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Driving circular economy: Key enablers for a sustainable meat supply chain in India

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ABSTRACT

In the current era, the meat supply chain plays a vital role in the food industry. The meat supply chain is experiencing significant challenges due to the increase in demand and Circular Economy (CE) challenges. In the meat supply chain, a huge waste is generated during the meat processing, and it is much needed to manage waste effectively, considering the large quantities of by-products, packaging, and residues generated. The current research focuses on identifying and examining the factors that enable a shift towards a CE for sustainable meat supply chain. The study uses IMF-SWARA and Triangular Fuzzy Bonferroni Mean (TFBM) methods to identify the key enablers and validated through industry and academic experts. Findings indicate that reverse logistics, followed by the principles of reducing, reusing, and recycling (3Rs), and strong leadership commitment, are crucial enablers for adopting a CE in the Indian meat supply chain. This research offers policies and strategies to the managers and practitioners to adopt a sustainable meat supply chain for CE.

1. Introduction

In recent years, the Circular Economy (CE) has gained unprecedented momentum for food organizations to re-evaluate their practices and adopt more responsible approaches in food supply chain. The meat (beef, chicken, lamb, pork) industry, which plays a pivotal role in the global food system [1]. As the demand for meat products continues to rise, the need for sustainable circular practices is became important. The conventional linear model that characterizes the current meat supply chain is marked by inefficiencies, wastefulness, and a heavy reliance on finite resources.

The concept of a CE revolves around the idea of regenerating resources, minimizing waste, and fostering a closed-loop system where materials are continuously recycled [2]. It stands in stark contrast to the linear take-make-dispose model, which is not only environmentally detrimental but also economically unsustainable in the long run. Numerous scholarly investigations have examined various facets of sustainability and waste management in the wider framework of Indian agrifood systems. Nonetheless, consideration needs to be given to the unique dynamics and difficulties present in the meat supply chain, such as problems with waste production, resource use, and environmental effects. Prior research on the implementation of CE principles in different sectors or areas could offer significant perspectives; however, applying these findings directly to the meat supply chain in India could ignore subtleties and context-specific aspects.

As a result, there exists a significant study gap concerning the comprehensive identification and prioritization of the CE enablers within the Indian meat supply chain. Reducing this disparity will contribute to the advancement of theoretical understanding and provide valuable insights for scholars, industry participants, and policymakers seeking to promote sustainability and resilience in this significant field. To address these gaps, research questions are formulated as follows:

RQ.1: What are the enablers for CE in the Indian Meat Supply chain?

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RQ.2: Which enabler is the most significant for CE in the meat supply chain?

To form steps to answer the above-mentioned questions, objectives are formulated as follows:

RO.1: To identify the enablers for CE in Indian Meat Supply Chain.
RO.2: To prioritize the identified enablers with the help of the IMF-SWARA technique.

The paper from now on delves into various sections, and its structure is as follows: Section 2 explain the Systematic literature review, Section 3 explains the research methodology including a flow chart, Section 4 provides for the preparation process, Section 5 explains the related techniques and their results, Section 6 provides for discussion and implications and lastly, Section 7 shows the conclusion and gives future scope for the study.

2. Systematic literature review

There has been an increasing trend of CE implementation in the meat supply chain all over the world. These studies are included in popular and entrusted databases such as Scopus and Web of Science. In order to find out the relevant literature, systematic research is carried out with the help of the following keywords in Scopus: TITLE-ABS-KEY ("CIRCULAR ECONOMY" OR "SUSTAINABILITY" AND "MEAT SUPPLY CHAIN"). In order to be in line with the latest literature updates, authors limited the research period from 2010 to 2024. Thirty research articles were selected as a major source of the literature.

2.1. Circular economy

In this context, embracing a CE presents a compelling alternative that not only addresses environmental concerns but also contributes to economic and social sustainability. CE refers to reusing, repairing, refurbishing, and recycling present materials and items to convert wastes into resources [3,4]. CE has been popular worldwide as a sustainable framework for resource management and economic growth; little is known about how it might be used in industries and geographical areas. One of the primary issues plaguing the Indian meat supply chain is its significant environmental footprint. From deforestation for livestock grazing to the immense water consumption associated with meat production, the sector is intrinsically linked to various environmental challenges [5].

2.2. Food waste

According to Gustavsson et al. [6], the food waste is defined by the Food and Agriculture Organization (FAO) as losses that occur in the upstream stages of the food supply chain (that is, through industrial processes for transformation from agricultural output), while food waste is represented by food that is discarded during the consumption and retail stages. Food wates are usually handled by farmers and agri-food businesses in the early stages of the supply chain [7]. For SDG 12.3 to be achieved, their involvement in recognizing, evaluating, and minimizing food waste is essential. The numerous parties involved in the food supply chain must work together in harmony and have the appropriate tools to support decision-making and the implementation of strategies that integrate the CE pillars from a supply chain viewpoint is essential.

According to a progress report provided by Champions 12.3 [8], while over 25 % of the world's 50 largest food firms started measuring the amount of food waste produced during their industrial processes in 2017, only 20 % of these businesses established and implemented initiatives aimed at decreasing food waste [9]. This perspective holds that the CE can assist food companies and others in achieving SDGs other than SDG 12.1—such as those related to climate action or life on land. In the most recent CEAP edition [10], the European Commission underlined the importance of food waste reduction and listed it as a key component of the CE package [11].

2.3. Circular economy and meat loss

The highest rates of meat and meat product waste and per capita consumption are seen in industrialized nations. This waste at the consumption level accounts for around half of all meat loss and waste [12]. However, producing meat uses a lot more energy than creating meals based on plants because farms require a lot of diesel fuel and other utilities derived from fossil fuels to maintain and feed cattle as well as to grow and harvest animal feed crops. If meat and animal products are lost in the process of obtaining and preparing them, then these fuels and fertilizers are also wasted. Avoiding meat would significantly reduce linked greenhouse gas emissions in the food chain [13,14]. As such, it is important to consider the type as well as the quantity of food wasted.

Food waste has a range of detrimental externalities on the environment, society, and economy. Specifically, animal husbandry is the most carbon-intensive and resource-intensive activity. Based on the emission intensity factor, the industry produces 2.58 kg CO_{2eq}/$, which is more than the direct production of all other human foods [13,15]. Because of this, it has more negative consequences on the ecosystem, polluting streams and landscapes, and accelerating climate change [16]. Since meat contributes relatively little to food waste, reducing waste and meat loss should be given at least as much consideration as other commodities due to its high production cost and energy intensity [17,18]. Though it makes up just 7 % of waste overall [19], meat waste generates the most CO_2 emissions relative to waste from fruits and vegetables.

