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Sustainable strategies based on the social responsibility of the beverage industry companies for the circular supply chain

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A R T I C L E I N F O

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A B S T R A C T

Circular supply chain management (CSCM) offers a fresh approach to enhancing supply chain sustainability and minimizing waste. A significant amount of waste is generated daily in the beverage industry, primarily due to the extensive production of beverages. The increasing waste amount causes the destruction of the environment and many problems for human life. The social responsibility of the beverage industry dictates that social and environmental performances are combined with the company's economic performance to benefit society and the environment. The purpose of this research is to evaluate the effective factors and provide sustainable solutions for waste management in the CSCM of beverage industry companies based on their social responsibility. So in this regard, six sustainable strategies are suggested and evaluated based on the circular design, biodegradable packaging, product and manufacturer's responsibility, critical success factors, and corporate social responsibility criteria, and theirs 24 sub-criteria for improving CSCM in the beverage industry. A novel group decision-making approach is proposed by developing the base-criterion method (BCM) and multi-attribute border approximation area comparison (MABAC) under fuzzy Z-extended numbers in order to evaluate the criteria weights and the rank of the strategies. A comprehensive managerial sensitivity analysis was performed better to understand the impact of different criteria for each strategy. The results show that cooperation with charities to return the waste and spend the added value created to help the needy fulfill the company's social responsibility is one of the most important strategies specified by decision-makers and experts for improving the CSCM of beverage industry.

1. Introduction

The concept of circular economics (CE) is increasingly recognized as a viable alternative to linear economics as part of today's economic environment (Farooque et al., 2019a, 2022). The CE has attracted considerable attention among senior managers, policymakers, and researchers due to the production of very low waste at all stages of the product life cycle (Govindan and Hasanagic, 2018; Jawahir and Bradley, 2016). The CE seeks to keep resources in the supply chain closed even after life (Agyemang et al., 2019; Smol et al., 2015). The circular supply chain management (CSCM) combines CE thinking and supply chain management and is a new logical approach to supply chain sustainability. CSCM research is constantly evolving because it provides the prospect of promoting sustainable production and use (Lahane et al., 2020; Alamelu et al., 2023). In addition, the CSCM provided an opportunity to optimize the production process by producing sustainable products and ensuring that product value is maintained to the maximum extent possible (Govindan and Hasanagic, 2018; Li et al., 2023).

In CSCM, a part of the natural resources is converted into waste after being converted into products that prevent environmental degradation and enter a circular system with cost savings. This ensures that less waste is generated during the product life cycle and that industries move closer to sustainable resource use, closed-loop supply chains, and sustainable recycling (Cheraghalipour et al., 2017; Schroeder et al., 2018). Implementing CSCM in industries is essential to minimize and manage waste efficiently and effectively. Emerging economies can be benefited significantly from the circular supply chain through appropriate CSCM policy and implementation. Minimizing and managing waste in

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products such as paper packaging, plastics, food, and glass containers offers numerous opportunities for industries, and CSCM research in this area has grown (Cheraghalipour et al., 2018; Lahane et al., 2020). Due to its characteristics, the Beverage industry can use CSCM to reduce waste and optimize the circular production system (Zaman et al., 2022). In the beverage industry, due to the short life cycle of products, changes in customer needs and laws have caused companies to be active in two dimensions of product innovation and supply chain simultaneously.

The rapid increase in demand in the beverage industry indicates its traction in the consumer market, in which industries continuously produce new products and services to meet the diverse demands of customers (Wandosell et al., 2021). Therefore, to succeed in this rapidly changing environment, managers should pay attention to factors affecting CSCM to achieve innovation and productivity in production (Vegter et al., 2021, 2023).

