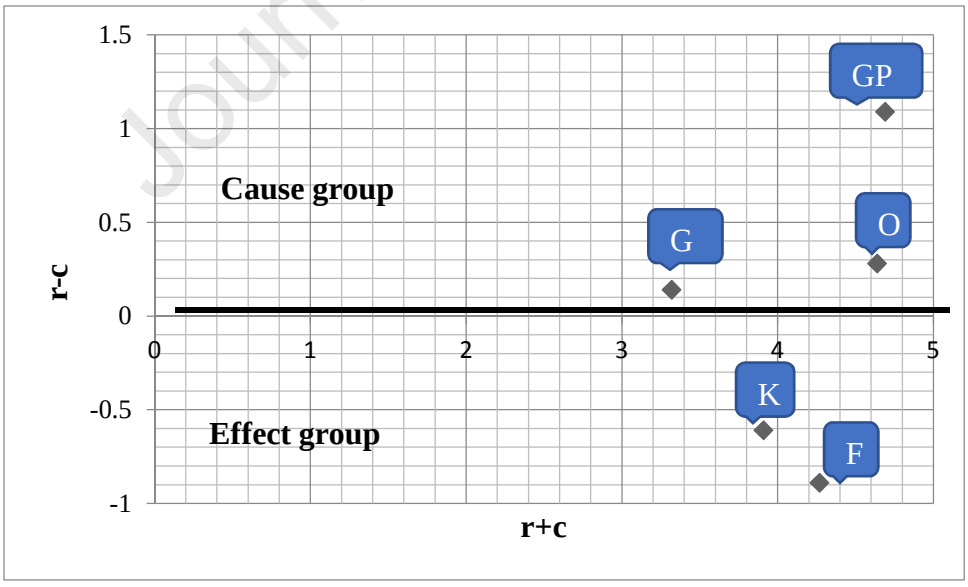

Figure 2a: The causal digraph of the main challenges to the FS initiatives

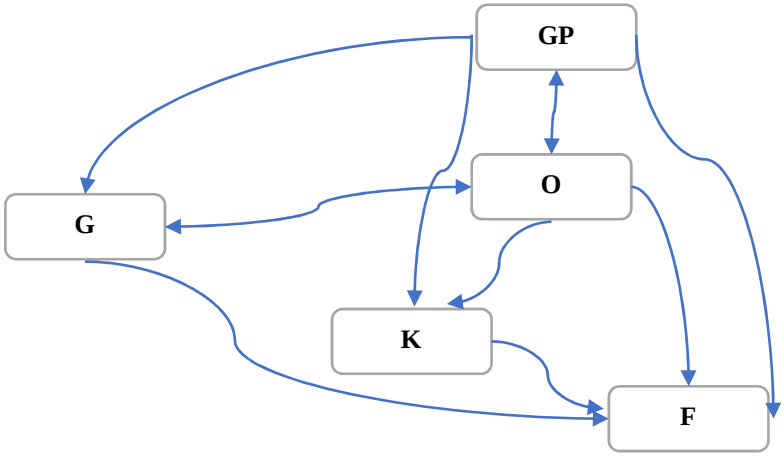

Figure 2b: The relationship diagram of the main challenges to the FS initiatives

Further, the results from the DEMATEL analysis for the sub challenges are shown in Tables B.1 to B.15 and Figures B.1.1 to B.5.2.

Table B.1: Average direct-relation matrix for organisational related challenges to FS

	O1	**O2**	**O3**	**O4**	**O5**	**O6**
O1	0.00	1.00	1.23	1.00	0.89	2.00
O2	0.86	0.00	1.00	1.00	0.78	1.25
O3	0.84	0.56	0.00	0.12	1.00	1.21
O4	2.00	1.23	1.00	0.00	0.46	1.10
O5	0.12	1.00	1.00	1.10	0.00	0.45
O6	0.10	1.00	0.54	1.00	0.87	0.00

Source: DEMATEL analysis.