Meat may deteriorate rapidly if it is not handled, stored, or distributed correctly as well as if it is not processed correctly. The meat inefficiencies have cost the economy trillions of dollars; the losses rise when social and environmental consequences are included. Zhang et al. [20]; Němec et al. [21]; Guo [22] various scholars have investigated the challenges and enabling strategies for the implementation of the meat supply chain for sustainable operations and distribution. Indian meat industry is significantly facing many challenges. India's meat supply chain differs significantly due to its fragmented and largely informal structure, where small-scale slaughtering, processing, and retail dominate [1]. Consumers are growing more aware of the origin and quality of meat. Thus, transparency in the meat supply chain is necessary to guarantee the quality, safety, and trust of consumers in meat products [23]. Furthermore, implementing the circular economy is one strategy to deal with the problem of meat waste in the food supply chain.

3. Methodology

A two-phase methodology is used to conduct the research. In the first stage, the two primary keywords "meat supply chain" and "circular economy" were selected to explore the relevant research studies. This process led to a list of 30 papers out of 45 papers; these were finally chosen for the study.

After finalization of the enablers for the research articles, the questionnaire was developed and administered for the pilot survey, and as advised by experts in the supply chain discipline, three factors were removed out of 10, and the remaining 7 factors led to the final questionnaire framing. The last step consisted of two phases: phase 1-preparation process and phase 2- calculation of weight values of criteria which will be explained in the following sections. The flow diagram is presented in Fig. 1.

3.1. Preparation process

The research problem was identified after a comprehensive analysis of the research papers related to meat supply chain and CE. From the

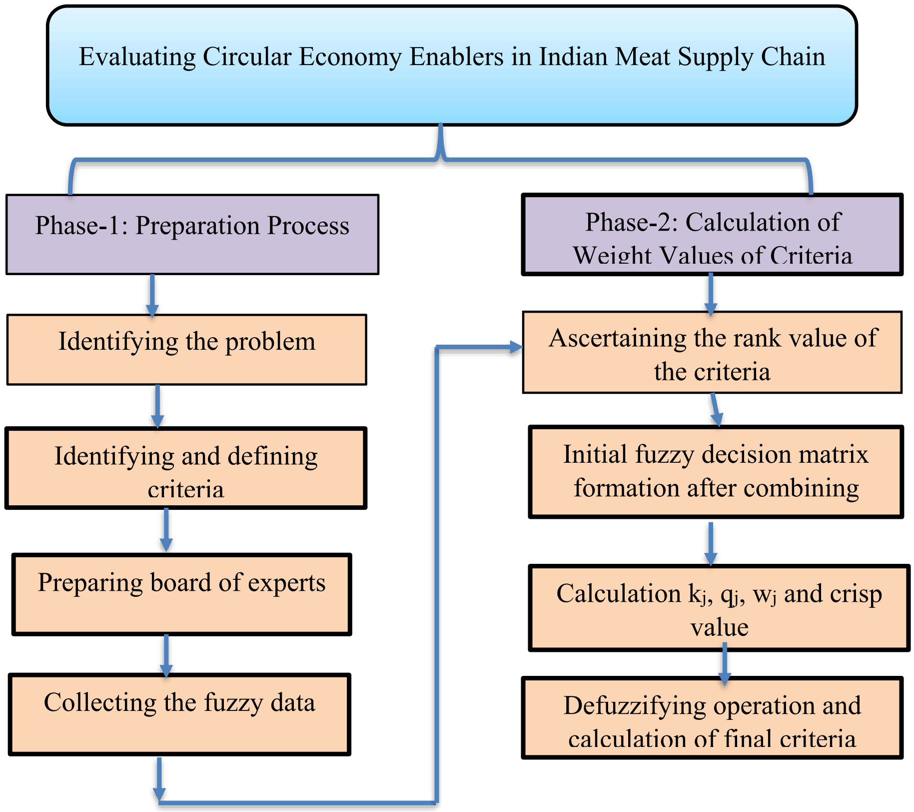

Fig. 1. Flow diagram for Application of IMF SWARA Technique.

literature, it was found that the Indian meat supply chain and CE remain significantly underexplored. Therefore, identifying and ranking CE enablers for meat supply chain would help future researchers save time in prioritizing these enablers and work on the actual implementation of these enablers. After various meetings with a team of experts, the CE enablers were identified which were finally used for the collection of the fuzzy data.

The board consists of a wide range of qualified professionals, from graduate to doctorate level, with experience ranging from 1 to 20 years. Being a part of either the meat supply chain industry or research experience in this domain was a primary condition for selecting the board of experts for this participatory role. The secondary condition was that they must have a determinative role in their respective industries, hence their input was considered suitable to contribute to this body of knowledge. According to the conditions mentioned, the experts are given below in Table 1.

They were initially given free-form questions to complete and instructed to develop a list of options and selection standards required for a CE enablers selection evaluation process. After these lists were compiled, duplicate criteria were removed, and the last set of options and the selection standards were obtained. The CE enablers and their description are presented in Table 2.

Table 1
Expert team and their details.

D.M.	Professional Qualification	Position	Work Experience
DM-1	Graduate	Executive	Less than 5 years
DM-2	Postgraduate	Middle Management	5–10 years
DM-3	Postgraduate	Middle Management	5–10 years
DM-4	Postgraduate	Middle Management	5–10 years
DM-5	Graduate	Executive	16–20 years
DM-6	Doctorate	Middle Management	5–10 years
DM-7	Graduate	Executive	Less than 5 years
DM-8	Doctorate	Middle Management	16–20 years

3.2. *Calculation of weight values of criteria*

In the current business environment, it is crucial to provide best analytical techniques for data collection and analysis. The AHP (Analytic Hierarchy Process) technique faced a lot of criticism due to the large number of pairwise comparisons and calculations it requires. These problems complicate and limit the technique's applicability. Moreover, it requires the use of an additional technique to determine consistency. Similarly, the results of the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) approach are likewise unreliable due to the rank reversal issue. Now the authors will provide reasoning for not using the original Fuzzy SWARA method [35]. Vrtagić et al. [36] did a comparative analysis of both fuzzy SWARA method as well as IMF SWARA technique and found that it is not possible to gain results if two criteria have equal fuzzy weights whereas by applying IMF SWARA, those criteria can have equal values. Additionally, as the number of criteria in the model rises, the least significant criteria acquire values that may be negligible or tend toward zero. When using the improved fuzzy SWARA technique, less important criteria can have larger values and a greater voice in the decision-making process. IMF SWARA in comparison with FUCOM, LBWA, and BWM is more convenient approach that offers greater transparency and better suitability for complex problems.