Beverages, which contribute to a large part of daily human consumption, have become so popular that they have become a large industry with a significant turnover. The beverage industry is diverse, including dairy drinks, water, fruit juices, and carbonated beverages. In the beverage industry, companies prioritizing CSCM innovation are more successful in production (Wandosell et al., 2021; Hader et al., 2022). On the other hand, a high percentage of R&D-related projects fail, and maintaining a competitive advantage in today's markets has become more complicated. Given the speed of change and market trends, the ability to produce and sell is no longer a sufficient condition to ensure the company's survival. The historical course of research has increasingly emphasized the coordination of supply chain management (Dallasega et al., 2018). Alignment and effectiveness of supply chain management components lead to improved company performance (Weng et al., 2020).

This study aims to examine the factors that affect CSCM and to provide the basis for achieving it in the beverage industry. It is the goal of this study to present and evaluate sustainable strategies to optimize waste management in the beverage industry's CSCM. Evaluation of sustainable strategies for the CSCM of the Beverage Industry requires the assessment of several affecting criteria. In other words, evaluating the sustainable strategies for the CSCM of the Beverage Industry based on a criterion is impossible and will not lead to reliable results. Therefore, it is necessary to use multi-criteria decision-making (MCDM) methods to evaluate the weights of the criteria and the ranks of the alternatives. Several MCDM methods have been introduced in recent years to solve decision problems in various scientific fields. Considering the judgment of a group of decision-makers (DMs) or experts can lead to more accurate results better than the judgment of one DM or expert (Ecer and Pamucar, 2022; Sotoudeh-Anvari, 2022). Therefore, develops of the MCDM methods into the group version can lead to more accurate results.

In this regard, Haseli et al. (2020) introduced the BCM as a criteria-weighting method for addressing decision-making challenges, employing pairwise comparisons for criteria evaluations. Positioned as a recent and highly efficient approach in MCDM, the BCM method stands out for its effectiveness in determining criteria weights, requiring fewer pairwise comparisons compared to similar methods. Unlike AHP (Saaty, 1980) and BWM (Rezaei, 2015), which demand (n(n-1))/2 and 2n-3 pairwise comparisons, respectively, the BCM obtains criteria weights through n-1 comparisons. Additionally, the outcomes of criteria weights in the BCM exhibit complete consistency (Haseli and Sheikh, 2022).

Also, the MABAC firstly introduced by Pamučar and Ćirović (2015) as a simple method that gives different type of the results. In addition to determining the rank of the alternatives, the MABAC method calculates both positive and negative values for each alternative. This capability is one of the distinguishing features of the MABAC method, utilized for strategy evaluation. Apart from obtaining the final rank for each strategy, calculating the ultimate value for each strategy is equally crucial. Strategies with positive values are particularly significant for consideration in the implementation phase. Consequently, the MABAC method has been chosen for development in this research.

Addressing ambiguity and uncertainty presents challenges for decision-making methods. Zadeh (1965) introduced fuzzy sets as a means of grappling with the uncertainty and ambiguity inherent in decision-making. In this regard, various fuzzy sets and fuzzy numbers proposed in the literature have further advanced the theory of fuzzy sets (Sotoudeh-Anvari, 2020, 2024). Reliability stands out as another critical consideration. Zadeh (2011) suggested fuzzy Z-numbers as a mechanism to incorporate the trustworthiness of decisions made by DMs. Additionally, Tian et al. (2021) expanded the concept of fuzzy Z-numbers to account for the reliability of group DMs and experts' opinions.

Reliability is an important factor to consider in judgments, alongside uncertainty mentioned in the classic fuzzy sets. In recent years, certain decision-making methods, utilizing fuzzy Z-numbers, have been developed to incorporate a degree of reliability and yield more dependable decisions. However, with an increasing number of DMs and experts, there is a growing need for more comprehensive frameworks for assessing reliability.

In the context of fuzzy ZE-numbers, an intriguing concept has been introduced, suggesting a voting approach involving the participation of diverse groups of experts. This feature aids in identifying expert judgments and minimizing the impact of conflicting opinions when discrepancies arise among DMs. Such a feature contributes to more reliable final decisions and comprehensive evaluations by experienced experts.