Table B.2: Normalised direct-relation matrix for sub challenge of O (organisational related challenges)

	O1	**O2**	**O3**	**O4**	**O5**	**O6**
O1	0.00	0.16	0.20	0.16	0.15	0.33
O2	0.14	0.00	0.16	0.16	0.13	0.20
O3	0.14	0.09	0.00	0.02	0.16	0.20
O4	0.33	0.20	0.16	0.00	0.08	0.18
O5	0.02	0.16	0.16	0.18	0.00	0.07
O6	0.02	0.16	0.09	0.16	0.14	0.00

Source: DEMATEL analysis

Table B.3: Total relation and direct–indirect influence matrix (T) of organisational sub challenges

	O1	O2	O3	O4	O5	O6	Sum= r_i	r +c	r-c	Cause/Effect
O1	0.39	*0.64*	*0.65*	*0.58*	*0.56*	*0.86*	3.67	6.14	1.20	Cause
O2	0.46	0.41	*0.54*	*0.51*	0.47	*0.67*	3.08	6.11	0.05	Cause
O3	0.35	0.39	0.30	0.31	0.41	*0.54*	2.31	5.28	-0.66	Effect
O4	*0.68*	*0.67*	*0.64*	0.45	*0.51*	*0.78*	3.73	6.45	1.01	Cause
O5	0.30	0.46	0.46	0.44	0.28	0.46	2.39	5.00	-0.22	Effect
O6	0.28	0.45	0.38	0.42	0.39	0.36	2.29	5.97	-1.39	Effect
Sum = c_j	2.47	3.03	2.97	2.72	2.61	3.68	Threshold value=0.48			

Source: DEMATEL analysis.

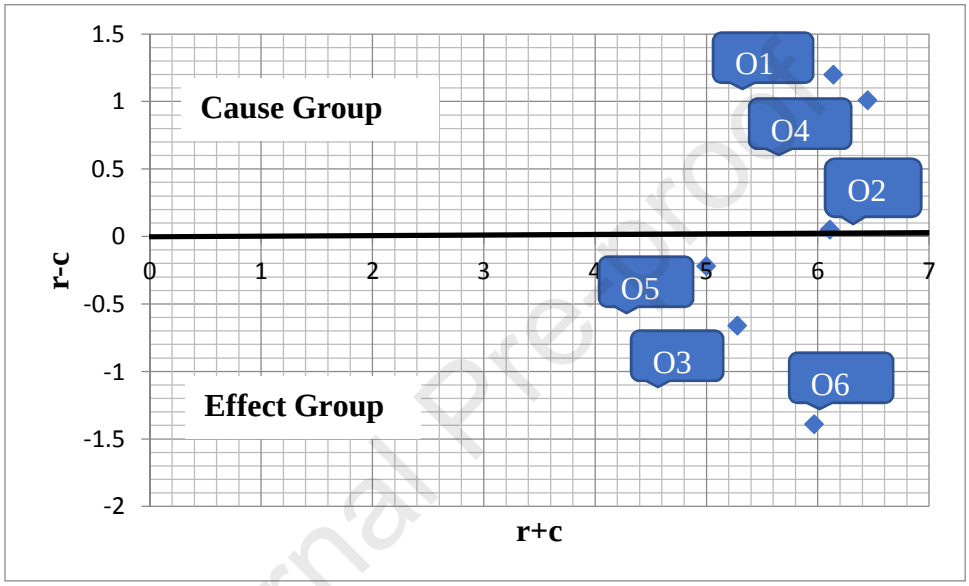

Fig B.1.1: The causal digraph of (organisational sub-challenges)

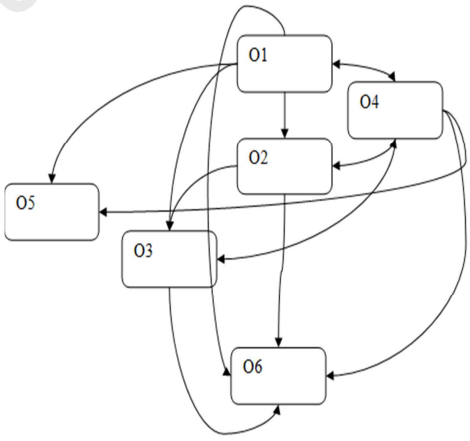

Fig B.1.2: The relationship diagram of (organisational sub-challenges)

