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RESEARCH ARTICLE

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Attaining Sustainable Development Goals through embedding circular economy principles: Evidence from food processing small- and medium-sized enterprises in India

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Abstract

Various industries are gradually sifting away from the linear economy and toward the circular economy (CE), but its advancement is crawling far behind the environmental contamination by the food processing industry in developing countries. Hardly any research analyzes the CE performance of food processing small- and medium-sized enterprises (FPSMEs) in an emerging economy context. Hence, developing a CE performance evaluation framework is imperative to facilitate this transition. This research proposes a comprehensive framework for evaluating CE performance based on three real-world cases of Indian FPSMEs. Initially, 15 essential criteria are shortlisted from the literature and refined by the experts. Afterward, data are collected through questionnaires administered to experts and structured interviews. Next, this research employs a multi-criteria decision-making (MCDM)–based approach, in which the Criteria Importance Through Inter-criteria Correlation (CRITIC) method is used to compute the objective weights of criteria and the Vlse Kriterijumska Optimizacija Kompromisno Resenje (VIKOR) method is used to determine the performances of FPSMEs and rank them accordingly. The results reveal that "investment in Corporate Social Responsibility (CSR)," "use of renewable energy," "increase in scrap recycling rate," "total CO_2 emission," and "total water consumption" are the top five criteria for CE performance. Investment in CSR emerges as the most influential criterion for strategic corporate transformation, which blends the notions of CE and CSR as a feasible solution for designing circular business processes.

KEYWORDS
circular economy, food supply chain, multi-criteria decision-making, performance evaluation, small- and medium-sized enterprises

Abbreviations: CE, circular economy; CSR, corporate social responsibility; FSC, food supply chain; MCDM, multi-criteria decision-making; SDG, sustainable development goals; SME, small- and medium-sized enterprises.

1 | INTRODUCTION

1.1 | Research motivation

The world's population is predicted to reach 9 billion by 2050 and 10.1 billion by the end of the 21st century, leading to a 70% increase in food production (World Resources Institute, 2019). As the world's population grows, so does food consumption, putting enormous strain on the planet's capacity to meet those demands (Dey et al., 2020). The food and beverage industry and food supply chain (FSC) support a rapidly expanding population and have spurred economic development and product expansion (Ghos et al., 2023a). However, increases in productivity are expensive because food production in a linear way uses finite resources (Ghosh et al., 2023b). Furthermore, the existing food production model is inefficient since it causes several detrimental environmental impacts due to its waste creation, fertilizer consumption, and land use (Kumar, Sharma, Raut, et al., 2022). Even though enough food is produced to feed the world's population, huge waste is created across FSC due to large-scale food production and global distribution of food products (Kumar, Raut, Jagtap, & Choubey, 2022). It is worth noting that one-third of global food is either lost or wasted, amounting to over 1.3 billion tons yearly (World Bank, 2020). According to the Food Waste Index Report 2021, total food loss and waste will reach up to 2.1 billion tons worth $1.5 trillion by 2030 (UN Environment Programme, 2021). Furthermore, the resources, money, and labor used to produce food are also lost when food is wasted. Moreover, massive waste generation and unsustainable food consumption are the primary causes of greenhouse gas (GHG) emissions, the global food crisis, and hunger (Al-Obadi et al., 2022). Statistics show that the food processing industry (FPI) accounts for about 30% of global GHG emissions and for about 70% of freshwater consumption (World Economic Forum, 2022). Additionally, the carbon footprint of total annual food wastage is 3.3 billion tons of CO_2 equivalents of GHG emissions into the environment (Ogunmoroti et al., 2022). These problems are undermining overall FSC sustainability. Thus, producing adequate food, efficiently distributing it, and reducing its wastage and environmental footprints are a few challenges that the FPI is confronting in modern times (Zhong et al., 2017).

Given the scarcity of natural resources, the growing population with diverse consumption habits, climate change, food insecurity, and the world's growing hunger index, it is vital to ensure that food waste is kept to a minimum throughout the FSC (Chiaraluce et al., 2021). According to the UN, the most critical Sustainable Development Goals (SDGs) among the 17 specified targets for SD is "zero hunger," and approximately 828 million people are starving and do not have enough food to eat (FAO, n.d.). Hence, the food sector should work on eliminating waste and enhancing food security (Kumar, Raut, Jagtap, & Choubey, 2022). Therefore, appropriate strategies aimed at food waste minimization must be implemented immediately. As a result, governments and international organizations are advocating that FPI rethink their business models in light of the SDGs, including social and environmental goals in their commercial agendas to achieve zero waste (Chiaraluce et al., 2021). To this end, stakeholders across FSCs are experiencing tremendous pressure to establish a synchronization of food production with environmental sustainability. In this regard, implementing CE business models (Ghosh et al., 2023a) in FSC has become imperative, promoting the transition towards a sustainable agro-food system and a zero-waste economy (Kumar, Sharma, Raut, et al., 2022). The CE is an economical approach that aims to enhance resource utilization and reduce the requirement for virgin materials by eliminating waste and retaining the value of materials (Marrucci et al., 2021a). Effective incorporation of CE principles into FSC offers multi-faceted benefits, such as reduced waste and improved food security (Kazancoglu et al., 2021), and simultaneously provides a competitive stance, employing opportunities and growing consumer satisfaction (Kumar, Raut, Jagtap, & Choubey, 2022). FPI can acquire both environmental, economic, and social sustainability (Mehmood et al., 2021) by adopting the concept of 4Rs, that is, reduce, reuse, recycle, and recover (Kumar, Sharma, Raut, et al., 2022). Therefore, the SDGs for sustainable consumption and production (SDG12) may be attained by applying CE principles in FSC. During the last couple of years, the CE approach has been explored by several authors in various industrial segments, such as the furniture industry (Susanty et al., 2020), the textile and apparel industry (Jia et al., 2020), the construction industry (Eberhardt et al., 2020), leather industry (Moktadir et al., 2018), automobile industry (Agrawal et al., 2020; Ghosh et al., 2021c; Ghosh, Bhowmik, et al., 2023), electronics equipment industry (Rosa et al., 2019), oil and gas industry (Jain et al., 2020), and plastics industry (Balwada et al., 2021). However, CE research remains an under-exploited area of FSC studies and is a relatively recent venture (Khoshnava et al., 2020). Even if CE practices have the potential to change the FSC realm, only a few studies have offered concrete empirical evidence, particularly in the setting of a developing country.

1.2 | Research context

In the latest "Global Hunger Index scores by 2022," India ranks 107th out of 121 countries, trailing neighboring countries like Sri Lanka (64th), Nepal (81st), Bangladesh (84th), Myanmar (71st), and Pakistan (99th). India has an acute level of hunger that is nearly alarming situation. Given India's current position, it is crucial to adopt CE practices into the FSC in order to reduce losses at all stages of the value chain (Kumar, Raut, Jagtap, & Choubey, 2022). The FPI in India is one of the largest in the world, with a net present worth predicted to reach US 535 billion dollars by 2025–2026 and 9 million jobs created by 2024 (Sawhney, 2021). The Indian FPI, which comprises both organized and unorganized sectors, with a significant number of small- and medium-sized enterprises (SMEs) contributing the most, is generally portrayed as a low-tech sector. The capacity of FPSME to innovate is significant because innovation provides a competitive advantage to enterprises, industries, and, ultimately, economies (Ghosh et al., 2022c). CE innovation has the ability to pursue sustainable development in individual SMEs at the micro level as well as aggregate sectors and economies at the macro level. Overall, it has not been attributed to increased levels of R&D and has shown only lower levels of innovation (Virmani et al., 2022). This is because FPSMEs in India are not very sensitive toward CE implementation, and there are several barriers, such as insufficient technological competence, the reluctance of top management, lack of financial assistance, and legislation (Dey et al., 2020). Oftentimes, FPSMEs are unaware of the CE-related practices that must be followed. However, research investigating how FPSME moving toward CE implementation is relatively scant. A thorough exploration of existing literature indicates that there is plenty of research on various aspects of CE in the context of developed nations (Dey et al., 2020; Diaz et al., 2022; Horbach & Rammer, 2019; Kazancoglu et al., 2021; Maione et al., 2022; Prieto-Sandoval et al., 2019; Urain et al., 2022). On the contrary, there is a lack of CE research in developing nations (Ethirajan et al., 2021; Moktadir et al., 2020). Although various organizations in developing countries are incorporating CE practices in supply chain (SC) activities in their recent ventures (Zhang et al., 2022), there still is a shortage of comprehensive decision frameworks for measuring their CE performances and monitoring progress toward CE implementation. In order to implement CE practices efficiently, industry practitioners and policymakers need to be equipped with a proper performance evaluation framework in an industrial and national context. As depicted by relevant studies (Gupta et al., 2021; Sassanelli et al., 2019; Wang et al., 2021), the performance evaluation of business organizations through the lens of the CE is a typically new concept. By evaluating the real-time CE performance of India-based FPSMEs, this research aims to bridge these knowledge gaps.

1.3 | Research questions

The following three research questions are offered based on the aforementioned analysis:

RQ1 What is the current status of CE implementation in FPSME in India?

RQ2 What are the influential evaluation criteria for CE performance in FPSME?

RQ3 How to measure the CE performance of FPSME and prioritize them in a developing country setting?

In order to answer the research questions, a comprehensive framework is proposed in this research, paving the way for FPSME to clarify the CE implementation strategies and potential performance improvement. This research presents a case study with three prominent Indian FPSMEs and a CE performance evaluation framework. CE performance evaluation includes criteria identification, weight determination, and model development. It is often considered an MCDM-type problem since it includes various conflicting quantitative and/or qualitative criteria and yields a solution requiring a consensus (Sufiyan et al., 2019; Wu & Jia, 2018). An integrated MCDM model is utilized, in which the CRITIC method is used to determine the objective weights of criteria, and the VIKOR method is utilized to calculate the performance values of the FPSME. The following are the grounds for integrating the CRITIC and VIKOR methods: (i) This combination is crucial because of VIKOR and CRITIC's dual-disciplinary approaches and its capacity to manage complicated decision-making processes in a rational, practical, and sensible manner. (ii) A few MCDM methods widely used include "analytical hierarchy process (AHP)," "technique for order of preference by similarity to ideal solution (TOPSIS)," "ÉLimination Et Choix Traduisant la REalité (ELECTRE)," and "COmplex PRoportional ASsessment (COPRAS)." However, these methods seem vulnerable while dealing with conflict and variability in the decision attributes (Kumaran, 2022). According to a recent report, the VIKOR method yields a better ranking of alternatives in the presence of conflict by introducing the closeness of coefficients (Li et al., 2022) and it was commonly used in SC management–related decision-making. (iii) During solving MCDM-type problems, the determination of criteria weight is vital for the rationality of MCDM. While common MCDM techniques such as AHP (Franco et al., 2021) and interpretative structural modeling (ISM) (Eberhardt et al., 2020) employ experts' subjective opinion and pairwise comparison, the CRITIC method considers the contrast intensity among criteria and yields a more objective result. Although there is a handful of research employing integrated CRITIC-VIKOR method in various fields, such as "renewable energy technology adoption in rural areas" (Kamali Saraji et al., 2023), "risk management of subsea pipelines" (Li et al., 2022), and "evaluating financial performance index of Initial Public Offering firms" (Kumaran, 2022). However, to the best of the author's knowledge, no combined CRITIC-VIKOR assessment approach is used for dealing with challenges related to FPSME, particularly in developing countries.

The remainder of this paper is organized as follows: Section 2 provides the theoretical foundation. Section 3 describes the proposed framework. Section 4 shows a real-world application of the proposed framework. Section 5 discusses the important results. Section 6 summarizes the research's implications. Finally, Section 7 concludes by indicating limitations and scopes for future research.

2 | THEORETICAL FOUNDATION

This section portrays a comprehensive overview of CE literature, including the CE principle, CE performance evaluation, various criteria and tools used in CE performance evaluation, and research gap identification.

2.1 | The CE principle

The CE is a viable strategy for economic growth that promotes material circularity while also considering environmental and social advantages (Yadav et al., 2020). Scarpellini et al. (2019) defined CE as "an economic system in which waste is converted into inputs at the extraction, production, and consumption phases." Apart from the increased capacity of landfills and the number of people using them for disposing of waste in developing countries, a significant portion of the waste contains valuable items that could be reused, recovered, or recycled (Dey et al., 2020). CE is an emerging paradigm for the production and consumption of materials sustainably in a closed loop to reduce the requirement for virgin materials, minimize waste, enhance the circularity of material, and extend the product life cycle (Horbach & Rammer, 2019). CE principles have been proven to be

TABLE 1 Glimpses of some notable research in the field of CE.