To achieve this goal, the development of MCDM methods under fuzzy ZE-numbers can offer the possibility of considering the opinions of different groups of DMs while simultaneously addressing reliability concerns. Given these challenges, this research introduces two decision-making methods based on a novel robust approach to fuzzy sets and fuzzy numbers. These methods are designed to evaluate affecting criteria and select optimal strategies while considering the ambiguity, uncertainty, and reliability of DMs and experts. Consequently, the results obtained from these methods are expected to be more accurate and reliable.

This study contributes the following novelties and contributions:

- Comprehensive evaluation based on the effective criteria of circular design, biodegradable packaging, product and manufacturer's responsibility, critical success factors, and corporate social responsibility criteria, and theirs 24 sub-criteria for improving CSCM in the beverage industry.
- Proposing the six strategies for CSCM to prevent environmental degradation and meet corporate social responsibility by turning waste into products.
- Providing strategies obliges beverage industry companies to cooperate in waste management with their corporate social responsibilities.
- Developing a novel group decision-making model using extended MCDM methods under fuzzy ZE-numbers in order to rank affecting criteria and suggested strategies.
- Designing a novel framework for evaluating experts' and DMs judgments in two non-similar ways to reach optimal conclusions.

The rest of this paper is organized into the following steps. A review of the literature is provided in Section 2, describing the literature on corporate social responsibility, biodegradable packaging, and the research gaps of the present study. Section 3 explained the problem definitions. Section 4 presented the details of the methodology. The results of the criteria weights, alternatives rank, and sensitivity analyses are presented in Section 5. The discussion is provided in Section 6. Finally, the conclusion, limitations, and future research are provided in Section 7.

2. Literature review

The CSCM research is constantly evolving because it provides the prospect of promoting sustainable production and use (Lahane et al., 2020). Farooque et al. (2019a) reviewed 261 research papers on the current state of CSCM research. They showed that researchers want more studies in the areas that have received less attention, such as procurement and CSCM, circular design, circular supply chain collaboration, biodegradable packaging, circular consumption, CSCM drivers and barriers, product technology and commitments, and constructive responsibility. Lahane et al. (2020) believe the CSCM research on drivers, enablers, new circular business models, critical success factors, and innovative frameworks explore new dimensions in CSCM.

Agyemang et al. (2019) pointed out that CE has been considered because of its environmental and social benefits. To support their claims, they cited profitability, cost reduction, business and environmental concerns as critical factors, lack of expertise, ignorance, and cost constraints. Singhal et al. (2019) considered remanufacturing and recycling as suitable options for success in CSCM. They considered attitude, subjective norms, and perceived green benefits as factors for success. Centobelli et al. (2021) showed that transparency, traceability, and reliability are three critical factors in CSCM Blockchain design. They showed that Blockchain as a technological capability, effectively improves recycling, product return, and waste transfer.

Walker et al. (2021) claimed that CSCM is considered a good resource for the study of sustainability, with the lowest social dimension of sustainability. De-Angelis et al. (2018) considered the circular production method to eliminate the shortcomings of linear production. To expand CSCM, they have mentioned improving supply chain relations, flexible communication, and setting up local loops, creating a loop in technical cycles, Improving relationships with supply chain agents. Farooque et al. (2019b) examined the barriers to integrating CE into CSCM. They used FDEMATEL to examine barriers and identify causal relationships between them. Results showed that implementing environmental laws is the weak point of CSCM obstacles in the food industry in China. Khandelwal and Barua (2020) considered the plastics industry to implement CSCM using the FAHP method and identified the two main obstacles of the poor implementation of environmental protection laws and the lack of tax relief policies in the implementation. Chen et al. (2021) studied the relationship between CSCM acceptance and research and development intensity. They showed that research and development intensity positively affected firms' CSCM acceptance, which increases with the intensity of competition. According to Walker et al. (2021), the most common evaluation approaches in CSCM are MCDM methods. In general, various research have been conducted in this field to enrich the supply chain using decision-making and optimization methods (Chen and Su, 2022; Puška and Stojanović, 2022; Song et al., 2023).