Source: DEMATEL analysis

Table B.4: Average direct-relation matrix for government and policy related challenges to FS

	GP1	GP2	GP3	GP4	GP5	GP6
GP1	0.00	1.56	2.89	2.00	1.75	1.75

GP2	1.00	0.00	1.56	2.48	1.56	1.12
GP3	0.26	0.35	0.00	1.00	0.78	1.00
GP4	1.56	1.89	1.00	0.00	1.54	1.02
GP5	1.00	1.12	1.25	1.00	0.00	1.56
GP6	1.23	1.00	0.23	1.00	0.15	0.00

Source: DEMATEL analysis.

Table B.5: Normalised direct-relation matrix for sub-challenge of GP (government and policy related challenges)

	GP1	**GP2**	**GP3**	**GP4**	**GP5**	**GP6**
GP1	0.00	0.16	0.29	0.20	0.18	0.18
GP2	0.10	0.00	0.16	0.25	0.16	0.11
GP3	0.03	0.04	0.00	0.10	0.08	0.10
GP4	0.16	0.19	0.10	0.00	0.15	0.10
GP5	0.10	0.11	0.13	0.10	0.00	0.16
GP6	0.12	0.10	0.02	0.10	0.02	0.00

Source: DEMATEL analysis.

Table B.6: Total relation and direct–indirect influence matrix (T) of government and policy sub-challenges

	GP1	**GP2**	**GP3**	**GP4**	**GP5**	**GP6**	**Sum= r_i**	**r +c**	**r-c**	**Cause/Effect**
GP1	0.22	*0.39*	*0.52*	*0.48*	*0.40*	*0.42*	2.42	3.80	1.04	Cause
GP2	*0.28*	0.22	*0.37*	*0.46*	*0.35*	*0.32*	2.00	3.58	0.42	Cause
GP3	0.11	0.13	0.10	0.20	0.16	0.19	0.90	2.67	-0.87	Effect
GP4	*0.31*	*0.37*	*0.32*	0.25	*0.34*	*0.31*	1.91	3.83	-0.01	Effect
GP5	0.23	0.26	*0.29*	*0.29*	0.15	*0.31*	1.54	3.07	0.01	Cause
GP6	0.22	0.21	0.16	0.24	0.14	0.13	1.10	2.78	-0.58	Effect
Sum = c_j	1.38	1.58	1.77	1.92	1.53	1.68	Threshold value=0.27			

Source: DEMATEL analysis.

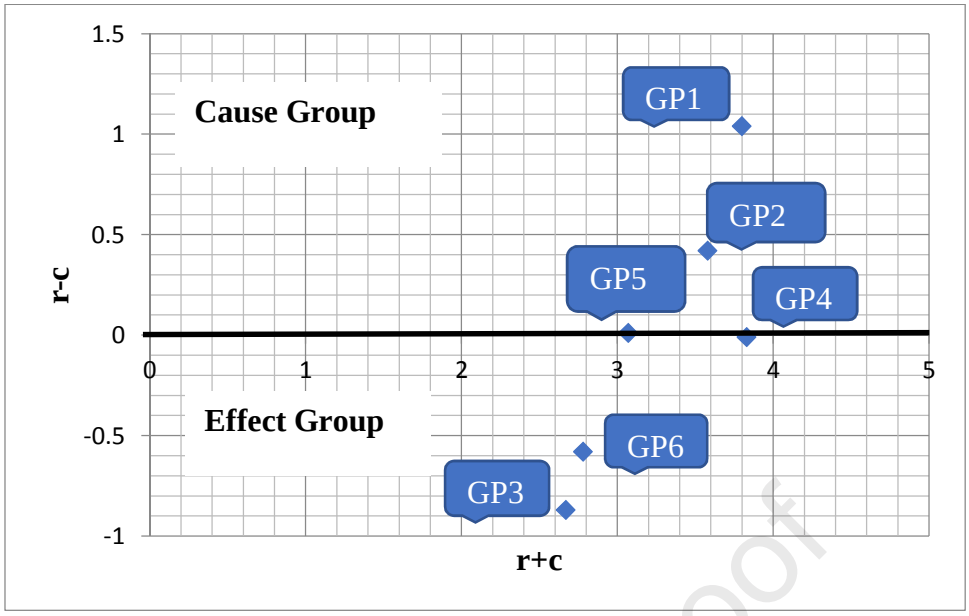

Fig B.2.1: The causal digraph of (government and policy sub challenges)