Authors	Objectives	Methods used	Criteria/CE practices/ attributes/parameters used	Sample Size	Country context	Industrial segment
Haleem et al. (2021)	Constructed a supplier evaluation model in the CE context and building a resilient business environment	"Fuzzy-CRITIC," TOPSIS	"Remanufacturing, energy efficiency, use of alternative energy, recycling, cost-effectiveness, design for durability, eco-friendly packaging, waste management, resource consumption, material recovery, compliance with CE policy, local government regulations, eco-friendly transportation, optimization of logistics, management commitment"	5	India	Automobile industry
Oliveira et al. (2021)	Developed a combined model for evaluating the transition towards CE across multiple sustainability dimension	"Life cycle assessment," "emergy accounting," "sustainable value chain mapping"	"Water scarcity, renewability, land use responsibility, non-renewable resource consumption, energy efficiency, sustainable industrialization, innovation, resilient infrastructure, decent labor condition, product pricing, gender equality, poverty eradication, health and well-being, food security, natural resources depletion, climate change mitigation, biodiversity protection"	NA	NA	NA
Hussain and Malik (2020)	Identified "organizational enablers of circular SC" and examined their relationship with the "environmental performance of organizations"	"Structural equation modeling (SEM)," "hypotheses testing"	"Understanding of CE insights, awareness of CE potential for revenue gains, sustainability awareness, collaborative interactions between tiers of SC from multiple industries, enhanced information and technology sharing within value chain, structural flexibility, end of life returns, managing byproducts and waste, compliance to environmental regulations, reduction in energy consumption, reduction in the usage of toxic material"	175	United Arab Emirates (UAE)	Multiple SC
Julianelli et al. (2020)	Proposed a framework that represents the relationship between critical success factors (CSFs) and reverse logistics in the context of CE	"Tertiary literature review," "content analysis"	"Competitive advantage, internal environment management, materials management, purchasing management, demand and market management, product and service system, product design, industrial ecology, industrial symbiosis, operational cost reduction, industry 4.0 tools, information systems, collaborative relationships among stakeholders"	NA	NA	NA
Yadav et al. (2020)	Identified CE indicators and developed a framework for CE adoption.	"Best worst method (BWM)," "decision-making trial and evaluation laboratory (DEMATEL)"	"Effective inventory management, top management commitment, sustainable resource management, employee empowerment and motivation, adoption of 6'r policy, reduction in carbon emission, collaboration among SC, technology transfer, effective IoT system"	6	India	Heavy manufacturing company
Moktadir et al. (2020)	Identified and prioritized CSFs for effective adoption of CE practices	"BWM," "DEMATEL"	"Eco-design, waste management, top management commitment, funding support from the government, scarcity of resources, strong legislation mandating CE, knowledge of CE, reverse logistics practices, pressure from competitors"	15	Bangladesh	Leather industry

TABLE 1 (Continued)

Authors	Objectives	Methods used	Criteria/CE practices/ attributes/parameters used	Sample Size	Country context	Industrial segment
Dey et al. (2020)	Identified CE implementation difficulties and possibilities in SMEs and investigated numerous critical tactics to support effective CE adoption	"Mixed method approach"	"Productivity, turnover, cost reduction, energy efficiency, waste reduction, resource efficiency, accident reduction, CSR investment, eco-design, lean practices, energy consumption, use of renewable energy, social well-being, after-sales service, repair, reuse, recycle, reverse logistics, carbon offsetting, inventory optimization, green marketing, green procurement, management commitment, financial support"	130	West Midlands County, United Kingdom (UK)	Manufacturing SMEs
Horbach and Rammer (2019)	Explored whether firms with CE innovations outperform others in terms of sales growth and employment.	"Hypotheses testing"	"Process-related CE variables, reduced energy, recycled waste, water, or materials, use of renewable energy sources, hazardous substances, extended product life, durability, improved recycling of product after use"	56	Western Germany	Manufacturing and service firms
Govindan et al. (2020)	Developed a framework for order allocation and supplier selection in a circular SC	"Fuzzy-analytic network process (ANP)," "fuzzy-DEMATEL"	"Air pollution, eco-friendly raw material, eco-design, eco-friendly packaging, eco-friendly transportation, clean technology, quality control system, customer satisfaction, after-sales service, on-time delivery, time management"	5	Alborz Province, Iran	Automotive parts industry
Sarfraz et al. (2021)	Conducted explanatory research on the influence of environmental, social, and economic variables on CE performance, with the moderating function of organizational competitiveness taken into account.	"Regression analysis," "correlation analysis"	"Recycle, refuse, rethink, reduce, reimagine, reuse, repair, recondition, remanufacture, redesign, and recover, social dimension, economic dimension, environmental dimension, organizational competitiveness, organizational performance, organizational strategy for business"	320	China, Italy	Textile industry
Prieto-Sandoval et al. (2018)	Established the major elements that are essential for evaluating the degree of CE adoption	"Delphi method"	"Selection of biodegradable materials, environmental efficiency of production processes, sustainable energy sources for production, environmental innovation, design of sustainable products and services, recovery of resources, development of a sustainable logistics system, channels of communication with customers to retrieve products, sharing infrastructure/services with industrial neighbors, trust and transparency among potential partners, government and public institution intervention, environmental management system (EMS)"	13	European Union	SMEs

(Continues)

TABLE 1 (Continued)

Authors	Objectives	Methods used	Criteria/CE practices/ attributes/parameters used	Sample Size	Country context	Industrial segment
Ethirajan et al. (2021)	Concentrated on identifying and analyzing various risk factors associated with CE implementation to promote circular initiatives in the manufacturing industry	"Linear programming," "mixed-integer linear programming," "fuzzy linear programming," "integer programming," "interpretive structural modeling (ISM)," "grey-DEMATEL"	"Material delay, workers' coordination, material quality, safety measures, specified machine, supplier performance, product quality, marketing strategies, controlled cash-flow, return on investment, natural disaster, processing environment, machine maintenance, branding, reputed customers, balanced offers, vision statements, report governing, customer satisfaction, product performance, product service life, resale value, genuine publicity, decision-making, communication, social responsibilities, standards, transparent process, policies and procedures, cargo thefts"	9	India	Electrical component manufacturer, electric cable wire manufacturer, and recycling facility
Kazancoglu et al. (2021)	Analyzed the environmental hazards caused by reverse logistics activities within FSC management	"Regression model," "system dynamics model"	NA	6	Turkey	Milk and dairy industry
Maione et al. (2022)	Provided insight into the trends and significant changes in the application of CE practices from the standpoint of various value chains under the effect of major barriers and drivers.	"Longitudinal analysis"	"Process cost, consumer demand, market shift competition virgin/recycled plastics, material properties, technological readiness, industrial infrastructure development, urban infrastructure development, toxic additives, and substances, energy consumption, environmental impact, CE and SD directives, incentives/tax schemes, market regulation, data transparency, consumer awareness, and behavior"	51	Italy	Plastic packaging sector
Urain et al. (2022)	Developed and validated a tool for integrating CE in multiple industrial companies	"Industrial circular economy questionnaire," "self-diagnosis questionnaire"	"Politics, compromise, responsibilities, resources, competitor, awareness, communication, marketing, documented information, product/service requirement, materials, design and development, externally supplied products, processes, and services, emergency response, reverse logistics"	30	Spain	Automotive, metal working, and machine tool company
Diaz et al. (2022)	Provided insight into the circular product design in private sector organizations for developing value retention strategies	"General morphological analysis"	"Product ecosystem design, sustainable material selection, energy-efficient design, design for repair, design for remanufacture, predictive maintenance, reliability, durability, serviceability, perceived quality"	15	Austria, France, Sweden, Netherlands, the United Kingdom,	Telecommunications, automotive, energy sector, aviation industry

genuinely relevant and contribute directly to achieving various SDGs (Schroeder et al., 2018). Previously, CE was treated as a theoretical approach, but in recent times, industries are looking at opportunities to implement it (Maione et al., 2022). Although the investment cost is high, organizations will gain economic benefits in terms of lower raw material costs and many other long-term benefits (Mishra et al., 2022). Table 1 shows various contributory works in the CE field.

2.2 | Application of CE principles in FSC

Today's FSC becomes vulnerable due to rapid urbanization, unavailability of agricultural fields, SC disruption caused by natural disasters like the COVID-19 pandemic, poor governance, and food waste (Sufiyan et al., 2019). The CE has recently stimulated the interests of academicians, industry practitioners, and policymakers, particularly in the food industry. The entire CE transition is governed by certain principles, namely, (i) eliminating waste and pollution, (ii) keeping products and materials in use, and (iii) regenerating natural systems (Kazancoglu et al., 2021). The notion of CE in the FSC context is defined as a nexus between economic and industrial systems that apply the 3R policy, that is, reduce, reuse, and recycle (Horbach & Rammer, 2019). Better design and/or management at the production and consumption phases can help reduce resource use, energy consumption, and waste disposal (Mackey et al., 2019). Reducing food waste levels could increase grain supply, food availability, and food security without wasting other resources, such as land, labor, water, and other inputs (Zhang et al., 2022). Food, food by-products, and food packaging can all be reused in various forms to save them from being discarded too early in the supply Chain (Kumar, Sharma, Raut, et al., 2022). Reprocessing wastes from discarded food items and/or food packaging materials can allow them to be redistributed or transformed into valuable resources (Wang et al., 2021).

2.3 | CE performance evaluation

Performance evaluation is vital for organizations as it provides valuable insights for strategic, tactical, and operational decision-making (Ghosh, Mandal, & Ray, 2023). Sassanelli et al. (2019) conducted a systematic literature review and concluded that CE performance evaluation is still uncommon in businesses. The practical implementation of CE practices at the micro level requires the development of tools that can help decision-makers (DMs) measure CE performance, establish CE strategic goals, and monitor their progress (Gao et al., 2021). This review will focus on measuring CE performance in various industrial contexts. Table 2 summarizes various researches on CE performance evaluation in various industrial contexts. Many similar types of research on circular systems have been successfully documented. However, there has been relatively little research on the FSC, which supports determining the performance of FPSME to make the FSC circular in a developing country like India.

2.4 | Criteria used in CE performance evaluation

Criteria selection is of utmost importance for evaluating the CE performance of business enterprises. Performance evaluation within the SC is becoming more complicated due to the many conflicting criteria. CE performance evaluation criteria are different from those for a conventional SC (Franco et al., 2021). Unlike a conventional SC, which is evaluated in terms of cost, quality, delivery, and after-sales delivery (Govindan et al., 2020), circular SC is assessed concerning resource utilization and environmental footprint throughout the SC (Prieto-Sandoval et al., 2019). The majority of previous research (Table 1) uses triple bottom line (TBL) concepts in CE performance assessment and considers several CE performance indicators (criteria) such as environmental criteria, economic criteria, and social criteria. Gupta et al. (2021) integrated the concepts of CE, Industry 4.0, and clean technologies along with TBL for performance evaluation.

2.5 | Methods and techniques used in CE performance evaluation

Previous research employs various methods for CE performance evaluation, such as the DEA method (Bronner et al., 2022; Ding, Lei, Wang, & Zhang, 2020; Ding, Lei, Wang, Zhang, & Calin, 2020; Wang et al., 2021), LCA method (Prosman & Sacchi, 2018), balanced scorecard method (Torgautov et al., 2022), statistical (multivariate) methods (Jain et al., 2020; Ray et al., 2021; Tedesco et al., 2022), and integrated MCDM techniques (Ahmed et al., 2022; Franco et al., 2021; Gupta et al., 2021). Although previous methods are excellent in their respective areas of application, most of them cannot deal with quantitative criteria and overlook the criteria conflicts and interrelationships. On the contrary, methods like COmplex PROportional Assessment (COPRAS), Entropy, CRITIC, and VIKOR (Cheng et al., 2021), which can deal with quantitative criteria, have not been used so far in CE performance evaluation studies. Table 1 and Table 2 show the latest tools and methods employed by various researchers.

2.6 | Research gaps

The extant literature survey reveals the following research gaps:

a. Although a vast number of papers explored various aspects of CE within industrial supply networks, such as barriers (Hartley et al., 2021; Mishra et al., 2022), drivers (Agyemang et al., 2019; Moktadir et al., 2018), enablers (Hussain & Malik, 2020; Maione et al., 2022), and CSFs (Julianelli et al., 2020; Moktadir et al., 2020), research which develops frameworks and measures the CE performance of FPSME is almost non-existent.
b. Frequent performance evaluation is essential for continuous improvement. Previously, no one has focused on CE-based

TABLE 2 List of previous studies on CE performance evaluation.