As can be seen, research on circular design, biodegradable packaging, product and manufacturer liability, corporate social responsibility, and critical success factors has not been reviewed. However, studies have shown that each of these criteria has the subcriteria, and comparing them with each other highlights important points. As Lahane et al. (2020) point out, a wide field exists for CSCM growth. One of the ways to check CSCM is through advanced quantitative modeling and multi-criteria decision-making techniques.

2.1. Corporate social responsibility

Recent decades have seen an increase in the concept of corporate social responsibility. Social responsibility is a business unit's accountability for its activities' consequences on society and the environment (Zaman et al., 2022). Social responsibility is, first of all, a framework for ethical oversight of business units, based on which they take actions that improve the conditions of society. Social responsibility includes social and environmental factors in corporate decisions (Fatima and Elbanna, 2022). In this regard, social and environmental performance are combined with the company's economic performance to benefit society, the environment, and the business unit. Indeed, the activities of business units must be balanced between the profitability of economic activities, environmental protection, and social justice in society (Okafor et al., 2021; Hämäläinen and Inkinen, 2019). Making a profit for shareholders should not be to the detriment of the environment and individuals in the community. In other words, social justice and environmental protection must be observed in making a profit.

Corporate social responsibility includes the company's responsibilities to society, which have the company's responsibilities to the environment, economy, society, and improving the lives and health of citizens and other stakeholders. In recent decades, issues such as occupational safety and health, environmental pollution control, improving the quality of company products, creating equal job opportunities for minorities and women, and respecting workers' rights are among the expectations that have been considered corporate social responsibility (Zaman et al., 2022). Failure to comply with these duties significantly affects the continuity of companies. The rise of the idea of corporate social responsibility in recent decades within global scientific, economic, and political spheres can be attributed to the growing intricacies of the business landscape, the prevalence of multinational corporations, the effects of economic globalization, government pressures, a call for greater business transparency, and the occurrence of social and environmental crises (Tundys, 2021; Hameed et al., 2022). In the contemporary business landscape, enterprises, particularly those engaged in global markets, need to work towards achieving equilibrium among social, economic, and environmental aspects (Cezarino et al., 2022).

The concept of corporate social responsibility can be divided into two categories: internal and external (Zaman et al., 2022). Internal corporate social responsibility includes actions demonstrating management performance toward employees (Macassa et al., 2021; Orji et al., 2022). Internal corporate social responsibility has helped companies reduce resource waste and improve environmental efficiency in SCM (Hur et al., 2019). Internal corporate social responsibility can positively affect value creation (Trivellas et al., 2018), which increases employees' creativity and, as a result, may lead to SCM change and innovation in it. External corporate social responsibility includes actions examining external stakeholders' management practices (environment, society, and consumers) (Macassa et al., 2021). External corporate social responsibility has caused companies to feel societal pressure (García-Sánchez et al., 2022). To change the status quo and improve the environment, they are more inclined to be drawn to CSCM.

2.2. Biodegradable packaging

Today, many materials used in food packaging are obtained from petroleum products. These materials are not biodegradable and cause environmental pollution (Goudarzi et al., 2017). In recent years, researchers have been examining the potential contamination caused by petroleum-derived packaging materials and various decontamination methods (such as disposal, incineration, and recycling) to find appropriate alternatives to this type of packaging. (Jayasekara et al., 2022).

Since the middle of the twentieth century, plastics have been widely used for packaging due to their ease of use, low cost, flexibility in molding, good resistance to environmental and mechanical factors (Powell et al., 2022), and ease of production (Yao et al., 2020). However, this type of packaging poses environmental risks, The decomposition of these materials takes a long time. It carries the risk of chemical diffusion, as additives added to this type of packaging for more significant beauty and durability may affect the quality of food (Horodytska et al., 2018; Tharanathan, 2003). Because of all the reasons listed above, biodegradable packaging is promoted instead of plastic packaging due to health and environmental concerns. Biodegradable packaging is made from natural biopolymers, including polysaccharides, lipids, and proteins, which decompose rapidly and are non-toxic and recyclable (Mohammadalinejhad et al., 2020). Consumer preferences and expectations have changed, and packaging plays a more important role than ever before, enhancing shelf life as well as measuring the quality of packaged foods.