3.2.1. *Improved fuzzy stepwise weight assessment ratio analysis (IMF SWARA) technique*

To prioritize the enablers of CE, the Improved Fuzzy Stepwise Weight Assessment Ratio Analysis (IMF SWARA) Technique was used. The SWARA technique is an MCDM method that Kersuliene et al. [37] provided for figuring out the weights of the selection criteria. Unlike the conventional MCDM approach, the SWARA strategy, according to

Table 2
CE enablers with their description and literature source.

S. No.	CE Enablers	Description	References
CEE1	Top management commitment	As stewards of strategic vision, top management may play a pivotal role in enabling the transition to a CE. They establish organizational commitment, aligning policies, and resources towards circularity goals.	[24] [25]
CEE2.	Digital Technologies (RFID, Blockchain and Cyber Physical Systems)	RFID enables accurate tracking of materials through the supply chain, optimizing resource allocation and reducing waste; Blockchain may enable seamless tracking of resources, materials, and products, facilitating efficient recycling, reuse, and remanufacturing processes; Cyber-physical systems (CPS) can be instrumental in catalysing the CE by integrating digital technologies with physical processes.	[26] [27] [28] [29]
CEE3.	Supply Chain Collaboration	Collaborative efforts may streamline material flows, facilitating the recovery and reuse of resources across multiple stages of production and consumption.	[30]
CEE4.	Reverse logistics	It encompasses activities such as product returns, recycling, refurbishment, remanufacturing, and, thus increasing the lifespan of goods and minimizing waste.	[31]
CEE5.	3Rs (Reduce, Reuse and Recycle)	"Reduce" involves minimizing resource consumption and waste generation through efficient production and consumption practices. "Reuse" emphasizes extending the lifespan of products and materials by encouraging refurbishment, repair, and sharing economies. "Recycle" promotes the recovery and reprocessing of materials to create new products, closing the loop of resource utilization.	[32]
CEE6.	Globally harmonized standards	These standards may streamline regulations, facilitating consistency in product design, recycling processes, and waste management protocols.	ICC [33]
CEE7.	Capacity Building	Through training programs, workshops, and educational initiatives, capacity building may foster awareness and understanding of circular principles.	[34]

Table 3
Triangular Fuzzy Number (TFN) scale and IMF SWARA linguistic variable.

Linguistic Variable	Abbreviation	TFN Scale		
Absolutely less significant	ALS	1.000	1.000	1.000
Dominantly less significant	DLS	0.500	0.667	1.000
Much less significant	MLS	0.400	0.500	0.667
Really less significant	RLS	0.333	0.400	0.500
Less significant	LS	0.286	0.333	0.400
Moderately less significant	MDLS	0.250	0.286	0.333
Weakly less significant	WLS	0.222	0.250	0.286
Equally significant	ES	0.000	0.000	0.000

Mardani et al. [38], aims to forecast decision-makers' preferences and uses these estimations to evaluate the process. By following these procedures, decision-makers can easily execute the SWARA technique's algorithm to determine the criteria's weights [39]. Assessed and Prioritized Construction Contracting Risks with an Extended FMEA Decision-Making Model in Uncertain Environments [40]. discussed Sustainable Supplier Selection Based on a Comparative Decision-Making Approach Under Uncertainty [41]. discussed that the Sustainability service chain capabilities in the oil and gas industry using Fuzzy hybrid approach SWARA-MABAC. Additionally, to address the ambiguities that arise during the evaluation process, the fuzzy SWARA approach (F SWARA) [35] was developed as a subjective evaluation method based on fuzzy sets. Its use as a mathematical tool has helped people make more rational and logical decisions [42–44]. However, Vrtagić et al. [36] noted that the linguistic scale used to compare criteria pairwise [35] is inadequate, and they proposed improving the technique, using a new scale (Vrtagić et al., 2021). They introduced a brand-new method to achieve this goal, known as the improved fuzzy stepwise weight assessment ratio analysis (IMF SWARA).

3.2.2. Basic steps of (IMF SWARA)

The authors claim that computations will not produce identical weights for these criteria if decision-makers conduct a linguistic evaluation in which they see the jth criterion as being equally relevant as the jth-1 criterion. Based on these, the IMF SWARA method's basic assumptions determine that TFN is (1,1,1). Nevertheless, if the linguistic scale recommended by the IMF SWARA technique is used, the TFN can be found as (0,0,0); as a result, it is feasible to have the final weights of these criteria equal to one another [36]. Evaluating the effects of the criteria weights on the ranking of the decision alternatives requires presenting a realistic and consistent evaluation tool that reflects the subjective evaluations performed by DMs [45]. [36] In order to accomplish this, the IMF SWARA technique is used, as it enables to establish the weights of the criteria and the steps necessary to use the technique [36].

3.2.2.1. Step 1. Determine the criteria's rank value: When using the IMF SWARA technique for the first time, decision-makers rank the criteria according to their evaluations. The crucial factor is ranked first, while the least significant component is placed last.

3.2.2.2. Step 2. Comparing criteria pairwise: Decision-makers (DMs) decided the relative relevance of each criterion using the linguistic scale presented in Table 3. For this purpose, DMs calculate the proportionate importance of the jth criterion with respect to jth -1. Each criterion is compared to the one that came before it; these correlations, or ratios, are denoted by the symbol $\tilde{s}_j$ and are given as the comparative significance of the average value ([37]; Vrtagić et al., 2021).

3.2.2.3. Step 3. Calculating the coefficient value: During this phase of implementation, the recalculated component weight values are combined with the final relative relevance scores of the selection criterion. This is how the coefficient value is calculated with Equation (1) [37,42]:

$$\tilde{k}_j = \{\tilde{1}, j = 1 \;\; \tilde{s}_j + 1, j > 1\} \quad \text{(eqn. 1)}$$

Table 4
Criteria weights calculated for Decision Maker-1.

Rank	DM1	S_j (Comparative Significance)			K_j (Fuzzy Coefficient)			q_j (Calaulated weights)			w_j (Fuzzy weight coefficient)			CV (Crisp value)
1	CEE4				1	1	1	1.000	1.000	1.000	0.382	0.404	0.433	0.405
2	CEE1	1.000	1.000	1.000	2	2	2	0.500	0.500	0.500	0.191	0.202	0.217	0.203
3	CEE5	0.400	0.500	0.667	1.4	1.5	1.67	0.300	0.333	0.357	0.115	0.135	0.155	0.135
4	CEE7	0.333	0.400	0.500	1.33	1.4	1.5	0.200	0.238	0.268	0.076	0.096	0.116	0.096
5	CEE2	0.286	0.333	0.400	1.29	1.33	1.4	0.143	0.179	0.208	0.055	0.072	0.090	0.072
6	CEE6	0.333	0.400	0.500	1.33	1.4	1.5	0.095	0.128	0.156	0.036	0.052	0.068	0.052
7	CEE3	0.250	0.286	0.333	1.25	1.29	1.33	0.071	0.099	0.125	0.027	0.040	0.054	0.040
								2.309	2.477	2.615				

Table 5
Criteria weights calculated for Decision Maker-2.