Authors	Objectives	Region/context	Methods deployed	Levels covered			Findings	Limitations/Remarks
				Macro	Meso	Micro		
Ding, Lei, Wang, and Zhang (2020)	Aimed to assess dynamic evolution and overall efficiency of the industrial CE (ICE) system	"China's Yangtze River Delta region"	"Cooperative game network," "data envelopment analysis (DEA)," "extended Malmquist index method"	✓			The findings show that the overall effectiveness of the ICE system varies by city and is mostly driven by environmental remediation methods	This study is confined to the CE performance evaluation at the city level only
Gupta et al. (2021)	Based on Industry 4.0, cleaner production, and CE norms, a novel framework for planning and monitoring the sustainable and ethical performance of manufacturing organizations was proposed.	5 India-based manufacturing organizations	"Best worst method (BWM)," "combined compromise solution (CoCoSo) method"			✓	"SC traceability/information," "Reuse and recycling infrastructure," and "Natural and clean environment" are three top practices for manufacturing organizations to enhance sustainability	Although social dimension is an important pillar of sustainability, social criteria have been overlooked in the performance evaluation framework proposed in this study
Gao et al. (2021)	Established an analytical framework to evaluate CE performance and determined the factors affecting the CE performance of a city	16 cities of Shandong Province in East China	"Ecological network analysis"	✓	✓		The amount of financial growth has a strong positive association with urban resource productivity	Operational aspects were ignored while evaluating key performance indicators for CE at the city level
Ding, Lei, Wang, Zhang, and Calin (2020)	Developed a novel framework for evaluating marine CE performance	11 coastal regions in China	"Cooperative game network DEA model"		✓		Various inefficient environmental treatment measures lead to poor CE performance	The research is constrained to meso-level of CE implementation
Marrucci et al. (2021b)	Empirically Investigated the contribution of green human resource management (GHRM) to the transition toward CE	819 European EMS-registered organizations	"Hypothesis testing"	✓			There is a positive association between GHRAM and economic and environmental performances	Authors limited the sustainability sphere to the economic and environmental dimensions only
Wang et al. (2021)	Evaluated urban CE performance using a large dataset while considering CE indicators uncertainties	264 Chinese cities	"Fuzzy-DEA"	✓			Due to the negative trend of pollution emission reduction and economic output, urban CE may perform poorly	It necessitates the acquisition of intermediate factor data, which is difficult to get from current databases
Bronner et al. (2022)	Provided an in-depth analysis of the	Water sector in German federal states	"Dynamic network DEA"	✓			Recycling and reusing wastewater may lead to	The research considers regional circumstances

TABLE 2 (Continued)

Authors	Objectives	Region/context	Methods deployed	Levels covered: Macro	Meso	Micro	Findings	Limitations/Remarks
	performance assessment of the circular water economy						sustainability and higher resource efficiency	only, which limits the generalizability of the results
Franco et al. (2021)	Proposed a strategic framework for measuring and monitoring the circularity performance at the micro level	Hypothetical organization	"General morphological analysis," "AHP-TOPSIS"			✓	"Material consumption reduction," "Energy consumption reduction," and "Water consumption reduction" are three influential criteria for CE performance from a transition perspective	Attention has not been paid to the interrelation among considered criteria
Tedesco et al. (2022)	Conducted an exploratory research to evaluate how industries in a developing country are adopting the principles of CE. Authors also determined a set of CE practices among companies.	72 forestry companies in planted tree sector in Brazil	"ReSOLVE framework," "principal component analysis (PCA)"		✓		The most developed CE practice by companies is "separation of organic and recyclable waste," followed by "using raw materials from renewable sources," "practicing reverse logistics of inputs," "recyclability of products," and "importance of consumer awareness to increase the market demand for circular products	The outcome from the proposed methodology may be subjected to human bias as it primarily deals with qualitative indicators. Authors emphasized environmental operational criteria rather than economic and social criteria.
Ahmed et al. (2022)	Developed a comprehensive CE assessment framework for evaluating the circularity of products and process from a vast range of industrial segments	"Friction Stir Back Extrusion (FSBE) process"	"Fuzzy Inference System (FIS)," "AHP," "Entropy," "TOPSIS," "ANP," "Grey relational analysis (GRA)"	✓	✓	✓	To promote circularity and engage their organizations in the nation's CE model, manufacturing firms must use FSBE instead of traditional extrusion, in addition to other circular activities	Although, quantitative and qualitative indicators were evaluated simultaneously in this research, authors emphasized only environmental and operational indicators
Torgautov et al. (2022)	Created a strategic development framework for identifying specific CE measures and employing them to minimize construction and	Kazakhstan-based Construction companies	"Generic balanced scorecard approach"		✓		The following practices as the most important: C&DW transportation cost," "adoption of CE to decrease C&DW," "management by each	There are limiting uncertainties associated with the final outcome

(Continues)

TABLE 2 (Continued)

Authors	Objectives	Region/context	Methods deployed	Levels covered: Macro	Meso	Micro	Findings	Limitations/Remarks
	demolition waste (C&DW) in the construction sector.						contractor of their own C&DW," "accurate material estimation," and "internal knowledge sharing"	
Ray et al. (2021)	Presented an exploratory framework for measuring sustainability performance from the perspective of a developing country	6 India-based construction organizations	"Multivariate analysis," "item analysis," "PCA," "simple additive weighting (SAW) method"			✓	"Capital Budgeting," "Lifecycle Design," "Use of Energy-Efficient Technology," and "Cost of Waste Disposal" are the most influential parameters in the inception, design and planning, construction and maintenance, and demolition and reverse logistics stages, respectively.	The integrated approach proposed in this research can yield reliable results, yet errors may be present due to the use of subjective criteria and human bias in the survey
Kayal et al. (2018)	Developed a comprehensive CE index to measure the circularity of wastewater industry	10 Wastewater treatment plants	NA		✓		Treatment technology has a significant role in influencing a wastewater treatment plant's "production efficiency," "reuse rate," and "recycling performance"	CE index is largely affected by production efficiency. However, these findings do not explain how to maximize the operational efficiency of this system
Jain et al. (2020)	Examined the influence of "environmental management system" and "organizational flexibility" on CE performance	280 firms in Indian Oil and Gas sector	"Covariance-based SEM," "confirmatory factor analysis (CFA)"	✓			Businesses employ EMS to achieve CE performance. Flexible organizations, as opposed to rigid ones, are more capable of dealing with coercive restrictions by deploying EMS	Authors did not connect findings with SDGs

performance evaluation of FPSME, particularly in emerging economies. To overcome the aforementioned gap, FSC requires the development of a circular-driven performance evaluation framework.

c. CE performance assessment should include CE activities within the following three levels: macro level (regional, national, global), meso level (eco-industrial parks; industrial symbiosis), and micro level (firms, sole organizations). According to Table 2, most prior CE research has focused on macro and/or meso levels, with little emphasis given to the micro level.
d. CE is often considered a gateway to sustainability in business enterprises. But most of the previous research mainly focuses only on economic aspects without paying much attention to environmental, social, and operational aspects of CE performance evaluation. This biased approach that prefers economic aspects over other factors can result in quasi-optimizations and it may diminish the broader approach to sustainability.
e. As depicted in Table 1, prior research mostly considers qualitative criteria that cannot manage uncertainty and eliminate vagueness in decision-making. Conversely, quantitative criteria were used rarely in previous studies and most of them belong to productivity, profitability, and lifecycle thinking aspects. These criteria are useful but not able to holistically measure CE performance because these criteria mainly focus on tangible factors (procurement cost, resource efficiency, energy consumption, eco-design, material recovery, recycling, etc.) and simultaneously ignore intangible factors (management commitment, corporate social responsibility, CE awareness, employee wellbeing, etc.) that indirectly influence the CE performance.

Therefore, the research gap analysis indicates that the development of a systematic and CE-focused performance evaluation framework is required, which corroborates current research objectives.

3 | PROPOSED FRAMEWORK

3.1 | Research design

In the absence of proper frameworks for evaluating the CE performance of SMEs, the current study aims to evaluate the CE performance of FPSMEs in a developing country. Since there are no prior studies available that explore important performance criteria, a mix of qualitative and quantitative method approaches is necessary. The qualitative method includes an extant literature review and expert survey in the quest for potentially influential CE performance criteria that are refined via a Delphi study. The quantitative method includes the evaluation of the criteria and alternatives using an integrated MCDM approach. CE performance assessment is an MCDM-type problem, as it evaluates multiple criteria and alternatives and simultaneously reaches the most optimal decision. Although several MCDM tools are available, such as simple additive weighting or SAW (Ghosh, Bhowmik, et al., 2021), AHP (Ghosh et al., 2022a), TOPSIS (Ghosh et al., 2021a), COPRAS (Ghosh et al., 2022d), and GRA (Ghosh et al., 2022b), this research applies an integrated CRITIC-VIKOR approach that has not been previously used in this area. It adopts a three-phase methodology, namely, Phase 1: preparation phase, Phase 2: weight determination phase, and Phase 3: evaluation phase. Figure 1 shows the methodology framework.

In Phase 1, performance evaluation criteria are identified from the literature. The expert committee verifies and finalizes the list of criteria identified from the literature. Then, necessary data are gathered via questionnaire administration and interviews with selected industry experts. In Phase 2, the objective weights of the criteria are calculated by applying the CRITIC method. In Phase 3, weights obtained from the CRITIC method are employed in the VIKOR method. By computing VIKOR indices, the performances of alternatives (case organizations) are determined, and alternatives are ranked accordingly. The stepwise procedures for CRITIC and VIKOR methods are given in the following sub-sections.

3.2 | CRITIC method

CRITIC is a criterion weighting tool used when the model criteria are correlated. Other MCDM tools like AHP are effective only when the criteria are independent and qualitative (Awasthi et al., 2018; Das et al., 2020). The utility of this method is mainly two-fold: (i) The contrast intensity that illustrates each criterion individually is quantified based on the standard deviation, and (ii) the degree of disagreement or conflict among criteria is measured based on the linear correlation coefficients. CRITIC has several applications in decision-making fields, such as performance evaluation of SC (Kozarević & Puška, 2018), SC risk management (Abdel-Basset & Mohamed, 2019), and sustainable supplier selection (Rostamzadeh et al., 2018). The stepwise procedure of the CRITIC method is shown below:

Step 1: In this step, a data matrix $[x_{ij}]_{m\times n}$ including m alternatives and n criteria is constructed, which expresses the performance measure (x_{ij}) of i^{th} alternative concerning j^{th} criterion ($1 \le i \le m; 1 \le j \le n$) as shown below:

$$[x_{ij}]_{m\times n} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}.$$

Step 2: In this step, the normalized data matrix $[\overline{x_{ij}}]_{m\times n}$ is developed using Equation (1) and Equation (2). $\overline{x_{ij}}$ is the normalized performance measure of i^{th} alternative concerning j^{th} criterion.

$$\overline{x_{ij}} = \frac{x_{ij} - x_j^{worst}}{x_j^{best} - x_j^{worst}}, \text{when the criterion is of benefit type} \quad (1)$$

$$\overline{x_{ij}} = \frac{x_j^{best} - x_{ij}}{x_j^{best} - x_j^{worst}}, \text{when the criterion is of cost type} \quad (2)$$