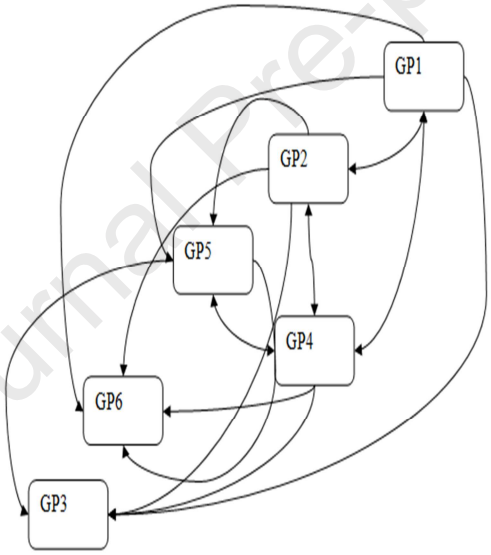

Fig B.2.2: The relationship diagram of (government and policy sub challenges)

Source: DEMATEL analysis

Table B.7: Average direct-relation matrix for global related challenges to FS

	G1	G2	G3	G4	G5
G1	0.00	1.00	1.26	1.00	2.00
G2	1.26	0.00	1.00	1.35	2.00
G3	1.00	1.27	0.00	1.98	1.56
G4	1.00	1.58	1.12	0.00	0.25
G5	0.58	1.45	1.00	0.50	0.00

Source: DEMATEL analysis.

Table B.8: Normalised direct-relation matrix for sub-challenge of G (global related challenges)

	G1	G2	G3	G4	G5
G1	0.00	0.17	0.22	0.17	0.34
G2	0.22	0.00	0.17	0.23	0.34
G3	0.17	0.22	0.00	0.34	0.27
G4	0.17	0.27	0.19	0.00	0.04
G5	0.10	0.25	0.17	0.09	0.00

Source: DEMATEL analysis.

Table B.9: Total relation and direct–indirect influence matrix (T) of global sub challenges

	G1	G2	G3	G4	G5	Sum= r_i	r +c	r-c	Cause/Effect
G1	0.69	*1.08*	*0.96*	*0.97*	*1.25*	4.95	8.80	1.10	Cause
G2	0.91	*0.98*	*0.96*	*1.05*	*1.30*	5.20	10.33	0.07	Cause
G3	0.91	*1.19*	0.85	*1.17*	1.27	5.39	9.69	1.09	Cause
G4	0.74	*0.99*	0.81	0.71	0.89	4.14	8.76	-0.48	Effect
G5	0.61	*0.89*	0.72	0.71	0.74	3.68	9.13	-1.77	Effect
Sum = c_j	3.85	5.13	4.30	4.62	5.45	Threshold value=0.93			

Source: DEMATEL analysis.