Rank	DM2	S_j (Comparative Significance)			K_j (Fuzzy Coefficient)			q_j (Calaulated weights)			w_j (Fuzzy weight coefficient)			CV (Crisp value)
1	CEE5				1	1	1	1.000	1.000	1.000	0.197	0.205	0.216	0.205
2	CEE1	0.286	0.333	0.400	1.286	1.33	1.4	0.714	0.750	0.778	0.140	0.154	0.168	0.154
3	CEE7	0.000	0.000	0.000	1	1	1	0.714	0.750	0.778	0.140	0.154	0.168	0.154
4	CEE6	0.000	0.000	0.000	1	1	1	0.714	0.750	0.778	0.140	0.154	0.168	0.154
5	CEE2	0.250	0.286	0.333	1.25	1.29	1.333	0.536	0.583	0.622	0.105	0.119	0.134	0.120
6	CEE4	0.000	0.000	0.000	1	1	1	0.536	0.583	0.622	0.105	0.119	0.134	0.120
7	CEE3	0.222	0.250	0.286	1.222	1.25	1.286	0.417	0.467	0.509	0.082	0.096	0.110	0.096
								4.631	4.884	5.086				

Table 6
Criteria weights calculated for Decision Maker-3.

Rank	DM3	S_j (Comparative Significance)			K_j (Fuzzy Coefficient)			q_j (Calaulated weights)			w_j (Fuzzy weight coefficient)			CV (Crisp value)
1	CEE5				1	1	1	1.000	1.000	1.000	0.324	0.363	0.427	0.367
2	CEE2	0.500	0.667	1.000	1.5	1.67	2	0.500	0.600	0.667	0.162	0.218	0.285	0.220
3	CEE6	0.333	0.400	0.500	1.33	1.4	1.5	0.333	0.428	0.500	0.108	0.156	0.214	0.157
4	CEE3	0.286	0.333	0.400	1.29	1.33	1.4	0.238	0.321	0.389	0.077	0.117	0.166	0.118
5	CEE7	0.400	0.500	0.667	1.4	1.5	1.667	0.143	0.214	0.278	0.046	0.078	0.119	0.079
6	CEE1	1.000	1.000	1.000	2	2	2	0.071	0.107	0.139	0.023	0.039	0.059	0.040
7	CEE4	0.250	0.286	0.333	1.25	1.29	1.333	0.054	0.083	0.111	0.017	0.030	0.048	0.031
								2.339	2.755	3.083				

Next, using Equation (2), the weight values of the criteria q_j are determined.

$$\underline{q}_j = \left\{ \tilde{1}, j = 1 \;\; \frac{\tilde{q}_{j-1}}{k_j}, j > 1 \right. \quad \text{(eqn. 2)}$$

Lastly, the fuzzy weight coefficient values of the criteria are produced using Equation (3):

$$\tilde{w}_j = \frac{q_j}{\sum_{j=1}^{n} \tilde{q}_j} \quad \text{(eqn. 3)}$$

where $\tilde{k}_j$ is the criterion's coefficient values and $\tilde{q}_j$ is the fuzzy weight of the jth criterion that has been recalculated. $\tilde{w}_j$, where n is the total number of criteria, indicates the fuzzy relative weight values of the jth criterion.

3.2.2.4. Step 4. Defuzzifying the criterion weights: Equation (4) is used in the last stage of the IMF SWARA approach to defuzzify the fuzzy values in the manner described below [46]:

$$w_{Crisp\ value} = \frac{w^{(l)} + 4w^{(m)} + w^{(u)}}{6} \quad \text{(eqn. 4)}$$

3.2.2.5. Step 5. Final weights calculation: The final weights to determine the end value of each criterion is calculated using Triangular Fuzzy Bonferroni Mean which is equation (5) [47].

Let $[a_i^L, a_i^M, a_i^U]$ (i = 1,2,3 … ….n) be as set of triangular fuzzy number, then,

$$\text{Triangular Fuzzy Bonferroni Mean } (\text{TFBM})^{p,q}(a_1, a_2, \ldots\ldots\ldots a_n) = \left[\left(\frac{1}{n(n-1)} \sum_{i,j=1\ i\neq j}^{n} \left(a_i^L\right)^p \left(a_j^L\right)^q \right)^{\frac{1}{(p+q)}}, \left(\frac{1}{n(n-1)} \sum_{i,j=1\ i\neq j}^{n} \left(a_i^M\right)^p \left(a_j^M\right)^q \right)^{\frac{1}{(p+q)}}, \left(\frac{1}{n(n-1)} \sum_{i,j=1\ i\neq j}^{n} \left(a_i^U\right)^p \left(a_j^U\right)^q \right)^{\frac{1}{(p+q)}}, \right] \quad \text{(eqn. 5)}$$

Where n = No. of experts.

And $p,q \geq 0$ *i.e.* non-negative numbers.

3.3. Applying the IMF-SWARA method

The implementation of the IMF-SWARA technique has addressed the selection of important CE enablers in the Indian meat supply chain. Even if the weight values of the selection criterion were determined using IMF SWARA. One method used to evaluate the ranking importance of the CE enablers is the Triangular Fuzzy Bonferroni Mean formula.

3.3.1. Criteria weights values calculation

Based on the formulas previously mentioned to perform IMF-SWARA technique, this section shows the weight values of various criteria, presented in Tables 4–11.

From the analysis, it is depicted that the DM1 has opined CEE4 as the most significant criteria followed by CEE1 for evaluating CE enablers whereas CEE3 as the most insignificant. According to DM2, CEE5 is the most influential enabler as compared to others and CEE3 is the least influential one. The DM3 has found CEE4 as the most insignificant, whereas CEE5 is the most significant enabler. Also, DM4 opined that CEE4 is the most crucial enabler followed by CEE5 and CEE1 is the least crucial among all. According to DM5, the most significant enabler is CEE4 whereas CEE7 is the least significant one. The DM6 has found CEE5 to be crucial in the meat supply chain whereas CEE3 is the least crucial among all. DM7 has opined that CEE1 is the most significant criteria followed by CEE4 and CEE6 is the least significant one. As for DM8, CEE5 is significant, followed by CEE1 and CEE4, but CEE7 is the

Table 7
Criteria weights calculated for Decision Maker-4.