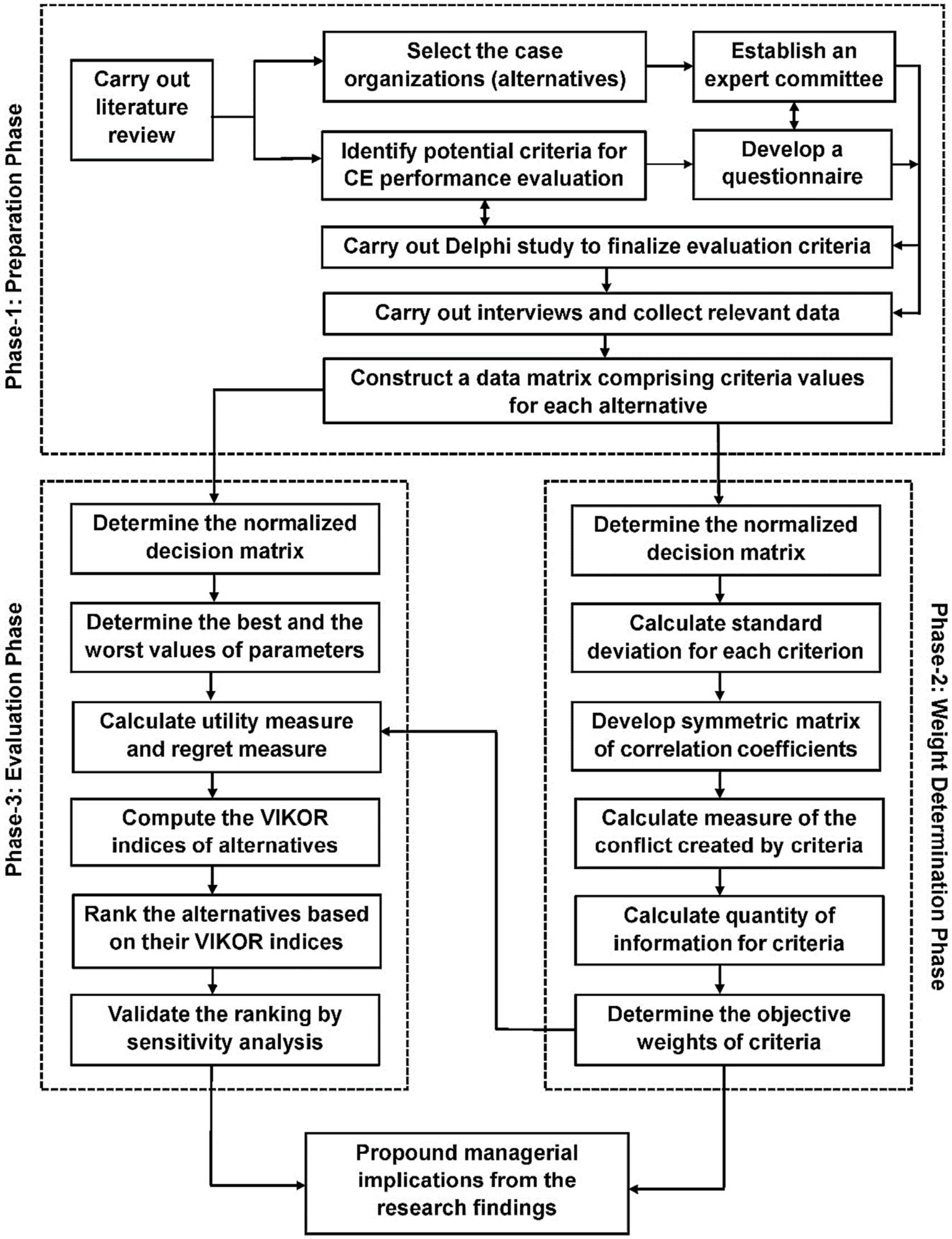


FIGURE 1 Flowchart of methodology framework.

In the above two equations, x_j^{best} is the best performance of the j^{th} criterion and x_j^{worst} is the worst performance of the j^{th} criterion. x_j^{best} and x_j^{worst} are determined as follows:

$$x_j^{best} = \begin{cases} max_i(x_{ij}), \text{ If the criterion is of benefit type} \\ min_i(x_{ij}), \text{If the criterion is of cost type} \end{cases}$$

$$x_j^{worst} = \begin{cases} min_i(x_{ij}), \text{ If the criterion is of benefit type} \\ max_i(x_{ij}), \text{ If the criterion is of cost type} \end{cases}$$

Step 3: In this step, the standard deviation (SD) (σ_j) value is calculated for each criterion separately.

Step 4: In this step, a symmetric matrix $[r_{jj'}]_{n\times n}$ is constructed, in which $r_{jj'}$ represents the linear correlation coefficient between j^{th} and j'^{th} criterion.

Step 5: In this step, the measure of the conflict (M_j) created by the j^{th} criterion concerning the decision situation defined by the rest of the criteria, is calculated using Equation (3)

$$M_j = \sum_{j'=1}^{n} (1 - r_{jj'}) \quad (3)$$

Step 6: In this step, the quantity of the (C_j) about each criterion is calculated using Equation (4)

$$C_j = \sigma_j \times M_j = \sigma_j \times \sum_{j'=1}^{n} (1 - r_{jj'}) \quad (4)$$

Step 7: In this step, the value of information transmitted by each criterion is normalized using Equation (5), which, in turn, reveals the objective weight of each criterion (w_j).

$$w_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \quad (5)$$

3.3 | VIKOR method

VIKOR was developed by Serafim Opricovic in 1998 and later extended to solve MCDM problems (Opricovic & Tzeng, 2002). VIKOR is used to rank and select the most optimal alternative by determining compromise solutions for a problem with multiple conflicting criteria. This method has been applied widely for solving MCDM problems in various fields, such as sustainable supplier selection (Awasthi et al., 2018), green supplier selection (Wu et al., 2019), resilient supplier selection (Valipour Parkouhi & Safaei Ghadikolaei, 2017), and multi-criteria group decision-making problems (Shemshadi et al., 2011). The steps of the VIKOR method are given below:

Step 1: In this step, a data matrix with m alternatives and n criteria is constructed, which is similar to that of the CRITIC method.

Step 2: In this step, the normalized decision matrix $[f_{ij}]_{m \times n}$ is developed, in which f_{ij} is determined using Equation (6).

$$f_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad (6)$$

Step 3: In this step, the utility measure and the regret measure are calculated for each alternative. This helps to determine compromise solutions based on the negotiated preferences of DMs. To this end, a $L_{p,i} - metric$ is formed using Equation (7), which is used as an aggregating function in determining compromise solutions.

$$L_{p,i} = \left\{ \sum_{j=1}^{n} \left[w_j \left(f_j^* - f_{ij}\right) / \left(f_j^* - f_j^-\right) \right]^p \right\}^{1/p}; (1 \le p \le \infty) \quad (7)$$

In the above equation, w_j is the corresponding weight of the j^{th} criterion, obtained from the CRITIC method. Conversely, f_j^* is the best value and f_j^- is the worst value of each criterion and determined as follows:

$$f_j^* = \begin{cases} \max_i f_{ij}, & \text{If the criterion is of benefit type} \\ \min_i f_{ij}, & \text{If the criterion is of cost type} \end{cases}$$

$$f_j^- = \begin{cases} \min_i f_{ij}, & \text{If the criterion is of benefit type} \\ \max_i f_{ij}, & \text{If the criterion is of cost type} \end{cases}$$

$L_{1,i}$ is defined as "the maximum group utility of majority" or S_i, and $L_{\infty,i}$ is defined as "the minimum individual regret of the opponent" or R_i. The S_i and R_i values are expressed in Equation (8) and Equation (9), respectively.

$$S_i = L_{1,i} = \sum_{j=1}^{n} w_j \frac{\left(f_j^* - f_{ij}\right)}{\left(f_j^* - f_j^-\right)} \quad (8)$$

$$R_i = L_{\infty,i} = \max_j \sum_{j=1}^{n} w_j \frac{\left(f_j^* - f_{ij}\right)}{\left(f_j^* - f_j^-\right)} \quad (9)$$

Step 4: In this step, the VIKOR index (Q_i) is computed using Equation (10).

$$Q_i = v \times \frac{(S_i - S^-)}{(S^* - S^-)} + (1 - v) \times \frac{(R_i - R^-)}{(R^* - R^-)} \quad (10)$$

In the above equation, $S^* = \max_i(S_i)$, $S^- = \min_i(S_i)$, $R^* = \max_i(R_i)$, $R^- = \min_i(R_i)$, and $v \in [0,1]$ denotes the strategy of the maximum group utility. Presently, its value is set to 0.50. Finally, the alternatives are ranked based on the decreasing order of Q.

4 | A REAL-WORLD APPLICATION

To examine the viability of the proposed framework, the performance evaluation framework proposed in this research is applied to three leading FPSMEs in India.

4.1 | Industrial background

According to a World Economic Forum report (World Economic Forum, 2022), CE practices might save \$1 trillion per year due to decreasing ecological impact and reliance on finite resources. According to estimates, India may unleash \$0.5 trillion in economic value by implementing CE practices by 2030 (Dey et al., 2020). On the contrary, SMEs have been regarded as one of the prime movers of Indian economy because of their multifaceted contributions in terms of collective productivity, job creation, export promotion, and overall gross domestic product. Nowadays, the concerns for CE practices implementation become high in SMEs as these firms continually consume natural resources. The FPI largely dominates the Indian economy. It is the principal source of livelihood for approximately half of the country's population. The Indian FPI consists of the following units: agri-food chains, restaurants, beverages processing plants, rice and oil mills, cold storages, dairy firms, and spices, snacks, confectionery, and other perishable food item producers. The Indian FPI is mainly dominated by SMEs. The implementation of CE practices at the micro level especially food processing and packaging SMEs can be a booming opportunity for achieving sustainability in Indian FSC. Incorporating CE practices across the supply network of SMEs in India is arguably in its embryonic phase, both empirically and practically. Therefore, this research targets Indian FPSME for evaluation and possible performance improvement.

4.2 | Selection of the case organizations

Due to the organization's privacy policies, the detailed information of the SMEs is not disclosed in this research. Instead, they are abbreviated as *SME*1, *SME*2, and *SME*3. The selected SMEs are presently located in West Bengal, a North-Indian state of India. These SMEs encompass a broad range of CE-relevant characteristics and circular potentials within their products, processes, and services. The selected SMEs have been in operation for the past 40 years. There were recent ventures in the top management of respective SMEs to nurture CE-focused cultures. Several endeavors have already been taken to foster material recovery and reuse, remanufacturing used products, and recycling. However, they are optimizing design for durability and design for reusing for their packaging components to maximize resource utilization. They have also started evaluating environmental auditing and green supplier engagement programs to build a CE environment within the organizations. They are interested in evaluating their CE performance and comparing it with other leading SMEs in the market; however, the policymakers have been facing difficulties in evaluating CE performances and managing allied practices in the SC. A brief business profile of the case SMEs is given in Table 3.

4.3 | Formation of an experts' committee

There is no specific rule about the number of experts to be selected for data collection. Murry and Hammons (1995) suggested 10 to 30, whereas Paul et al. (2021) suggested 10 experts. In this research, initially, 20 experts were approached from diverse domains, including public sector officials, managerial executives from different levels of case SMEs (strategic, tactical, and operational), business officials, and academicians from prestigious institutes. The experts communicated via e-mail conversations, telephone calls, WhatsApp chats, and physical site visits. The experts were chosen based on their area of specialization and expertise in SC operations and CE-related practices, along with a minimum corporate experience of 10 years. The snowball sampling method has also been adopted for expert selection. After approaching one expert, he referred the authors to another specialist in the same field who has great expertise and understanding of our study topic. Out of the 20 experts, 15 accepted the invitations and showed eagerness in this evaluation project, resulting in an approximate 75% response rate. Among the 15 experts, nine are from the three cases of SMEs, and the rest are from other domains. There are many prior researches utilizing a limited number of experts compared to data-driven approaches. On the contrary, expert systems allow us to rely on a smaller number of experts. As a result, we continued with the 15 experts and it seemed to be enough for making accurate decisions. They are willing to develop CE business frameworks and support organizational missions to achieve CE goals. The detailed demographic information of experts is given in Table 4.

4.4 | Identification of evaluation criteria

Due to the scarcity of research exploring a suitable set of quantitative criteria for CE performance evaluation, a thorough review of literature

TABLE 3 Brief profile of case organizations.

Name	SME1	SME2	SME3
Industry type	Food processing	Food processing	Food processing
Annual turnover	172 crore INR	135 crore INR	94 crore INR
Types of food products manufactured	Nutrient supplements, refreshing beverages, energy drinks, soft drinks, juices, health drinks, packaged drinking water, canned foods, sauces	Bakeries, cakes, biscuits, snack foods, chips, crisps, breakfast cereals, spices, condiments, fruit pickles, refined oil, rice, flour, pulses, processed grains	Dairy products (butter, ghee), sweet, sugar and confectioneries, dry and ripe fruits, chocolates, noodles, ice cream, jams, honey, frozen foods
Number of raw materials, suppliers	135	80	97
Number of manufacturing facilities and service outlets	22	17	12
Number of employees	220	180	167

TABLE 4 Demographic profile of experts.