2.3. A review on the utilized methodology

Various fuzzy sets have been incorporated into BCM for application across a wide range of scientific domains, causing the BCM to garner increasing interest among researchers. Initially, fuzzy BCMs were developed to resolve uncertain decision-making scientific problems (Narang et al., 2021; Narang et al., 2022a; Bisht and Pal, 2023). Then, Narang et al. (2022b) created the fuzzy BCM using the hesitant fuzzy multiplicative approach, specifically for its application in group decision-making. Also, Haseli and Jafarzadeh Ghoushchi (2022) introduced the Spherical fuzzy BCM and Bisht & Kumar (2022) proposed the BCM with evidence theory. Zafaranlouei et al. (2023) introduced fuzzy Z-numbers with BCM to address the decision problems in the waste management. Also, the new BCM framework under utility additives, proposed by Ayough et al. (2023).

The MABAC captured the interest of researchers as a pragmatic approach. Over the recent years, numerous enhancements to the MABAC method have been suggested, incorporating various fuzzy sets and fuzzy numbers, such as interval rough numbers (Pamučar et al., 2018), picture 2-tuple (Zhang et al., 2020; Wang et al., 2023), hesitant fuzzy (Büyüközkan et al., 2021), Type-2 fuzzy neutrosophic (Deveci et al., 2021; Simic et al., 2022), fuzzy R-numbers (Zhao et al., 2022), fuzzy Z-cloud rough number (Huang et al., 2022), 2-dimensional uncertainty (Liu and Wang, 2022), spherical fuzzy sets (Zhu et al., 2023), Fermatean fuzzy (Tan et al., 2022), and interval type-2 fuzzy rough (Chen and Luo, 2023; Naz et al., 2023).

Furthermore, fuzzy ZE-numbers have successfully been used to develop MCDM methods that can be applied to a variety of scientific areas. For the first time, Haseli et al. (2023a) applied fuzzy ZE-numbers to develop the BWM and CoCoSo methods to make reliable decisions about the supplier selection problem. After that, Haseli et al. (2023b) extended the MARCOS and BCM methods to select the Female technologies. Also, Haseli et al. (2024a) used fuzzy ZE-numbers to make a reliable decision-support model for sustainable transportation in Mexico City. Additionally, the fuzzy ZE-numbers have been successfully used by Haseli et al. (2024b) to providing the green finance strategies for the land-use transport projects based on the climate change resilient. Finally, the fuzzy ZE-numbers have been applied by Ecer et al. (2024) to solve the sustainable cold chain suppliers problem.

2.4. Research gap

The environment is a global issue that is exposed to severe threats at the international level. In the global ecosystem, everything is interconnected, and one thing happening in one corner will also affect other parts of the world. The correct culture about nature should form a spirit of nature-friendliness and harmony with nature in industry, change the industry's view of the environment and natural resources and everything around it, and develop a sense of social responsibility towards them (Schultz et al., 2021). Corporate social responsibility has different meanings, including legal responsibility, socially responsible behavior regarding ethical issues, responsibility, and social awareness. Corporate Social Responsibility emphasizes responsibility and accountability as the basis of organizational behavior in society and oversees how businesses responsibly relate to wealth creation (Latapí Agudelo et al., 2019). Due to the complex relationship of the companies in the society with each other, the government, and the people of the society, a situation has arisen where the companies must be accountable not only to the beneficiaries but also to the people.