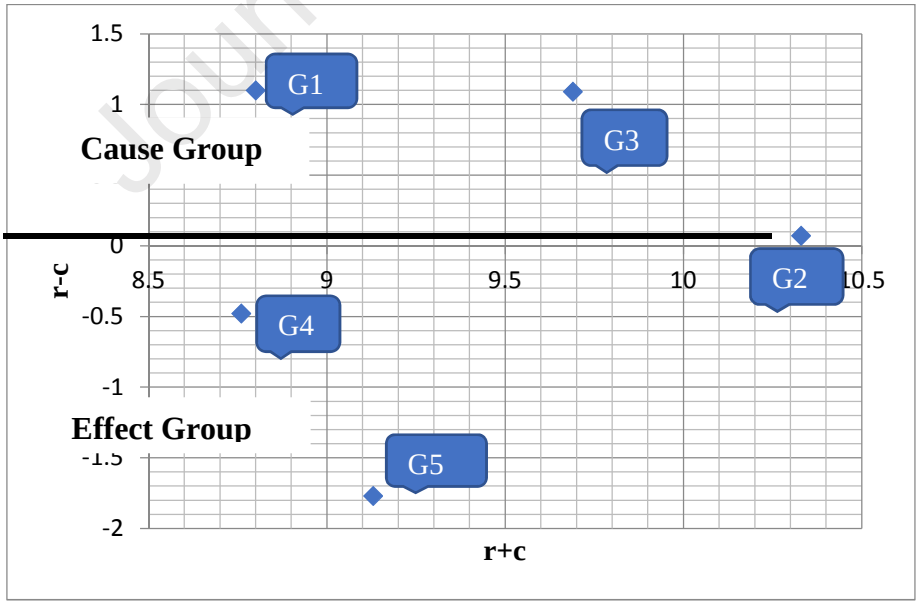

Fig B.3.1: The causal digraph of (global sub challenges)

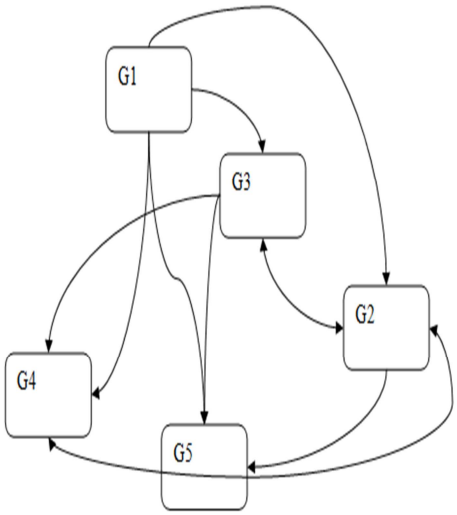

Fig B.3.2: The relationship diagram of (global sub challenges).

Source: DEMATEL analysis

Table B.10: Average direct-relation matrix for sub-challenge of K (Knowledge related challenges)

	K1	**K2**	**K3**	**K4**
K1	0.00	1.00	1.97	1.50
K2	1.00	0.00	1.98	1.57
K3	0.87	1.99	0.00	1.00
K4	2.00	1.95	1.59	0.00

Source: DEMATEL analysis.

Table B.11: Normalised direct-relation matrix for sub-challenge of K (Knowledge related challenges)

	K1	**K2**	**K3**	**K4**
K1	0.00	0.18	0.36	0.27
K2	0.18	0.00	0.36	0.28
K3	0.16	0.36	0.00	0.18
K4	0.36	0.35	0.29	0.00

Source: DEMATEL analysis.

Table B.12: Total relation and direct–indirect influence matrix (T) of knowledge sub-challenges

	K1	**K2**	**K3**	**K4**	**Sum r_i**	**r + c**	**r – c**	**Cause/Effect**
K1	0.84	*1.22*	*1.41*	1.10	4.57	8.56	0.78	Cause
K2	1.01	1.09	*1.43*	1.12	4.64	9.70	-0.42	Effect
K3	0.88	*1.22*	1.02	0.95	4.06	9.50	-0.38	Effect
K4	*1.27*	*1.53*	*1.59*	1.06	5.45	9.68	1.22	Cause
Sum c_j	3.99	5.06	5.44	4.23	Threshold value=1.17			

Source: DEMATEL analysis.