Expert	Gender, male/female	Experience (Years)	Academic qualification	Job role/designation	Affiliation/organization
1	M	12	M.Tech. in production engineering	Operations manager	SME1
2	F	14	MBA in human resource management	Planning executive	SME1
3	F	12	M.Com. in finance	Chief financial officer	SME1
4	M	13	M.Tech. in reliability engineering	Maintenance supervisor	SME2
5	M	18	Ph.D. in supply chain management	Production manager	SME2
6	M	16	MBA in marketing	Chief marketing officer	SME2
7	M	17	B.Tech. in manufacturing engineering	Procurement manager	SME3
8	M	15	B.Tech. in civil engineering	Project manager	SME3
9	F	21	M.Sc. in chemistry	Quality control officer	SME3
10	M	20	M.Sc. in public nutrition	Food safety officer	Food corporation of India
11	M	11	Ph.D. in operations management	Researcher	Multinational corporation
12	F	22	BBA in information systems	Consultant	Freight consulting agency
13	F	14	MBA in Entrepreneurship	Entrepreneur	Sole proprietorship business
14	M	25	Ph.D. in mechanical engineering	Professor	Public university
15	F	30	Ph.D. in industrial engineering	Professor	Public university

and documentary analysis on "Circular economy," "Circular economy performance evaluation," "Food processing SME," and so forth were performed by browsing the key platforms of peer-reviewed scholarly articles, such as IEEE Xplore, Wiley, Scopus, Web of Science, and Science Direct, within the time range of 2015 to 2022. Although CE is not a new concept in business management, it has captured the interest of academicians, industry practitioners, and policymakers in the past decade. Before 2015, no relevant research was published that addressed the adoption of CE practices in FPSME. Right now, there are just a few scholarly articles that have been conducted in the context of FPSME. This motivates the authors to carry out a systematic literature review of research papers published within the last 7 years from 2015 to 2022. Afterward, the PRISMA protocol was adopted to browse the Scopus and Web of Science databases by a list of specified search strings in the field of CE. A Google Scholar search was also added to supplement the original findings. A literature review on various topics such as "circular economy," "circular supplier selection," "sustainability," "performance evaluation," "sustainable supply chain management," "circular supply chain," "green supply chain management," and "reverse logistics" was conducted because the philosophies lying inside these concepts significantly interfere with the CE concept. Furthermore, the identified papers have been assessed to consider the research objectives; therefore, only articles fulfilling the search requirements are selected using the PRISMA protocol (Moslem et al., 2023; Streimikis & Saraji, 2022). The following criteria apply to inclusion: (i) Search keywords must be in the title, abstract, or index terms, and (ii) research papers must be published in scientific peer-reviewed journals, review papers, editorials, Ph.D. theses, book chapters, conference proceedings, and so forth. Considering all, 55 articles have been selected after segregating >150 publications. After studying these papers, 18 evaluation criteria were figured out, which seemed to have the potential for CE performance evaluation.

4.5 | Finalization of evaluation criteria through a Delphi study

After initial identification of the criteria, it was sent to all the 15 experts and a Delphi study was carried out to refine and finalize the criteria based on their vitality for CE performance evaluation problems. The Delphi study is a process for organizing group discussions that is structured and recurrent and is used to achieve consensus on a complex topic. It was utilized in this research since it has previously been used successfully in studies focusing on framework development (Kumar, Raut, Sharma, et al., 2022). This method is useful in this context for defining and quantifying the degree of relevance of each criterion in evaluating SMEs' CE performance. Furthermore, this method was selected because it enables for better accessibility to the perspectives of several experts from various regions. It is also confidential and recursive, giving the group controlled and statistical feedback. The Delphi study was designed into three rounds of review with the help of Google Forms. At the completion of each round, a full summary of the cumulative findings as well as comments from the anonymous experts were supplied to the experts. The first round of Delphi questions began with a quick poll on the concept of the CE

TABLE 5 Validation of criteria via Delphi study.

No.	Criteria	Mean	Median	SD	Approved/declined?
Original criteria (identified from literature review)					
1	Reduced resource consumption by designing products for effective resource utilization	4.4000	4	0.632460	Approved
2	Investment in CSR	4.6000	5	0.547720	Approved
3	Average return on investment	4.1428	4	1.715170	Approved
4	Investment in research and development	2.6000	3	0.54772	Declined
5	Reduction in water consumption	4.2000	5	1.207120	Approved
6	Reduction in toxic material consumption	3.8000	4	0.836666	Declined
7	Wastewater treatment capacity	4.1428	4	0.848280	Approved
8	Use of renewable energy	4.0714	4	0.813250	Approved
9	Reduced emissions from logistics operations	3.6666	5	1.799470	Declined
10	Savings in total energy cost	4.2000	5	1.082330	Approved
11	Total wastewater	4.2000	4	0.774597	Approved
12	Total water consumption	4.0000	4	0.925820	Approved
13	Total waste generation	4.2666	5	0.883715	Approved
14	Increase in scrap recycling rate	4.5333	5	0.743223	Approved
15	Reduction in environmental risk	3.4000	3	1.055600	Declined
16	Increase in sustainable sourcing rate	3.3333	3	1.234430	Declined
17	Returns from the sale of recycled waste products	4.0666	4	0.798809	Approved
18	Total CO_2 emission	4.1333	4	0.990430	Approved
Newly added criteria (adopted from experts' suggestions)					
1	Total outreach of health and hygiene program	4.0000	4	0.860660	Approved
2	Efficiency of waste heat recovery	4.0357	4	0.838080	Approved

Note: Experts, please give your rating for the importance of criteria. How are the criteria relevant for CE performance in your respective organizations?

approach to portray a coherent viewpoint among experts from the start of the investigation. However, the growth of CE knowledge concerning the research framework was subsequently addressed to the experts via an easy-to-understand interactive documentary. It was essential to ensure such knowledge of the issue to gain higher accuracy in the responses and prevent misinterpretations and illogical conclusions. In the second round, the experts were asked to check the relevance of the identified criteria by simply indicating "Yes" as relevant and "No" as irrelevant. Moreover, experts were requested to suggest any new criteria that might be relevant to CE performance in their respective domains according to their knowledge and experience. Afterward, two additional criteria ("Total outreach of health and hygiene program" and "Efficiency of waste heat recovery") were suggested by two experts. Thus, a total of 20 criteria were considered for the next round. In the third round, experts were asked to assess the importance of each criterion in the evaluation of CE performance based on a five-point Likert-type scale (Ghosh et al., 2022a), in which 1 implies "not important," 5 implies "extremely important," and the remaining imply intermediate qualities. Then, the responses received from the experts were synthesized in MINITAB software. Descriptive analysis was performed by calculating various statistical parameters such as mean, median, and standard deviation (SD). As per the proposed model by Kumar, Raut, Sharma, et al. (2022), criteria with a mean and median value of more than 4 (*threshold limit*) were accepted, while others were rejected. The original list of criteria and their statistical scores are shown in Table 5. Results showed that the mean and median values of the five criteria failed to reach the threshold limit. Hence, they were rejected. Finally, 15 criteria came out as the final criteria for CE performance evaluation, shown in Table 6. The final set of criteria encompasses environmental, economic, social, and operational dimensions.

4.6 | Instrument development and data collection

To facilitate the data collection for this research, a structured set of questionnaires was prepared in terms of CE practices and performance, which consisted of a series of standardized questions with fixed objectives. The first section comprises the queries regarding the demographic details of the experts. The second section contains queries regarding the scope of the study. The last section comprises questions related to additional information such as suggestions, improvement measures, and strategies. The questionnaire briefly described each criterion to guide the experts. Before employing the questionnaire in data collection, it was pre-tested using a pilot study with the experts' committee and five SC experts from a leading MNC (not included in the expert committee) for any potential improvement. The questionnaire was modified twice based on the feedback of

TABLE 6 Final set of criteria for CE performance evaluation.

Criteria	Unit	Dimension	Type
Reduced resource consumption by designing products for effective resource utilization (C1)	MT/Year	Operational	Benefit
Investment in CSR (C2)	Lakh (INR)/Year	Social	Benefit
Average return on investment (C3)	NA	Economic	Benefit
Reduction in water consumption (C4)	NA	Environmental	Benefit
Efficiency of waste heat recovery (C5)	NA	Operational	Benefit
Wastewater treatment capacity (C6)	Cubic meter/hour	Operational	Benefit
Use of renewable energy (C7)	%	Environmental	Benefit
Savings in total energy cost (C8)	Lakh (INR)/Year	Economic	Benefit
Increase in scrap recycling rate (C9)	%	Operational	Benefit
Total outreach of health and hygiene program (C10)	NA	Social	Benefit
Returns from sale of recycled waste products (C11)	Lakh (INR)/Year	Economic	Benefit
Total CO_2 emission (C12)	Tons/Year	Environmental	Cost
Total water consumption (C13)	Million Litre	Environmental	Cost
Total waste generation (C14)	Tons	Environmental	Cost
Total wastewater (C15)	Kilo Litre	Environmental	Cost

TABLE 7 Original data matrix.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
SME1	293	25.91	5.7	35	23	50	30	12.75	22.7	835,433	10.23	698,000	27.25	136,717	480,000
SME2	288	22.90	16	18	27	65	27	8.769	15.8	998,563	27.62	772,000	300	98,676	393,600
SME3	168	291	4.56	22	13	22	65	9.567	26	547,886	9.97	553,000	25.6	77,356	520,000

experts to ensure content validity and eliminate possible bias factors. The questionnaire contains three separate sections. Both the hard-copy and e-copy of the questionnaire were prepared and sent to the individual experts of the case SMEs.

Due to confined knowledge in this context, making a large sample size for case-specific research was challenging. Hence, this research was carried out using the data collected particularly for the case study SMEs. Before beginning the data collection, the current research's aim and objectives were explained clearly to the managerial representatives of the case organizations, and how the collected data would be used was also explained to them. To eliminate expert bias in the data curation process, face-to-face interviews were arranged, and interviews with each of the nine experts were held separately. Later, responses obtained from the experts were compiled together. Also, data in secondary forms were collected from company websites, annual reports, and historical databases.

4.7 | Data analysis

After sorting and segregating the collected data, the final data matrix was developed, as shown in Table 7. The data were analyzed with the Microsoft Excel application. The data analysis was conducted in two different steps, as presented below:

4.7.1 | Calculating relative weights of criteria using the CRITIC method

In this step, the CRITIC method is adopted to calculate the objective weights of the criteria. A data matrix (3 × 15) using criteria values is formed as shown in Table 6. Then, the data matrix is normalized using Equation (1) and Equation (2) and shown in Table A1 (see Appendix A). Next, SD values (σ_j) are calculated for each criterion and shown in Table A2 (see Appendix A). Then, a (15 × 15) symmetric matrix is formed as shown in Table A3 (see Appendix A). The measure of conflict (M_j) is calculated using Equation (3) and shown in Table A4 (see Appendix A). The quantity of information about each criterion (C_j) is determined using Equation (4), as shown in Table 8. Finally, the objective weights (w_j) of criteria are derived using Equation (5) and shown in Table 8.

4.7.2 | Calculating the performances of case SMEs using the VIKOR method

In this step, the VIKOR method is adopted to compute the performance of case SMEs and rank them accordingly. The data matrix is developed using the collected data, as shown in Table 7. After constructing the data matrix, the next step is to normalize the data matrix

TABLE 8 Objective weights of criteria.

Criteria	C_j	w_j
C1	7.750033795	0.064941
C2	9.367350989	0.078494
C3	7.808977277	0.065435
C4	7.68186957	0.064370
C5	7.064005947	0.059193
C6	6.972634023	0.058427
C7	9.071773293	0.076017
C8	7.748869298	0.064932
C9	8.1837296	0.068576
C10	6.958363349	0.058308
C11	8.172339212	0.068480
C12	8.274722279	0.069338
C13	9.056214757	0.075887
C14	8.088592637	0.067778
C15	7.139388341	0.059825

using Equation (6) as shown in Table A5 (see Appendix A). Then, the best (f_j^*) and the worst (f_j^-) values of all criteria are calculated and shown in Table A6 (see Appendix A). Then, the utility measure for each alternative is calculated using Equation (7) and shown in Table A7 (See Appendix A). The values of the maximum group utility (S_i) and minimum individual regret (R_i) are determined using Equations (8) and (9) and presented in Table 9. The VIKOR index (Q_i) is computed for each alternative using Equation (10). Finally, the case SMEs are ranked based on the ascending order of Q value as given in Table 9. The value of the VIKOR index of *SME*1 (0.455997) is the lowest, while the VIKOR index of *SME*3 and *SME*2 are 0.500000 and 0.785634, respectively. Therefore, *SME*1 secures the first rank. The ranking of case SMEs in the order of their CE performance is as follows: *SME*1 > *SME*3 > *SME*2.