Design, construction, and materials used in packaging play a vital role in maintaining food quality and freshness. Materials used in food packaging have traditionally included glass, metals, aluminum, foil, tin, and tin-free steel, paper, and polymers. Glass storage is the oldest method of food storage (Rhim et al., 2013). Glass has many advantages for use in food packaging. These materials are impermeable to gases and can withstand high temperatures. Their high transparency makes the product easier to see and recyclable. However, fragility, weight, and high cost have limited the use of glass in the beverage packaging industry.

Metals come in various shapes and sizes and have high physical protection and decorative potential. They have high resistance to external factors and are recyclable. The use of paper in packaging to protect drinks is minimal compared to other packaging methods. Over the past decades, other packaging materials have been used due to the valuable capabilities of polymer coatings (Idumah et al., 2019). Among these limiting factors in the use of various types of packaging is the lack of environmental degradation in the light of industrial products. As these products require the extraction of natural resources at the beginning of the supply chain as well as the generation of waste at the end, the importance of achieving CSCM is doubled. Since all production activities are carried out in the environment, humans also live as one of the factors of production in this context. Therefore the destruction of the environment, on the one hand, can limit access to resources for future production, and on the other hand, it can affect human health. In this regard, there is a need to conduct a study on the factors affecting CSCM.

CSCM has been studied in a number of ways, however, the investigation of the elements that influence CSCM from the point of view of corporate social responsibility, biodegradable packaging, circular design, product and manufacturer liability, and critical success factors has not been conducted simultaneously, as shown in Table 1, containing the most relevant works. The following criteria have been identified about these factors in line with CSCM in the beverage industry, which generally makes research on performance improvement in industries active in beverage production more effective. Most of the time, industries look locally at issues, whereas they have made significant progress in some areas, for example, biodegradable packaging, but corporate social responsibility has been inefficient. By demonstrating the situation of the investigated company about the identified factors, this research clarifies the weak points in order to create an optimal view of how to improve them.

Examining strategies can answer these questions:

- What are the identified CSCM agents in the beverage industry?
- What are the CSCM agents in Companies?
- What strategy is appropriate to achieve Companies goals?
- What are the CSCM strategies identified in Companies?

3. Problem definition

The beverage industry, especially cold drinks in Iran, has a better history, reputation, and turnover than other food industry areas. Today, innovations in the beverage industry have led to the significant growth and development of non-alcoholic beverages. Supplementary beverage production, processing, and packaging factories are prevalent in this industry. At present, various beverage industries in Iran meet a significant part of domestic demand, one of the most important of which is in terms of sales volume, reputation, and innovation of Companies. In general, the drinks produced by these companies are divided into two main categories of hot and cold beverages.

Generally, cold drinks are divided into two categories, carbonated and non-carbonated. These drinks include soft drinks, non-alcoholic beer, mineral water, fruit extracts, syrups, and buttermilk. The industry in question uses plastics, fruits, milk, and other food and packaging to produce its products. The industry recycles various materials and wastes and uses a circular design in the production structure of these products. The company's social responsibility requires it to reduce waste. Experts have selected the strategies outlined in Table 3 according to the essential indicators (Table 2) concerning the beverage industry's circular supply chain. These indicators were extracted based on previous studies and adjusted and finalized with the opinion of experts. The beverage industry in Iran believes that competition and gaining competitive advantages in global trade will be possible and achievable

Table 1
Examining the criteria in the most relevant articles to the current research.

Ref.	Industry	Circular design	Biodegradable packaging	Product and manufacturer's responsibility	Critical success factors	Corporate social responsibility	Provide strategies
De-Angelis et al. (2018)	Manufacturing			✔	✔		✔
Farooque et al. (2019b)		✔	✔	✔	✔		
Agyemang et al. (2019)	Automobile			✔	✔		✔
Singhal et al. (2019)				✔			
Tura et al. (2019)		✔	✔	✔			
Farooque et al. (2019a)	Food	✔			✔		
Lahane et al. (2020)				✔	✔		
Centobelli et al. (2021)	Plastic	✔			✔		✔
Walker et al. (2021)			✔				
Saraji and Streimikiene (2022)	Inter-firm	✔			✔		✔
Lahane and Kant (2022)	Home appliance	✔	✔	✔			
Niyommaneerat et al. (2023)	Renewable energy/ plastic waste recycling	✔				✔	
Gholian-Jouybari et al. (2023)	Soybean Industry	✔					
Dey and Giri (2023)	Waste recycling	✔				✔	✔
Current study	Beverage	✔	✔	✔	✔	✔	✔