Rank	DM4	S_j (Comparative Significance)			K_j (Fuzzy Coefficient)			q_j (Calaulated weights)			w_j (Fuzzy weight coefficient)			CV (Crisp value)
1	CEE4				1	1	1	1.000	1.000	1.000	0.337	0.387	0.470	0.393
2	CEE5	0.500	0.667	1.000	1.5	1.67	2	0.500	0.600	0.667	0.168	0.232	0.313	0.235
3	CEE6	0.400	0.500	0.667	1.4	1.5	1.67	0.300	0.400	0.476	0.101	0.155	0.224	0.157
4	CEE7	0.500	0.667	1.000	1.5	1.67	2	0.150	0.240	0.317	0.050	0.093	0.149	0.095
5	CEE3	0.333	0.400	0.500	1.333	1.4	1.5	0.100	0.171	0.238	0.034	0.066	0.112	0.068
6	CEE2	0.500	0.667	1.000	1.5	1.67	2	0.050	0.103	0.159	0.017	0.040	0.075	0.042
7	CEE1	0.400	0.500	0.667	1.4	1.5	1.67	0.030	0.069	0.113	0.010	0.027	0.053	0.028
								2.130	2.582	2.971				

Table 8
Criteria weights calculated for Decision Maker-5.

Rank	DM5	S_j (Comparative Significance)			K_j (Fuzzy Coefficient)			q_j (Calaulated weights)			w_j (Fuzzy weight coefficient)			CV (Crisp value)
1	CEE4				1	1	1	1.000	1.000	1.000	0.360	0.386	0.426	0.389
2	CEE5	0.400	0.500	0.667	1.4	1.5	1.67	0.600	0.667	0.714	0.216	0.258	0.304	0.258
3	CEE1	1.000	1.000	1.000	2	2	2	0.300	0.333	0.357	0.108	0.129	0.152	0.129
4	CEE2	0.333	0.400	0.500	1.333	1.4	1.5	0.200	0.238	0.268	0.072	0.092	0.114	0.092
5	CEE3	0.400	0.500	0.667	1.4	1.5	1.67	0.120	0.159	0.191	0.043	0.061	0.081	0.062
6	CEE6	0.286	0.333	0.400	1.286	1.33	1.4	0.086	0.119	0.149	0.031	0.046	0.063	0.046
7	CEE7	0.500	0.667	1.000	1.5	1.67	2	0.043	0.071	0.099	0.015	0.028	0.042	0.028
								2.348	2.587	2.779				

Table 9
Criteria weights calculated for Decision Maker-6.

Rank	DM6	S_j (Comparative Significance)			K_j (Fuzzy Coefficient)			q_j (Calaulated weights)			w_j (Fuzzy weight coefficient)			CV (Crisp value)
1	CEE5				1	1	1	1.000	1.000	1.000	0.309	0.348	0.409	0.351
2	CEE4	0.400	0.500	0.667	1.4	1.5	1.667	0.600	0.667	0.714	0.185	0.232	0.292	0.234
3	CEE1	0.500	0.667	1.000	1.5	1.667	2	0.300	0.400	0.476	0.093	0.139	0.195	0.141
4	CEE7	0.250	0.286	0.333	1.25	1.286	1.333	0.225	0.311	0.381	0.069	0.108	0.156	0.110
5	CEE6	0.333	0.400	0.500	1.333	1.4	1.5	0.150	0.222	0.286	0.046	0.077	0.117	0.079
6	CEE2	0.286	0.333	0.400	1.286	1.333	1.4	0.107	0.167	0.222	0.033	0.058	0.091	0.059
7	CEE3	0.400	0.500	0.667	1.4	1.5	1.667	0.064	0.111	0.159	0.020	0.039	0.065	0.040
								2.446	2.877	3.238				

most insignificant compared to the others.

3.3.2. *The Triangular Fuzzy Bonferroni Mean (TFBM) calculation*

The Triangular Fuzzy Bonferroni Mean (TFBM) was used to find out the average value for each criterion and then, the crisp value is calculated using the same formula as mentioned in the previous section. The final average value for each criterion and its crisp value is presented in Table 12. From the above, it is seen that after the completion of the analysis of the Fuzzy data, the following order of significance was obtained:

CEE4> CEE5> CEE1> CEE7> CEE2> CEE6> CEE3.

The same interpretation has been presented graphically using a bar chart in Fig. 2.

The result showed the following weight values in decreasing order of significance: Reverse Logistics [0.1772] > 3Rs (Reduce, Reuse and Recycle) [0.1140] > Top Management Commitment [0.1060] > Capacity Building [0.0525] > Digital Technologies (RFID, Blockchain and Cyber Physical Systems) [0.0486] > Globally Harmonized Standards [0.0416] > Supply Chain Collaboration [0.0337].

4. Discussion

The adoption of Circular Economy in meat supply chain increases responsiveness and resilience [48]. Circular Economy principles in India's meat supply chain helps to reduce carbon emissions, safeguarding natural resources, and promoting inclusive economic development [1]. Meat is usually produced and disseminated over a long period of time; it is susceptible to bacterial contamination and contamination when combined with other animal products. Meat is a relatively sensitive product, and it has been made public by major food crises and outbreaks [49–51].

In the meat supply chain, reverse logistics play in important and significant role as meat may deteriorate rapidly if it is not handled, stored, or distributed correctly as well as if it is not processed correctly. It encompasses activities such as product returns, recycling, refurbishment, remanufacturing, and thus increasing the lifespan of goods and

Table 10
Criteria weights calculated for Decision Maker-7.

Rank	DM7	S_j (Comparative Significance)			K_j (Fuzzy Coefficient)			q_j (Calaulated weights)			w_j (Fuzzy weight coefficient)			CV (Crisp value)
1	CEE1				1	1	1	1.000	1.000	1.000	0.340	0.393	0.481	0.399
2	CEE4	0.500	0.667	1.000	1.5	1.67	2	0.500	0.600	0.667	0.170	0.236	0.321	0.239
3	CEE5	0.500	0.667	1.000	1.5	1.67	2	0.250	0.360	0.444	0.085	0.142	0.214	0.144
4	CEE7	0.400	0.500	0.667	1.4	1.5	1.67	0.150	0.240	0.317	0.051	0.094	0.153	0.097
5	CEE3	0.333	0.400	0.500	1.33	1.4	1.5	0.100	0.171	0.238	0.034	0.067	0.115	0.070
6	CEE2	0.500	0.667	1.000	1.5	1.67	2	0.050	0.103	0.159	0.017	0.040	0.076	0.043
7	CEE6	0.400	0.500	0.667	1.4	1.5	1.67	0.030	0.069	0.113	0.010	0.027	0.055	0.029
								2.080	2.542	2.939				

Table 11
Criteria weights calculated for Decision Maker-8.