4.8 | Sensitivity analysis

To examine the robustness of the results, this research follows a sensitivity analysis proposed by Ghosh et al. (2022a). Sensitivity analysis indicates how the change in an input variable affects a resultant variable in a specific case. In this study, to analyze the sensitivity of the results, the selection index (SI_i) is calculated for each alternative using the equations proposed by Ray et al. (2010):

$$SI_i = \alpha \times SFM_i + (1-\alpha) \times OFM_i \tag{11}$$

$$OFM_i = \left[OFCM_i \times \sum_{i=1}^{n} OFCM_i^{-1}\right]^{-1} \tag{12}$$

In Equation (11), SI_i is the resultant variable and both $SFM_i, \alpha,$ and OFM_i are input variables. SFM_i denotes the subjective factor measure or ordinal measure of the i^{th} alternative. In this research, *SFM* values are extracted from the VIKOR indices (Q values in Table 9) of the alternatives. OFM_i is the objective factor measure or cardinal measure of the i^{th} alternative. *OFM* values are designed in such a way that indicates a non-dimensional quantity of contribution margin of each alternative. In equation (12), $OFCM_i$ is the objective factor contribution margin of the i^{th} alternative, which is defined as the performance measure (x_{ij}) of that alternative corresponding to the j^{th} criterion. The α value ($0 \le \alpha \le 1$) represents the attitude of the DM or the DM's preference for a particular j^{th} criterion. The DM's attitude plays a vital role in selecting an optimal alternative. However, existing sensitivity analysis models overlook the DM's attitude toward evaluation criteria (Ghosh et al., 2022b). Hence, *SFM* values are fixed values, but α, and *OFM* values are changed when the DM changes his/her preference for each criterion. The larger the SI_i value, the higher is the preference of the corresponding alternative. Thus, a sensitivity analysis is carried out in this research to understand the effect of changes in α, and *OFM* values on the *SI* value for the priority ranking of the alternatives.

TABLE 9 Final ranking of case organizations.

SMEs	S_i	R_i	Q_i	Rank
*SME*1	0.50964	0.07761	0.455997	1
*SME*2	0.52455	0.07849	0.785634	3
*SME*3	0.53575	0.06848	0.500000	2

In this research, out of 15 criteria, five($C2, C7, C13, C12,$ and $C9$) emerge as the top five influential criteria for CE performance since these criteria gained relatively higher weights than others. Therefore, five different cases are considered in the sensitivity analysis, where DM changes his/her preference for each of the five influential criteria accordingly. The following five cases show the variation in the selection priority of the case organizations (i.e., *SME*1, *SME*2, and *SME*3) concerning the variation in the attitude of DM.

4.8.1 | Case 1: When DM prefers/emphasizes C2 over other influential criteria

Figure 2 clearly shows that when the α value is 1, *SME*1 holds the first rank with a *SI* value of 0.79 (approx.). *SME*3 and *SME*2 hold the second and last positions with *SI* values of 0.50 and 0.45, respectively. *SME*1 remains the best alternative throughout the range of α values (from 0 to 1). In this case, break-even occurs in the selection of *SME*3 and *SME*2 at a α value of 0.9 (approx.). It means that when α value is 0.9, either *SME*3 or *SME*2 can be preferred. *SME*2 should be preferred over *SME*3, when α value lies between 0 and 0.9. However, again, *SME*3 should be preferred over *SME*2 when α value ranges from 0.9 to 1. Hence, the ultimate ranking of SMEs in this particular case is as follows: *SME*1 > *SME*3 > *SME*2.

FIGURE 2 Sensitivity graph (Case 1).

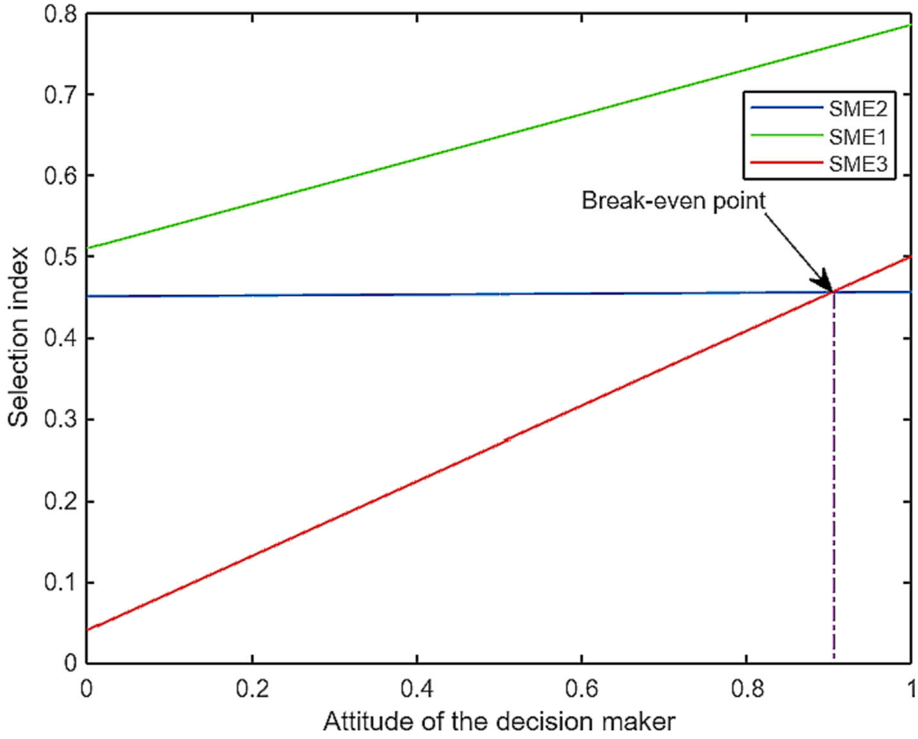
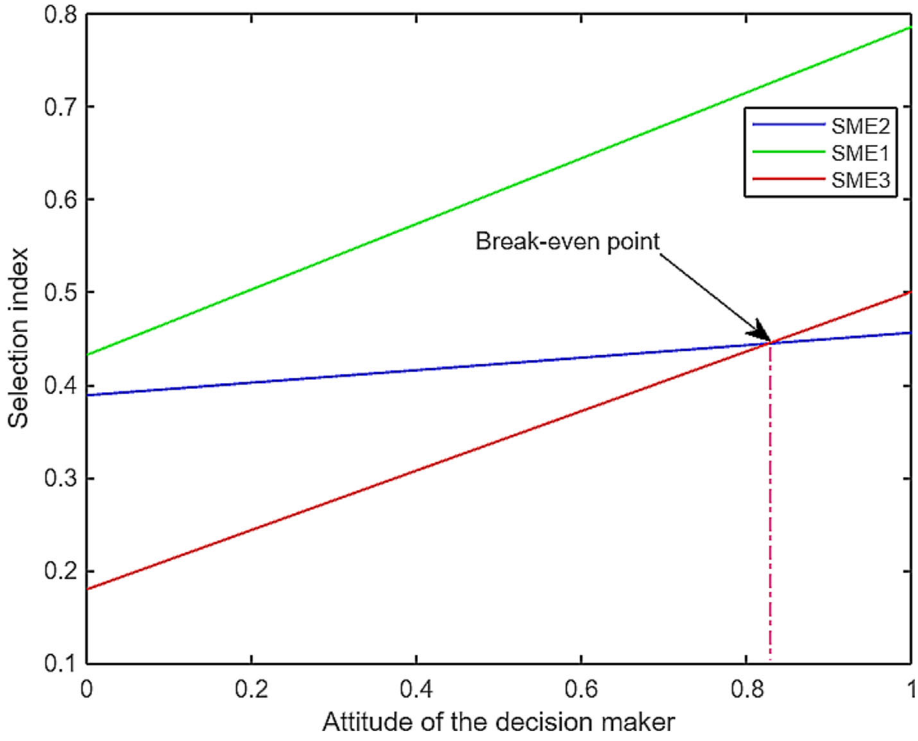


FIGURE 3 Sensitivity graph (Case 2).



4.8.2 | Case 2: When DM prefers/emphasizes C7 over other influential criteria

Figure 3 shows that *SME*1 remains the best alternative throughout the range of α values (from 0 to 1). In this case, break-even occurs in the selection of *SME*3 and *SME*2 at a α value of 0.82 (approx.). It means that when the α value is 0.82, any one of *SME*3 and *SME*2 can be preferred. *SME*2 should be preferred over *SME*3, when α value lies between 0 and 0.82. However, *SME*3 should be preferred over *SME*2 when α value diverges from 0.82 to 1. Hence, the final ranking of SMEs, in this case, is as follows: *SME*1 > *SME*3 > *SME*2.

4.8.3 | Case 3: When DM prefers/emphasizes C13 over other influential criteria

Figure 4 shows that two break-evens occur at a α value of 0.58 (approx.) and 0.61 (approx.), respectively. When α value is 0.61, either *SME*1 or *SME*3 can be preferred. When α value varies between 0 and 0.61, *SME*3 should be preferred over *SME*2, and *SME*1. When α value varies from 0.61 to 1, *SME*1 should be preferred over *SME*3, and *SME*2. Similarly, when α value is 0.58, either *SME*1 or *SME*2 can be preferred. When α value lies between 0 and 0.58, *SME*2 should be preferred over *SME*1. When α value exceeds 0.58, *SME*1 should be preferred over *SME*2. Considering the α value as 1, the final ranking of SMEs, in this case, is as follows: *SME*1 > *SME*3 > *SME*2.

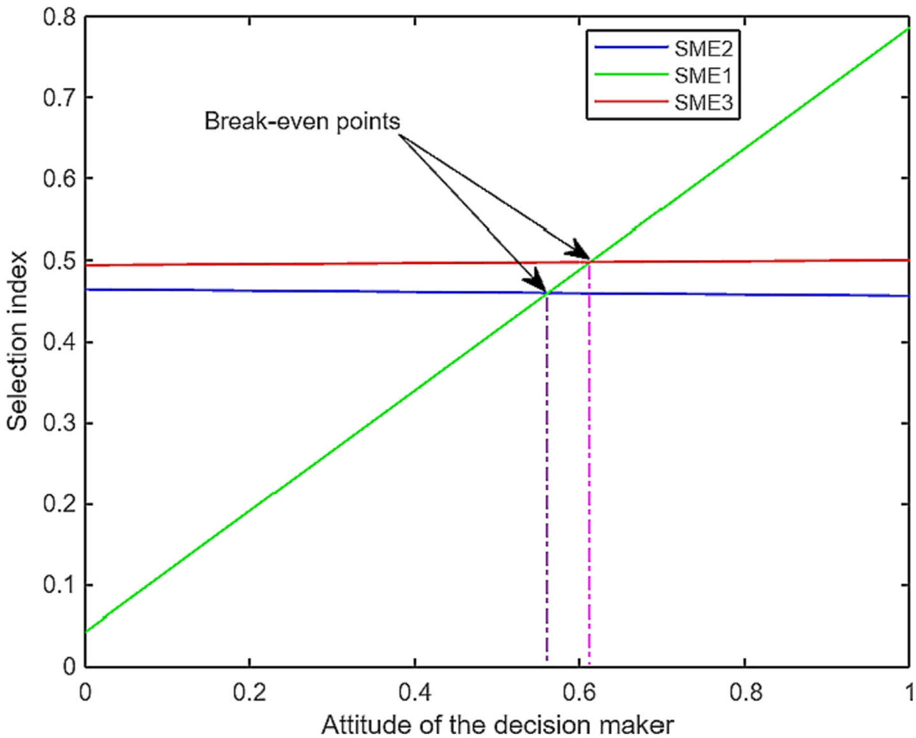


FIGURE 4 Sensitivity graph (Case 3).

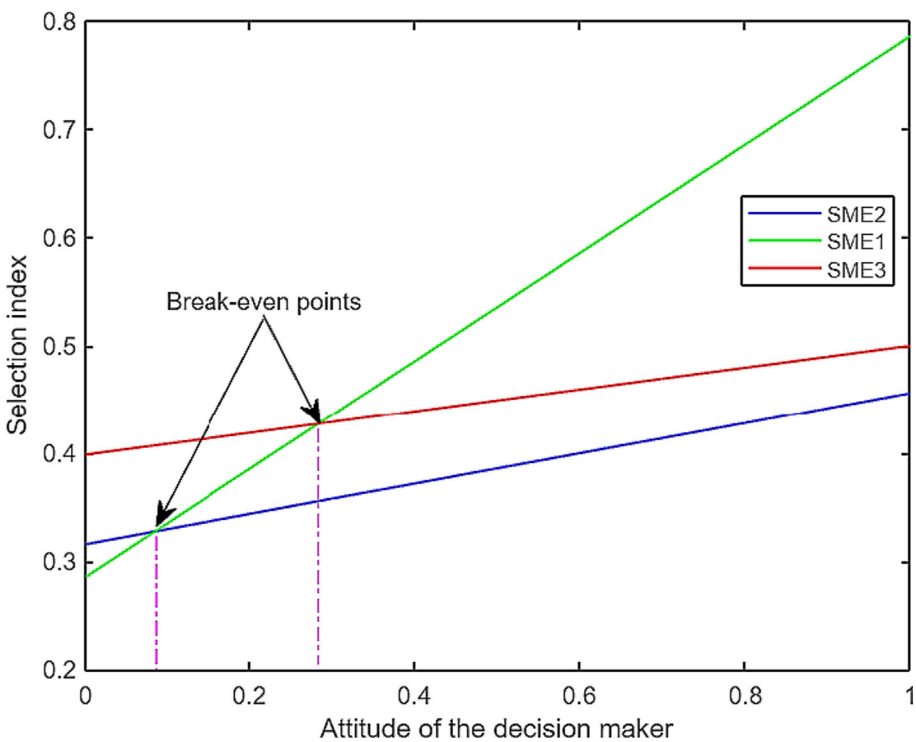


FIGURE 5 Sensitivity graph (Case 4).