with a well-codified strategic plan and strategy and with the help of strategic organizational planning. Accurate knowledge of the organization's strengths and in-depth understanding of the indicators presented in Table 2 is part of intelligently addressing them to help managers choose effective strategies in Table 3. Therefore, predictions are made by designing and reviewing various strategies in this field. Given the existing capacities of the industry, take steps to choose a strategy to achieve social responsibility and biodegradable packaging.

3.1. Affecting criteria

The affecting criteria and sub-criteria identified in this section are presented in Table 2.

The brief descriptions for each sub-criteria are provided as follows.

Ecological effects of the product life cycle (C_{11}): In the circular supply chain of the beverage industry, the ecological effects of the product life cycle encompass resource extraction, manufacturing emissions, transportation impacts, consumption habits, and end-of-life management. From raw material acquisition to disposal, each stage contributes to environmental degradation through resource depletion, pollution, and waste generation.

Stakeholder pressure (C_{12}): Stakeholders put pressure on the company for their benefit to earn their profit, which affects the company's decision-making.

Optimize circular network design (C_{13}): Optimize the production cycle from production to recycling.

Structural flexibility (C_{14}): The company must have a flexible structure that can suffer the least harmful fluctuations in different environmental conditions.

Environmental safety (C_{21}): The supply chain design company should act in such a way as to prevent environmental damage.

Environmental regulations (C_{22}): Companies must comply with regulations that have been put in place to protect the environment.

Reducing carbon and its harms (C_{23}): The tools used to produce products with fuel consumption produce carbon, which should be tried to reduce carbon.

Ability to recycle or reuse (C_{24}): the part of the product left after consumption or unusable should be recycled and used again.

Research and Development (C_{31}): Research and development is a creative work organized systematically to add to the existing knowledge and create new applications for this knowledge.

Distributor relationship management (C_{32}): To achieve the goals, the company improves the relationship with the distributors and takes measures to improve this relationship.

Innovative strategy in product packaging (C_{33}): Innovative strategy is a set of structured, comprehensive, and creative activities created to support the organization's future growth and reach the company's goals with better packaging.

Market strategy to improve the circular supply chain (C_{34}): Market strategy has effectively gained brand awareness and drove new customers to products and services.

Plan and improve operations to improve waste management (C_{35}): Waste produced after production can be reduced by enhancing production operations. With proper planning, the amount of production can be optimized so that the amount of waste becomes more reasonable.

Competitive Advantage (C_{41}): Competitive advantage is a set of factors or capabilities that allow companies to perform better than competitors consistently.

Reduction in costs (C_{42}): Cost includes all things to do, like any action, idea, or service.

Economic benefit in terms of implementing each strategy (C_{43}): The results of each strategy require the company to choose the most effective methods in order to ensure its survival.

Improve resource productivity (C_{44}): It should increase the number of goods or services produced compared to each unit of energy or work performed without reducing the quality.

Existence of a systematic information system (C_{45}): It consists of a set of integrated processes for collecting, storing, and processing data, generating information, knowledge, and digital products that can be used to provide services at a cost-effective rate.

Risk management and company readiness to deal with change (environmental) (C_{46}): An organization's risk management system identifies, evaluates, and controls threats to its capital and income, which can improve the company's ability to adapt to changing conditions.

Green awareness (C_{51}): Green awareness is based on the premise that to preserve and improve the environment for future generations, clarification should be made, and the production of green products will replace common products. This concern is caused by the changes in the earth's climate conditions and the cities becoming more polluted than before.