Rank	DM8	S_j (Comparative Significance)			K_j (Fuzzy Coefficient)			q_j (Calaulated weights)			w_j (Fuzzy weight coefficient)			CV (Crisp value)
1	CEE5				1	1	1	1.000	1.000	1.000	0.321	0.366	0.439	0.371
2	CEE1	0.500	0.667	1.000	1.5	1.67	2	0.500	0.600	0.667	0.161	0.219	0.293	0.222
3	CEE4	0.400	0.500	0.667	1.4	1.5	1.67	0.300	0.400	0.476	0.096	0.146	0.209	0.148
4	CEE3	0.286	0.333	0.400	1.29	1.33	1.4	0.214	0.300	0.370	0.069	0.110	0.163	0.112
5	CEE2	0.333	0.400	0.500	1.33	1.4	1.5	0.143	0.214	0.278	0.046	0.078	0.122	0.080
6	CEE6	0.500	0.667	1.000	1.5	1.67	2	0.071	0.129	0.185	0.023	0.047	0.081	0.049
7	CEE7	0.333	0.400	0.500	1.33	1.4	1.5	0.048	0.092	0.139	0.015	0.034	0.061	0.035
								2.276	2.734	3.115				

Table 12
Final Criteria weights calculated using Bonferroni Operator.

Enablers	Description	Bonferroni Operator (Average Value)			Crisp value
CEE1	Top management commitment	0.0915	0.1053	0.1232	0.1060
CEE2	Digital Technologies (RFID, Blockchain and Cyber Physical Systems)	0.0351	0.0483	0.0636	0.0486
CEE3	Supply Chain Collaboration	0.0221	0.0334	0.0469	0.0337
CEE4	Reverse logistics	0.1559	0.1762	0.2028	0.1772
CEE5	3Rs (Reduce, Reuse and Recycle)	0.0964	0.1134	0.1340	0.1140
CEE6	Globally harmonized standards	0.0289	0.0413	0.0558	0.0416
CEE7	Capacity Building	0.0385	0.0532	0.0701	0.0535

minimizing waste [31]. 3Rs (Reduce, Reuse and Recycle) is equally important Circular economy adoption. It plays an important role to avoid the meat crises, minimizing the waste and decreasing the environmental impact through better logistics [32].

Top management need to make as sufficient investment in digital technologies is required by meat processing industries to form a universal platform which incorporates various stakeholders and increases transparency of the movement of the products. This would help in keeping them aware of the product tracking which would ultimately help in quick decision-making. On the other hand, the investment in digital technologies is limited as the top management is very rigid due to the heavy investment cost. The adoption Circular economy requires more awareness campaigns first as many meat processing industries are found to be more profit-oriented rather than addressing the damage caused to the environment. Pakdel et al. [52] discussed the hygienic design and food processing techniques for toward circularity and sustainability for meat industries.

Supply chain collaboration across a range of stakeholders, including government agencies, industrial players, research institutions, and civil society organizations is necessary to develop and implement policies for the transition to a CE. Despite certain obstacles such as infrastructure limitations of digital technologies implementation, cultural changes, technological breakthroughs, and supply chain collaboration, CE adoption far outweighs the costs [20]. The CE concepts can be completely applied by the Indian meat industry to create a more resilient, effective, and sustainable supply chain.

5. Implications of the study

Circular Economy principles encourage the transformation of post-use products into valuable resources. Innovative approaches, such as biogas production, composting, and the development of bio-based materials, present opportunities for the industry to extract maximum value from its waste streams. By reimagining waste as a valuable input rather than a liability, the meat supply chain can contribute to a more sustainable and closed-loop system. By addressing waste management, technological integration, and collaborative initiatives, this study offers a roadmap for industry stakeholders and policymakers to navigate the complexities of transitioning towards CE.

5.1. Practical implications

The practical implications of the study provide deeper insight to integrate the circular economy with the meat supply chain. It helps in reducing the environmental toxicity, turning waste into a valued product. The study provides the basis to integrate digital tools and techniques (IoT, digital twin, etc.). Through the identification and implementation of the enablers, the Indian meat supply chain can not only mitigate its

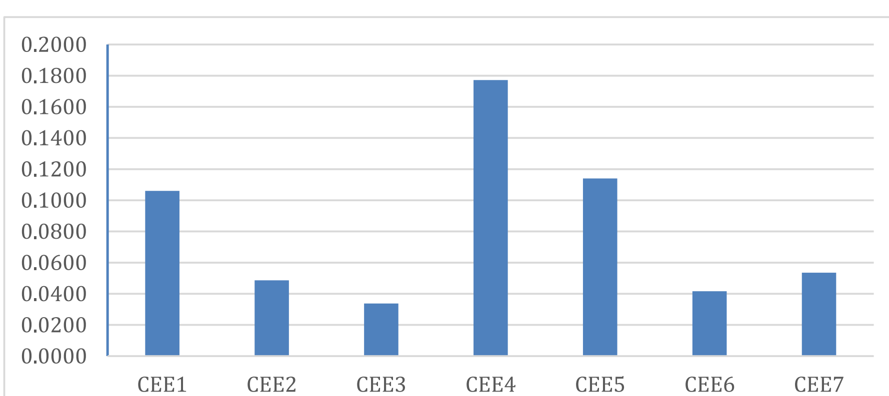

Fig. 2. Bar Chart representing final criteria weights.

environmental impact but also be part of a broader global effort toward building a more resilient and sustainable future.

6. Limitations of the study

The current research focuses on identifying and prioritizing the enablers towards circular economy for sustainable meat supply chain. The enablers were identified from the literature and few experts' opinion was taken from the meat industry situated in the northern part of India only. The study can be expanded with more expert opinion form the various parts of India from the meat sector. The current research is limited high cost of digital infrastructure cost, Support of top management, and stakeholder awareness. The study is also limited to the environmental aspect of circular economy, but the social and economic aspects of the CE implementation can also be considered in the Indian meat supply chain.

7. Conclusion

The concept of CE is crucial for the Indian meat supply chain to promote resource efficiency, sustainability, economic growth, and environmental stewardship. The study aims to evaluate and rank the CE enablers in the Indian meat supply chain. CE enablers were identified from the comprehensive analysis of published research articles related to Indian meat supply chain. After expert opinion, only 7 out of 10 enablers were found to be in line with the current study. Those enablers were then kept in the final questionnaire development which was filled by the respondents. The data were analysed using IMF-SWARA method followed by using Triangular Fuzzy Bonferroni Mean (TFBM) for calculating the final weights of each enabler. The results showed that the reverse logistics and 3Rs play a significant role in achieving CE and the digital technologies, blockchain and cyber physical systems draw attention to implementing sustainable meat supply chain strategies.