4.8.4 | Case 4: When DM prefers/emphasizes C12 over other influential criteria

Figure 5 shows that two break-evens occur at a α value of 0.10 (approx.) and 0.30 (approx.), respectively. When α value is 0.10, either *SME*1 or *SME*2 can be preferred. When α value is less than 0.10, then *SME*2 should be preferred over *SME*1. When α value exceeds 0.10, then *SME*1 should be preferred over *SME*2. Similarly, when α value is 0.30, either *SME*1 or *SME*3 can be preferred. When α value is less than 0.30, *SME*3 should be preferred over *SME*2 and *SME*1. When α value varies from 0.30 and 1, *SME*1 should be preferred over *SME*3 and *SME*2. Considering the α value as 1, the final ranking of SMEs, in this case, is as follows: *SME*1 > *SME*3 > *SME*2.

4.8.5 | Case 5: When DM prefers/emphasizes C9 over other influential criteria

Figure 6 clearly shows that *SME*1 remains the best alternative throughout the range of α value (from 0 to 1). In this case, break-even occurs in the selection of *SME*3 and *SME*2 at a α value of 0.48 (approx.). It means that when the α value is 0.48, either *SME*3 or *SME*2 can be preferred. *SME*2 should be preferred over *SME*3, when α value lies between 0 and 0.48. Conversely, *SME*3 should be preferred over *SME*2 when α value exceeds 0.48. Considering the α value as 1, the final ranking of SMEs, in this case, is as follows: *SME*1 > *SME*3 > *SME*2.

It is found that the ranking of SMEs in all the above five cases remains the same as that of the original ranking obtained from the integrated CRITIC-VIKOR approach. However, the ranking is not altered even when the DM changes his/her priority over a particular criterion. This justifies the robustness of the research findings.

5 | RESULTS ANALYSIS AND DISCUSSIONS

The proposed research framework was validated through a real-world case study, in which three Indian FPSMEs were considered for CE performance evaluation. With the help of a rigorous literature review and a Delphi study, 15 criteria were identified and prioritized using the CRITIC method. Based on the objective weights, the criteria are ranked as follows: *C*2 > *C*7 > *C*13 > *C*12 > *C*9 > *C*11 > *C*14 > *C*3 > *C*1 > *C*8 > *C*4 > *C*15 > *C*5 > *C*6 > *C*10.

The essential criterion emerges as "Investment in CSR (*C*2)" with a weight of 0.078494, which is the focus of the CE performance evaluation. Other studies in the literature also recognized that CSR practices contribute significantly to CE performance. For example, Fortunati et al. (2020) argued that CSR and CE are interrelated concepts, and CSR is an adequate tool to support CE implementation. "Use of renewable energy (*C*7)" is ranked just after *C*2 with a weight of 0.076017 and measures whether renewable energy resources may be leveraged to achieve greater energy efficiency. This criterion is widely documented in the CE literature, "green supply chain management," and "sustainable supply chain management." It is critically important to utilize renewable energy for the effective implementation of CE and to abate pollution levels. "Total water consumption (*C*13)" comes next with a weight of 0.075887, which

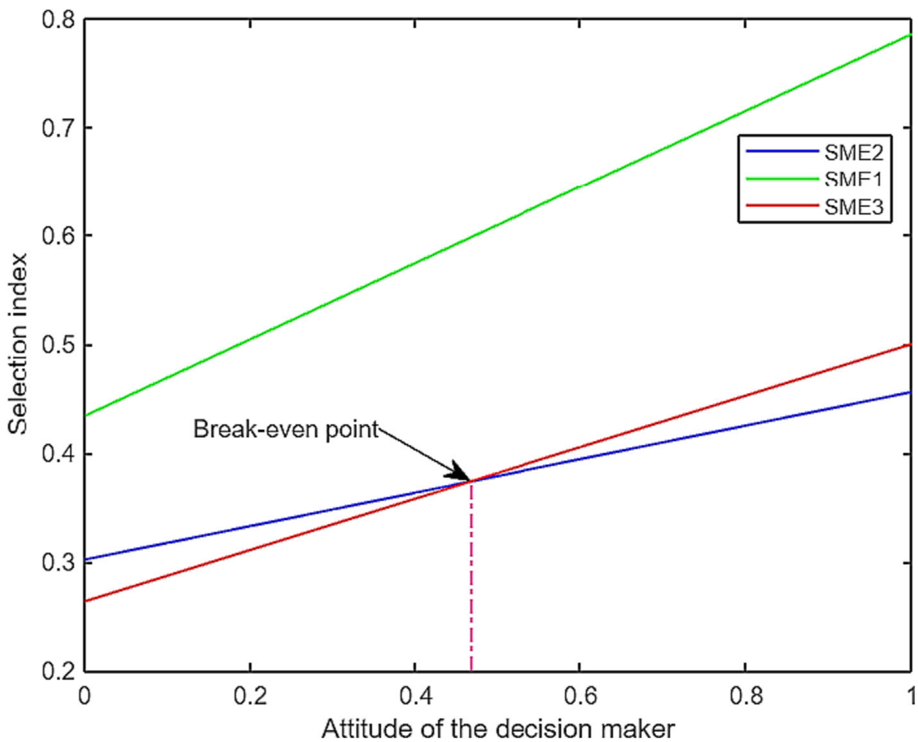


FIGURE 6 Sensitivity graph (Case 5).

signifies that SMEs should be more careful about freshwater consumption. Given the global problem of water scarcity and the criticality of water management in mitigating the water crisis, it has become critical to monitor the amount of freshwater extracted by industry. To achieve CE goals, SMEs can reduce water consumption by following processes like sewerage and wastewater treatment, and looping water consumption process (Sugiyono & Dewancker, 2020). "Total CO_2 emission ($C12$)" holds the next rank with the weight of 0.069338. This emphasizes that SMEs should reduce total CO_2 emissions in their production process, reducing the environmental burden. Implementing CE practices can cut billions of tons of total CO_2 emissions from industry, agriculture, forestry, and so forth and significantly reduce the ecological footprint. "Increase in scrap recycling rate ($C9$)" secured the fifth rank with a weight of 0.068576. This also signifies the SMEs' need to use more scrap materials to eliminate unnecessary landfilling of residues and reduce energy usage. Most of the metals used for industrial purposes can be recycled repeatedly without losing their properties, and processing such scrap metals significantly impacts CE implementation (Mackey et al., 2019). The weights of the remaining 10 criteria are considerably less. Despite having fewer weights, these criteria should be considered for CE performance evaluation in the FSC context. Hence, the aforementioned five criteria can be considered the top five criteria for CE performance.

On the contrary, "Total outreach of health and hygiene program ($C10$)" is the least important, with a weight of 0.058308. Most SMEs do not emphasize this social dimension in the CE transitioning process. One plausible explanation is that the existing linear business models of SMEs do not consider this criterion as they think such social welfare activities would not yield any immediate and positive benefit. While in the case of CE performance, social parameters like health and hygiene programs have a significant contribution and are considered for CE performance evaluation. On the contrary, the ranking of the SMEs obtained from the VIKOR method led to the finding that *SME*1 secured the first rank, whereas *SME*3 and *SME*2 secured second and third ranks, respectively. Hence, *SME*1 is the best SME in terms of CE performance and can be considered a benchmark SME. Other SMEs should follow the strategy of *SME*1 in order to improve their CE performance. Moreover, the results obtained from the CRITIC-VIKOR method indicated that the CE performance of *SME*1 is the best out of the three alternatives. On the other hand, five different cases in sensitivity analysis indicated that there was no change in the ranking of alternatives. This makes the proposed method more reliable. Hence, it can be concluded that the proposed method is able to deal with the performance evaluation problems in the SME sector.

6 | RESEARCH IMPLICATIONS

The results of this analysis corroborated the opinions of the group of experts. The theoretical, practical, and policy implications are given below:

6.1 | Theoretical implications

This research contributes to understanding the evaluation of CE performance through the application of a real-world case study on Indian FPSME. It makes four major contributions to CE research in general and FSC in particular. Firstly, this research proposes a decision framework by integrating CRITIC and VIKOR methods which provide researchers the tool to find priority weights of criteria and identify the most influential criteria. Furthermore, it helps to evaluate the individual performances and priority ranking of case organizations and find the best organization. Hence, this research fulfills the requirement for a robust framework–based empirical insight, specifically for the Indian food industry. To the best of the authors' knowledge, this is the first empirical endeavor to embed the CE principle into a performance evaluation of FPSME. Secondly, the proposed framework amalgamates a new dimension, that is, operational, to the existing TBL. Integrating all four dimensions (environmental, social, economic, and operational) in the CE performance evaluation acts as an enabler for holistic development in terms of environment, economy, society, and technology. Thirdly, an integrated CRITIC-VIKOR methodology is employed in this research, which solves complex decision-making problems efficiently to yield the most optimal solution. Finally, the results revealed that "Investment in CSR" is the most influential criterion for CE performance, confirming that underlying social responsibility practices are expected to impact CE performance to a greater extent. This contribution proposes a new multifaceted concept (i.e., CSR) into the FSC domain as a possible arena for CE business innovation and performance enhancement.

6.2 | Practical implications

The research's findings are important for the development of CE practices in the Indian FPSME. The study employed a sequential manner to delve into and validate the information extracted from the literature and expert opinions. The practical implications of this research are twofold. For the first implication, the research contributes by identifying various criteria that have a vital role for managers and DMs. Consequently, the managers of the respective SMEs need to address the various criteria of CE performance to remain competitive in the market. The proposed framework enables the calculation of the priority of the evaluation criteria in a logical, simple, and validated manner, which can otherwise be difficult to determine. This research identified 15 evaluation criteria, among which a set of five was found as the most influential criteria. As this research adopts a case study approach with three leading FPSMEs for in-depth analysis, it can measure the strength of criteria influencing CE performance. Furthermore, by observing the performance against each criterion, SMEs can benchmark their status against their competitors and prepare a course of action for improving their performance of compliance with CE principles.

The second implication of this research is a complete methodology for CE performance evaluation with application in three SMEs.

Earlier research methods typically utilized cross-sectional and qualitative approaches, but the current work introduced a novel methodology. Future research can use this methodology to thoroughly investigate the indicators impacting CE performance. This study differs from existing studies that applied various MCDM techniques for performance evaluation. This research employs an integrated CRITIC-VIKOR approach, which eliminates the conflict among criteria through computing correlation coefficients and ranks the alternatives by checking decision stability, thereby proposing an error-free channel for performance evaluation. Moreover, the proposed framework can also be utilized as a supplier selection tool.

6.3 | Policy implications

Based on the current research outcomes, various policies can be suggested for the Indian FPSME for CE performance improvement. FPSMEs should prioritize CSR activities within their system and invest a substantial amount in employee wellbeing, betterment of working ambiance, reduction in possible risks and hazards, and so forth. Simultaneously, FPSMEs should make use of renewable energy resources and replace conventional power setups with renewable energy and energy-efficient devices. FPSMEs are advised to install small power grids (like photovoltaic panels and solar collectors) within their factory premises. The power obtained from renewable energy can be utilized to run various electronic devices that are mainly used for various purposes, such as heating, cooling, and preservation of perishable food ingredients. FPSMEs also require efficient recycling facilities to increase scrap recycling rate and reduce the use of raw materials. Based on the research results, FPSMEs are advised to install emission control devices (like catalytic converters) at factory outlets.

Prior research has revealed that the majority of developing nations are lagging in SDG attainment. As the future of industrial sectors is and will be ever more driven by sustainability practices, CE practices will contribute towards achieving those goals. Therefore, policymakers should formulate strategies that facilitate the adoption of CE practices. Moreover, only implementing CE practices is not enough. Regular assessment and monitoring of CE performance are necessary for an effective outcome. The development and deployment of the proposed framework for CE performance evaluation provides guidelines and valuable criteria for regulatory enforcement. Policymakers can use the ranking of the specific criteria to design effective policies to improve the CE performance of SMEs.