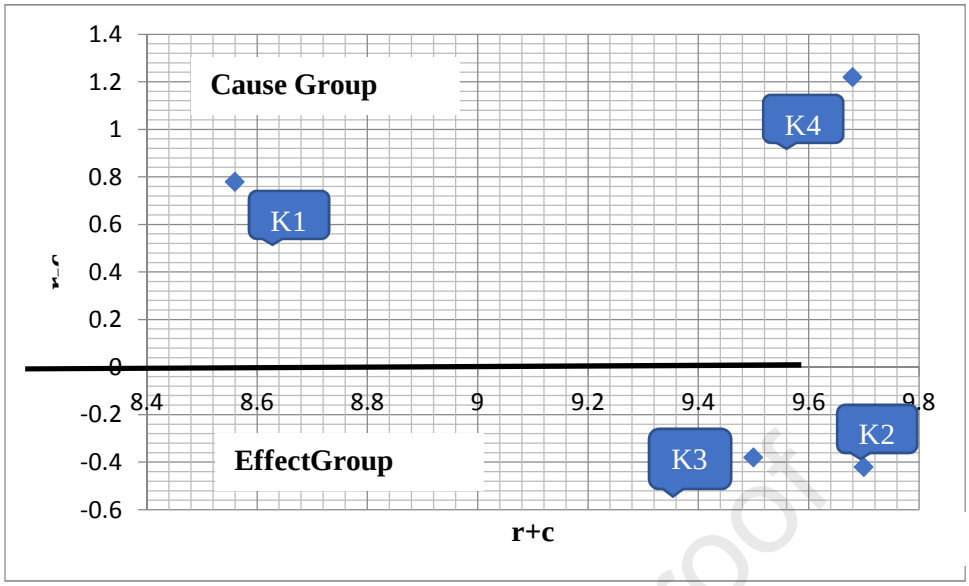

Fig B.4.1: The causal digraph of (knowledge sub challenges)

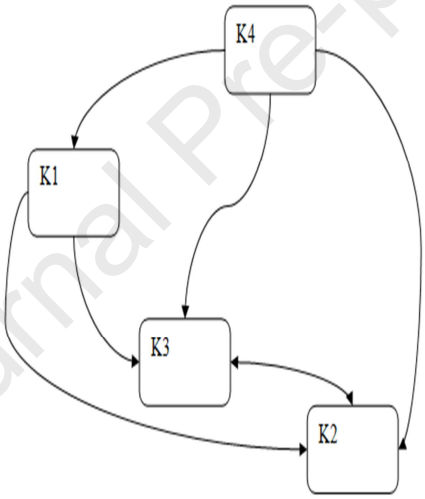

Fig B.4.2: The causal digraph and relationship diagram of (knowledge sub challenges).

Source: DEMATEL analysis

Table B.13: Average direct-relation matrix for sub-challenge of F (financial related challenges)

	F1	F2	F3	F4
F1	0.00	1.00	1.23	0.11
F2	0.10	0.00	0.54	1.00
F3	1.56	1.87	0.00	1.00
F4	0.45	1.00	1.25	0.00

Source: DEMATEL analysis**.**

Table B.14: Normalised direct-relation matrix for sub-challenge of F (financial related challenges)

	F1	F2	F3	F4
F1	0.00	0.23	0.28	0.02
F2	0.02	0.00	0.12	0.23
F3	0.35	0.42	0.00	0.23
F4	0.10	0.23	0.28	0.00

Source: DEMATEL analysis**.**

Table B.15: Total relation and direct–indirect influence matrix (T) of financial sub-challenges

	F1	F2	F3	F4	Sum r_i	r + c	r – c	Cause/Effect
F_1	0.20	*0.53*	*0.47*	0.26	1.46	2.72	0.20	Cause
F_2	0.17	0.24	0.30	0.35	1.06	3.24	-1.12	Effect
F_3	*0.57*	*0.84*	*0.41*	*0.52*	2.34	4.03	0.65	Cause
F_4	0.32	*0.57*	*0.51*	0.25	1.66	3.04	0.28	Cause
Sum c_j	1.26	2.18	1.69	1.38	Threshold value=0.40			

Source: DEMATEL analysis.