CRediT authorship contribution statement

Sumit Gupta: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Priyank Srivastava:** Writing – original draft, Visualization, Validation, Software, Resources, Formal analysis, Data curation. **Hammad Ansari:** Writing – original draft, Software, Resources, Investigation, Formal analysis, Data curation. **Rahul Mor:** Writing – original draft, Methodology, Investigation, Data curation. **Surya Prakash:** Writing – original draft, Visualization, Validation, Investigation, Formal analysis. **Sandeep Jagtap:** Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition, Formal analysis.

Declaration of competing interest

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

Data availability

Data will be made available on request.

References

[1] P. Srivastava, H. Ansari, M. Alrasheedi, R. Sharma, S. Prakash, S. Gupta, Leveraging supply chain collaboration with digital technologies for supply chain performance: an empirical investigation of Indian meat industries, Int. J. Food Sci. Technol. 59 (5) (2024) 3514–3522.
[2] F. Ciccullo, R. Cagliano, G. Bartezzaghi, A. Perego, Implementing the circular economy paradigm in the agri-food supply chain: the role of food waste prevention technologies, Resour. Conserv. Recycl. 164 (2021) 105114.
[3] A. Jurgilevich, T. Birge, J. Kentala-Lehtonen, K. Korhonen-Kurki, J. Pietikainen, L. Saikku, H. Schösler, Transition towards circular economy in the food system, Sustainability 8 (1) (2016) 69–82.
[4] S.K. Jakhar, S.K. Mangla, S. Luthra, S. Kusi-Sarpong, When stakeholder pressure drives the circular economy: measuring the mediating role of innovation capabilities, Manag. Decis. 57 (2018) 904–920.
[5] F. Cuadros, F. López-Rodríguez, A. Ruiz-Celma, F. Rubiales, A. González-González, Recycling, reuse and energetic valuation of meat industry wastes in Extremadura (Spain), Resour. Conserv. Recycl. 55 (4) (2011) 393–399.
[6] J. Gustavsson, C. Cederberg, U. Sonesson, R. Van Otterdijk, A. Meybeck, Global Food Losses and Food Waste, Food and Agriculture Organization of The United Nations, Rome, 2011 available at: http://www.fao.org/3/a-i2697e.pdf. (Accessed 29 May 2025).
[7] S. Li, Y. Xu, X. Liu, D. Yan, G. Liu, W. Wu, Introducing invisible food loss: an essential yet neglected dimension linking food safety and food security towards sustainable food system transition, Resour. Conserv. Recycl. 211 (2024) 107873.
[8] Champions 12.3, Road map to achieving SDG target 12.3, *Available at:*, https://champions123.org/wpcontent/uploads/2018/09/18_WP_Champions_Progress Update_final.pdf, 2018. (Accessed 29 May 2025).
[9] L. Principato, L. Ruini, M. Guidi, L. Secondi, Adopting the circular economy approach on food loss and waste: the case of Italian pasta production, Resour. Conserv. Recycl. 144 (2019) 82–89.
[10] European Commission, Communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions. A new circular economy action plan, in: For a Cleaner and More Competitive Europe, European Commission, Brussels, Belgium, 2020.
[11] European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Closing the Loop—An EU Action Plan for the Circular Economy 2015, European Commission, Brussels, Belgium, 2015.
[12] FAO, Global Food Losses and Food Waste – Extent, Causes and Prevention, Food and Agriculture Organization of the United Nations, Rome, 2011. Available at: www.fao.org/docrep/014/mb060e/mb060e.pdf. (Accessed 29 May 2025).
[13] R. Boehm, P.E. Wilde, M. Ver Ploeg, C. Costello, S.B. Cash, A comprehensive life cycle assessment of greenhouse gas emissions from U.S. household food choices, Food Policy 79 (2018) 67–76.
[14] L. Xue, N. Prass, S. Gollnow, J. Davis, S. Scherhaufer, K. Ostergren, S. Cheng, G. Liu, Efficiency and carbon footprint of the German meat supply chain, Environ. Sci. Technol. 53 (9) (2019) 5133–5142.
[15] M. Borello, Circular Economy in the agri-food Sector: Going Beyond Sustainability, University of Naples Federico II, 2016. PhD thesis.
[16] J. Abecassis, B. Cuq, J.L. Escudier, G. Garric, A. Kondjoyan, V. Planchot, J. M. Salmon, H. de Vries, Food chains; the cradle for scientific ideas and the target for technological innovations, Innov. Food Sci. Emerg. Technol. 46 (2018) 7–17.
[17] T. Searchinger, C. Hanson, J. Ranganathan, B. Lipinski, R. Waite, R. Winterbottom, A. Dihshaw, R. Heimlich, The great balancing act, in: Working Paper, *Installment 1 of Creating a Sustainable Food Future*, World Resources Institute, Washington, DC, 2013 available at: http://pdf.wri.org/great_balancing_act.pdf. (Accessed 29 May 2025).
[18] W.N. Sawaya, Impact of food losses and waste on food security, in: M. Sohail, B. Elias, D. Nuhad (Eds.), Water, Energy and Food Sustainability in the Middle East, Springer International Publishing, 2017, pp. 361–388.
[19] B. Lipinski, C. Hanson, J. Lomax, L. Kitinoja, R. Waite, T. Searchinger, Reducing food loss and waste, in: Working Paper, *Installment 2 of Creating a Sustainable Food Future*, World Resources Institute, Washington, DC, 2013 available online at: http://pdf.wri.org/reducing_food_loss_and_waste.pdf. (Accessed 29 May 2025).
[20] X. Zhang, D. Jiang, J. Li, Q. Zhao, M. Zhang, Carbon emission oriented life cycle assessment and optimization strategy for meat supply chain, J. Clean. Prod. 439 (2024) 140727.
[21] M. Němec, M. Riedl, J. Šálka, V. Jarský, Z. Dobšinská, M. Sarvaš, M. Hustinová, Consumer perceptions and sustainability challenges in game meat production and marketing: a comparative study of Slovakia and the Czech Republic, Foods 14 (4) (2025) 653.
[22] W. Guo, Evolution of meat production and consumption in the Bay of Bengal and south Asia: trends, challenges, and sustainable futures, Int. J. Food Syst. Dynam. 1 (aop) (2025) 1–15.
[23] A. Kassahun, R.J.M. Hartog, T. Sadowski, H. Scholten, T. Bartram, S. Wolfert, A.J. M. Beulens, Enabling chain-wide transparency in meat supply chains based on the EPCIS global standard and cloud-based services, Comput. Electron. Agric. 109 (2014) (2014) 179–190.
[24] R. Dubey, A. Gunasekaran, S.J. Childe, T. Papadopoulos, P. Helo, Supplier relationship management for circular economy: influence of external pressures and top management commitment, Manag. Decis. 57 (4) (2019) 767–790.
[25] A. Caccialanza, A. Sartori, S. Gubelli, F.R. Giannini, E. Capri, The sustainability of meat and cured meat supply chain: where are we now?, in: Sustainable Transition of Meat and Cured Meat Supply Chain: a Transdisciplinary Approach Springer Nature Switzerland, Cham, 2023, pp. 223–242.
[26] Vanderroost, M.P. Ragaert, J. Verwaeren, B. De Meulenaer, B. De Baets, F. Devlieghere, The digitization of a food package's life cycle: existing and emerging computer systems in the logistics and post-logistics phase, Comput. Ind. 87 (2017) 15–30.
[27] E. Hofmann, M. Rüsch, Industry 4.0 and the current status as well as future prospects on logistics, Comput. Ind. 89 (2017) 23–34.
[28] A. Panghal, S. Pan, P. Vern, R.S. Mor, S. Jagtap, Blockchain technology for enhancing sustainable food systems: a consumer perspective, Int. J. Food Sci. Technol. 59 (5) (2024) 3461–3468.