7 | CONCLUSION

According to the UN SDGs, food waste should be cut in half by 2030 (Mehmood et al., 2021). Hence, the CE concept must be promptly implemented in the FSC to promote sustainable growth by reducing waste, effective utilization of resources, and recycling. However, effective CE methods and techniques for development and adoption are still in the embryonic stage of development. This study develops a comprehensive and robust framework for measuring the CE performance of FPSME in the setting of a developing country, which is not just founded on a literature review but has also been verified by FSC experts. From a managerial standpoint, the proposed integrated framework's credibility is proved by its application to a real-world case study of three SMEs in the Indian FPI. Results of this research claim that *SME1* is the top-ranked organization concerning CE performance, whereas *SME3* secures the second position, and *SME*2 holds the last rank. Other SMEs can look to *SME1* as a benchmark SME in the field of CE practices implementation and follow its strategies to improve their CE performance. The criteria ranking indicates that “Investment in CSR” is the most influential criterion. Due to the social and ethical aspects of sustainability, investment in CSR is essential. It is also a component of strategic expansion for businesses that take into account the ideas of CSR and CE as viable solutions for building sustainable business operations. The “Investment in CSR,” “Use of renewable energy,” “Increase in scrap recycling rate,” “Total CO_2 emission,” and “Total water consumption” criteria are ranked as the five most influential criteria in CE performance evaluation and should be the focus for SMEs wishing to enhance their CE performance. SMEs may encourage CE innovation to enhance CE performance by focusing on influential criteria like renewable energy, waste minimization systems, and scrap recycling. On the contrary, “Total outreach of health and hygiene program,” “Total wastewater,” “Wastewater treatment capacity,” “Efficiency of waste heat recovery rate,” and “Water consumption reduction” criteria are the five least important criteria, having the lowest weights.

The findings of this research contribute to achieving SDG 12 concerning the commitment toward “responsible consumption and production.” SDG 12.5 aims at reducing waste generation substantially by promoting reducing, reusing, and recycling practices (Lahane & Kant, 2022), and SDG 12.9 attempts to advance the scientific knowledge to move towards sustainable production and consumption patterns in developing countries (Nayal et al., 2021). This research tries to advance the progress of SDG 12.5 and SDG 12.9 in the following ways: (i) investigating the level of CE implementation in the FPSME of a developing country and embedding various CE principles into the performances of FPSME and (ii) establishing a comprehensive framework to quantitatively measure the performances of country-level FPSME, providing new insights into the CE in FSC in the context of a developing country. The implications of this research can assist managers in designing their SC activities in a CE-focused way and making strategies for CE performance enhancement.

7.1 | Study limitations and avenues for further investigations

The present research has some limitations. Firstly, although this research thoroughly identified a set of essential evaluation criteria, there is a possibility that a few important criteria might have been overlooked; they should be considered in future research. Secondly, this study was carried out considering the FPI; hence, the results may suffer from generalizability issues. Despite these limitations, the scope of the present study can be broadened into various avenues. A similar study can be carried out in the future by considering other industrial segments with the same, or different, evaluation criteria. Other MCDM methodologies like Entropy, TOPSIS, and COPRAS can also be used to validate results obtained from current research and make a comparative study. Moreover, since the current work is developed in an Indian context, similar research can be carried out and extended to developing nations to identify if the results apply to any other developing country.

AUTHOR CONTRIBUTIONS

Sudipta Ghosh: Conceptualization, development, and design of methodology, data curation, and preparation of original draft, advanced draft, and final paper. **Rakesh D. Raut:** Selection of relevant theories, data analysis, co-writing of the advanced draft, and validation of the final paper. **Naoufel Cheikhrouhou:** Providing supplementary materials, synthesizing research data, editing, and evolution of overarching research goals. **Sudipta Sinha:** Idea generation, visualization, software applications, and co-writing of the conception and design. **Amitava Ray:** Supervision, project administration, revision of the whole manuscript, and overall investigation.

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CONFLICT OF INTEREST STATEMENT

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 STATEMENT

The authors confirm that the data supporting the findings of this study are available within the article.

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ANNEXURE A

TABLE A1 Normalized data matrix of CRITIC method.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
SME1	1	0.011227	0.09965	1	0.714286	0.651163	0.078947	1	0.676471	0.638033	0.014731	0.3379	0.993987	0	0.316456
SME2	0.96	0	1	0	1	1	0	0	0	1	1	0	0	0.640842	1
SME3	0	1	0	0.235294	0	0	1	0.200452	1	0	0	1	1	1	0

TABLE A2 Standard deviation values of criteria.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
SD	0.566157	0.574137	0.550842	0.522835	0.515079	0.50756	0.555963	0.529065	0.510275	0.506311	0.573145	0.508683	0.575622	0.506569	0.511106

TABLE A3 Symmetric matrix with correlation values.

Criteria	C1	C2	C3	C4	C5	C6	C7
C1	1	−0.99898	0.547055	0.325907	0.950372	0.926375	−0.99435
C2	−0.99898	1	−0.58425	−0.28294	−0.96343	−0.94242	0.998123
C3	0.547055	−0.58425	1	−0.6131	0.780341	0.82203	−0.63286
C4	0.325907	−0.28294	−0.6131	1	0.015602	−0.05413	−0.22367
C5	0.950372	−0.96343	0.780341	0.015602	1	0.997568	−0.97804
C6	0.926375	−0.94242	0.82203	−0.05413	0.997568	1	−0.96113
C7	−0.99435	0.998123	−0.63286	−0.22367	−0.97804	−0.96113	1
C8	0.360067	−0.31763	−0.58397	0.999339	0.051949	−0.01778	−0.25896
C9	−0.72487	0.755198	−0.97321	0.415034	−0.90322	−0.93094	0.793926
C10	0.92072	−0.93738	0.830339	−0.06885	0.996431	0.999891	−0.95695
C11	0.480405	−0.51947	0.996981	−0.67259	0.729428	0.775333	−0.57083
C12	−0.93091	0.946435	−0.815	0.041912	−0.99835	−0.99993	0.964434
C13	−0.4737	0.512934	−0.99636	0.678219	−0.72419	−0.77049	0.564545
C14	−0.7964	0.768313	0.070583	−0.83131	−0.56872	−0.51	0.72767
C15	0.719454	−0.75004	0.974978	−0.42214	0.899832	0.928049	−0.78914

TABLE A3 (Continued)

Criteria	C8	C9	C10	C11	C12	C13	C14	C15
C1	0.360067	−0.72487	0.92072	0.480405	−0.93091	−0.4737	−0.7964	0.719454
C2	−0.31763	0.755198	−0.93738	−0.51947	0.946435	0.512934	0.768313	−0.75004
C3	−0.58397	−0.97321	0.830339	0.996981	−0.815	−0.99636	0.070583	0.974978
C4	0.999339	0.415034	−0.06885	−0.67259	0.041912	0.678219	−0.83131	−0.42214
C5	0.051949	−0.90322	0.996431	0.729428	−0.99835	−0.72419	−0.56872	0.899832
C6	−0.01778	−0.93094	0.999891	0.775333	−0.99993	−0.77049	−0.51	0.928049
C7	−0.25896	0.793926	−0.95695	−0.57083	0.964434	0.564545	0.72767	−0.78914
C8	1	0.381677	−0.03253	−0.64524	0.005555	0.65105	−0.85097	−0.3889
C9	0.381677	1	−0.93622	−0.95242	0.926402	0.950063	0.160662	−0.99997
C10	−0.03253	−0.93622	1	0.784563	−0.99964	−0.77981	−0.49726	0.933442
C11	−0.64524	−0.95242	0.784563	1	−0.76755	−0.99997	0.147823	0.954774
C12	0.005555	0.926402	−0.99964	−0.76755	1	0.76264	0.520483	−0.92343
C13	0.65105	0.950063	−0.77981	−0.99997	0.76264	1	−0.15536	−0.95248
C14	−0.85097	0.160662	−0.49726	0.147823	0.520483	−0.15536	1	−0.15293
C15	−0.3889	−0.99997	0.933442	0.954774	−0.92343	−0.95248	−0.15293	1

TABLE A4 Measure of conflict.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8
C1	0	1.998983	0.452945	0.674093	0.049628	0.073625	1.994346	0.639933
C2	1.998983	0	1.584248	1.282942	1.963435	1.942416	0.001877	1.31763
C3	0.452945	1.584248	0	1.613104	0.219659	0.17797	1.632856	1.583973
C4	0.674093	1.282942	1.613104	0	0.984398	1.054128	1.223669	0.000661
C5	0.049628	1.963435	0.219659	0.984398	0	0.002432	1.978036	0.948051
C6	0.073625	1.942416	0.17797	1.054128	0.002432	0	1.96113	1.017784
C7	1.994346	0.001877	1.632856	1.223669	1.978036	1.96113	0	1.258961
C8	0.639933	1.31763	1.583973	0.000661	0.948051	1.017784	1.258961	0
C9	1.72487	0.244802	1.973208	0.584966	1.90322	1.930937	0.206074	0.618323
C10	0.07928	1.937381	0.169661	1.068849	0.003569	0.000109	1.956953	1.032528
C11	0.519595	1.519467	0.003019	1.672594	0.270572	0.224667	1.570825	1.645241
C12	1.930912	0.053565	1.815005	0.958088	1.998346	1.999925	0.035566	0.994445
C13	1.473701	0.487066	1.99636	0.321781	1.724188	1.770493	0.435455	0.34895
C14	1.796396	0.231687	0.929417	1.831307	1.568716	1.510002	0.27233	1.850967
C15	0.280546	1.750043	0.025022	1.422144	0.100168	0.071951	1.789141	1.388903

TABLE A4 (Continued)

Criteria	C9	C10	C11	C12	C13	C14	C15	Sum
C1	1.72487	0.07928	0.519595	1.930912	1.473701	1.796396	0.280546	13.68885
C2	0.244802	1.937381	1.519467	0.053565	0.487066	0.231687	1.750043	16.31554
C3	1.973208	0.169661	0.003019	1.815005	1.99636	0.929417	0.025022	14.17644
C4	0.584966	1.068849	1.672594	0.958088	0.321781	1.831307	1.422144	14.69272
C5	1.90322	0.003569	0.270572	1.998346	1.724188	1.568716	0.100168	13.71442
C6	1.930937	0.000109	0.224667	1.999925	1.770493	1.510002	0.071951	13.73757
C7	0.206074	1.956953	1.570825	0.035566	0.435455	0.27233	1.789141	16.31722
C8	0.618323	1.032528	1.645241	0.994445	0.34895	1.850967	1.388903	14.64635
C9	0	1.936222	1.952416	0.073598	0.049937	0.839338	1.999969	16.03788
C10	1.936222	0	0.215437	1.999636	1.77981	1.49726	0.066558	13.74325
C11	1.952416	0.215437	0	1.767551	1.999971	0.852177	0.045226	14.25876
C12	0.073598	1.999636	1.767551	0	0.23736	0.479517	1.923425	16.26694
C13	0.049937	1.77981	1.999971	0.23736	0	1.155363	1.952478	15.73291
C14	0.839338	1.49726	0.852177	0.479517	1.155363	0	1.15293	15.96741
C15	1.999969	0.066558	0.045226	1.923425	1.952478	1.15293	0	13.9685

TABLE A5 Normalized matrix for VIKOR method.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
SME1	0.660109	0.088416	0.324113	0.776246	0.608858	0.588888	0.392098	0.700819	0.598004	0.591442	0.328989	0.59225	0.090136	0.736995	0.592764
SME2	0.648845	0.078144	0.909791	0.399212	0.714746	0.765554	0.352888	0.481998	0.416232	0.70693	0.888237	0.655038	0.992323	0.531929	0.486066
SME3	0.378493	0.993014	0.25929	0.487926	0.344137	0.259111	0.849546	0.525862	0.684939	0.387874	0.320627	0.469218	0.084678	0.417	0.642161

TABLE A6 Best value and worst values of all criteria.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
f_j^* value	0.660109	0.993014	0.909791	0.776246	0.714746	0.765554	0.849546	0.700819	0.684939	0.70693	0.888237	0.655038	0.992323	0.736995	0.642161
f_j^- value	0.378493	0.078144	0.25929	0.399212	0.344137	0.259111	0.352888	0.481998	0.416232	0.387874	0.320627	0.469218	0.084678	0.417	0.486066

TABLE A7 Utility measure for each alternative.

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
SME1	0	0.077612	0.058915	0	0.016912	0.020382	0.070016	0	0.022186	0.021105	0.067471	0.045909	0.000456	0.067778	0.040893
SME2	0.002598	0.078494	0	0.06437	0	0	0.076017	0.064932	0.068576	0	0	0.069338	0.075887	0.024343	0
SME3	0.064941	0	0.065435	0.049224	0.059193	0.058427	0	0.051916	0	0.058308	0.06848	0	0	0	0.059825