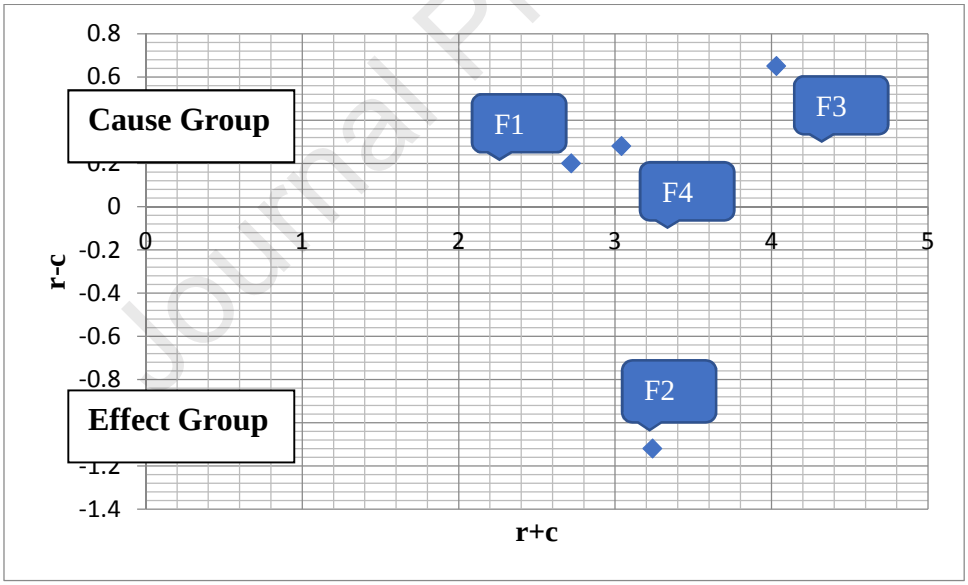

Fig B.5.1: The causal digraph of (financial sub-challenges)

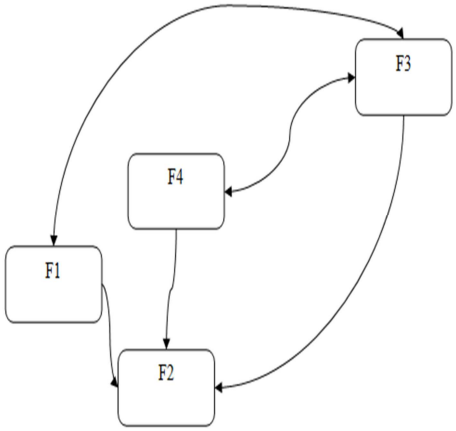

Fig B.5.2: The relationship diagram of (financial sub-challenges)
Source: DEMATEL analysis.

Highlights

- To meet demand for safe and secure food, food industries face several challenges.
- The research identified 25 challenges relating to food safety.
- BWM is applied to prioritise the challenges
- DEMATEL evaluates the challenges through causal and impact relationship maps.
- This work assists business managers in meeting the goals of sustainable and healthy food.

There is no conflict of interest for the below paper –

Abstract: Emerging economies, e.g. India, China and Brazil etc., face challenges to adopt food safety (FS) practices in their food supply chains. Considering food industry's operations and processes, this study identifies 25 challenges to the FS initiatives involving the opinions of practitioners from six major Indian food producers and academic experts. The challenges are grouped into five categories, viz. organisational, government and policy, global, knowledge and financial. We identify the best and worst challenges to the FS initiatives along with causality among them using combined Best Worst Method (BWM) and 'Decision Making Trial and Evaluation Laboratory' (DEMATEL) approaches. BWM prioritises these challenges, while DEMATEL identifies causal relationship maps for the prioritised challenges. The BWM results demonstrate that the government and policy related challenges are the key challenges followed by the organisational, global, knowledge and financial related challenges. The DEMATEL results exhibit the organisational, government and policy, and global related challenges as the cause group challenges. The knowledge and financial related challenges represent the effect group challenges. Mitigation of these challenges inherently necessitates stakeholders' involvement in the food supply chains. We identify constructs for food safety initiatives policy in the emerging economies to raise public awareness while encouraging greater collaboration and efficiency in food supply chains to help achieve the second Sustainable Development Goal (SDG) for securing food for everyone. The results of the study offer guidance and deeper insights to supply chain managers about synergy requirements between the government policymakers and key players of the industry in the emerging economies.

Keywords: Food safety; Supply chain management; Best Worst Method; DEMATEL; Emerging economy; Sustainability.