[29] R.M. Ellahi, L.C. Wood, M. Khan, A.E.D.A. Bekhit, Integrity challenges in halal meat supply chain: potential industry 4.0 technologies as catalysts for resolution, Foods 14 (7) (2025) 1135.
[30] P.C. Berardi, R.P. de Brito, Supply chain collaboration for a circular economy-from transition to continuous improvement, J. Clean. Prod. 328 (2021) 129511.
[31] Y. Fernando, M.S. Shaharudin, A.Z. Abideen, Circular economy-based reverse logistics: dynamic interplay between sustainable resource commitment and financial performance, Eur. J. Manag. Bus. Econ. 32 (1) (2022) 91–112.
[32] P. Manickam, G. Duraisamy, 3Rs and circular economy, in: Circular Economy in Textiles and Apparel, Woodhead Publishing, 2019, pp. 77–93.
[33] ICC, Key enablers for a circular economy. http://www.iccwbo.org/news-publications/policies-reports/key-enablers-for-a-circular-economy/, 2023. (Accessed 29 May 2025).
[34] M.C.S. de Abreu, D. Ceglia, On the implementation of a circular economy: the role of institutional capacity-building through industrial symbiosis, Resour. Conserv. Recycl. 138 (2018) 99–109.
[35] R.K. Mavi, M. Goh, N. Zarbakhshnia, Sustainable third-party reverse logistic provider selection with fuzzy SWARA and fuzzy MOORA in plastic industry, Int. J. Adv. Manuf. Technol. 91 (2017) 2401–2418.
[36] S. Vrtagić, E. Softić, M. Subotić, Ž. Stević, M. Dordevic, M. Ponjavic, Ranking road sections based on MCDM model: new improved fuzzy SWARA (IMF SWARA), Axioms 10 (2) (2021) 92.
[37] V. Keršuliene, E.K. Zavadskas, Z. Turskis, Selection of rational dispute resolution method by applying new step-wise weight assessment ratio analysis (SWARA), J. Bus. Econ. Manag. 11 (2) (2010) 243–258.
[38] A. Mardani, E.K. Zavadskas, Z. Khalifah, N. Zakuan, A. Jusoh, K.M. Nor, M. Khoshnoudi, A review of multi-criteria decision-making applications to solve energy management problems: two decades from 1995 to 2015, Renew. Sustain. Energy Rev. 71 (2017) 216–256.
[39] M. Mohammadi, S. Sarvi, S.J. Ghoushchi, Assessing and prioritizing construction contracting risks with an extended FMEA decision-making model in uncertain environments, Spectr. Decision Making Appl. 3 (1) (2026) 187–211.
[40] S.J.H. Dehshiri, Sustainable Supplier Selection Based on a Comparative Decision-Making Approach Under Uncertainty, Spectrum of Operational Research, 2026, pp. 238–251.
[41] A. Mehdiabadi, A. Sadeghi, A.K. Yazdi, Y. Tan, Sustainability service chain capabilities in the oil and gas industry: a fuzzy hybrid approach SWARA-MABAC, Spectr. Oper. Res. 2 (1) (2025) 92–112.
[42] S. Perçin, Evaluating airline service quality using a combined fuzzy decision-making approach, J. Air Transport. Manag. 68 (2018) 48–60.
[43] N. Zarbakhshnia, H. Soleimani, H. Ghaderi, Sustainable third-party reverse logistics provider evaluation and selection using fuzzy SWARA and developed fuzzy COPRAS in the presence of risk criteria, Appl. Soft Comput. 65 (2018) 307–319.
[44] D. Sengul, G. Cagil, Bulanık SWARA ve bulanık analitik hiyerarşi prosesi yöntemi ile iş degerlemesi, DUJE 11 (3) (2020) 965–976.
[45] F. Ecer, Çok kriterli karar verme geçmişten günümüze kapsamlı bir yaklaşım. Seçkin Yayıncılık, 2020.
[46] M. Stanković, Ž. Stević, D.K. Das, M. Subotić, D. Pamučar, A new fuzzy MARCOS method for road traffic risk analysis, Mathematics 8 (3) (2020) 457.
[47] R. Verma, J.M. Merigó, N. Mittal, Triangular fuzzy partitioned bonferroni mean operators and their application to multiple attribute decision making, in: *2018 IEEE Symposium Series on Computational Intelligence (SSCI)* IEEE, 2018, pp. 941–949.
[48] L. Bals, K.M. Taylor, E. Rosca, F. Ciulli, Toward a circular supply chain: the enabling role of information and financial flows in open and closed loop designs, Resour. Conserv. Recycl. 209 (2024) 107781.
[49] A. Marucheck, N. Greis, C. Mena, L. Cai, Product safety and security in the global supply chain: issues, challenges and research opportunities, J. Oper. Manag. 29 (2011) (2011) 707–720.
[50] C. Stamatis, C.A. Sarri, K.A. Moutou, N. Argyrakoulis, I. Galara, V. Godosopoulos, M. Kolovos, C. Liakou, V. Stasinou, Z. Mamuris, What do we think we eat? Single tracing method across foodstuff of animal origin found in Greek market, Food Res. Int. 69 (2015) (2015) 151–155.
[51] S. Jagtap, H. Trollman, F. Trollman, G. Garcia-Garcia, W. Martindale, Surviving the storm: navigating the quadruple whammy impact on europe's food supply chain, Int. J. Food Sci. Technol. 59 (6) (2024) 3652–3666.
[52] M. Pakdel, A. Olsen, E.M.S. Bar, Towards sustainability: a case study on the integration of hygienic design and sustainability in Norwegian meat processing facilities, J. Agric. Food Res. 19 (2025) 101642.