Mental norms (C_{52}): mental norms reflect social pressure perceived by a person and form a specific behavior. In other words, cognitive norms express a person's perception, whether others approve of his behavior or not.

Table 2
Identified criteria for evaluation of sustainable strategies.

Criteria	Sub-criteria	Type	Ref.
Circular design (C_1)	Ecological effects of the product life cycle (C_{11})	Benefit	Lahane et al. (2020)
	Stakeholder pressure (C_{12})	Cost	Agyemang et al. (2019)
	Optimize circular network design (C_{13})	Benefit	Walker et al. (2021)
	Structural flexibility (C_{14})	Benefit	De Angelis et al. (2018)
Biodegradable packaging (C_2)	Environmental safety (C_{21})	Benefit	Agyemang et al. (2019)
	Environmental regulations (C_{22})	Benefit	Agyemang et al. (2019), Tura et al. (2019), Farooque et al. (2019b)
	Reducing carbon and its harms (C_{23})	Benefit	Lahane et al. (2020)
	Ability to recycle or reuse (C_{24})	Benefit	Centobelli et al. (2021), Walker et al. (2021)
Product and manufacturer's responsibility (C_3)	Research and Development (C_{31})	Benefit	Farooque et al. (2019b), Centobelli et al. (2021)
	Distributor relationship management (C_{32})	Benefit	Agyemang et al. (2019), Tura et al. (2019), Farooque et al. (2019b)
	Innovative strategy in product packaging (C_{33})	Benefit	Agyemang et al. (2019)
	Market strategy to improve the circular supply chain (C_{34})	Benefit	Singhal et al. (2019), Tura et al. (2019)
	Plan and improve operations to improve waste management (C_{35})	Benefit	Tura et al. (2019), Lahane et al. (2020)
Critical success factors (C_4)	Competitive Advantage (C_{41})	Benefit	Lahane et al. (2020), Singhal et al. (2019)
	reduction in costs (C_{42})	Benefit	Agyemang et al. (2019),
	Economic benefit in terms of implementing each of the strategies (C_{43})	Benefit	Agyemang et al. (2019)
	Improve resource productivity (C_{44})	Benefit	Lahane et al. (2020)
	Existence of a systematic information system (C_{45})	Benefit	Lahane et al. (2020)
	Risk management and company readiness to deal with change (C_{46})	Benefit	Farooque et al. (2019a)
Corporate social responsibility (C_5)	Green awareness (C_{51})	Benefit	Singhal et al. (2019)
	Mental norms (C_{52})	Cost	Farooque et al. (2019a)
	Consumer participation in social responsibility (C_{53})	Benefit	Daú et al. (2019)
	Internal corporate social responsibility (C_{54})	Benefit	Wang et al. (2020)
	External corporate social responsibility (C_{55})	Benefit	Wang et al. (2020)

Involving consumers in social responsibility (C_{53}): Consumers' participation in social responsibility means consumers' participation in responding to the results of activities that affect society.

Internal corporate social responsibility (C_{54}): It has been made in response to activities that adversely affect the internal employees of the organization.

External corporate social responsibility (C_{55}): Responds to the consequences of activities that affect the company's external stakeholders.

Table 3
Sustainable strategies for Beverage industry companies.

Alt.	Strategies
A_1	Using vending machines in chain stores and receiving and pressing the packaging of used products for recycling.
A_2	Using incentive schemes for the return of plastic or glass used by consumers.
A_3	Cooperation with non-profit organizations such as municipalities to implement the return plan of plastic or bottles.
A_4	Cooperation with charities to return the product and spend the added value created to help the needy fulfill the company's social responsibility.
A_5	The company's branding strategy and the logo's selection to collect the waste of the sold products and help the environment.
A_6	Produce incentive by-products as gifts to help collect product waste.

3.2. Proposed strategies

The suggested sustainable strategies for Beverage industry companies based on social responsibility are listed in Table 3.

A_1: Vending machines can be placed in chain stores that automatically give the customer things like drinks, ice cream, juice or mineral water in exchange for money or credit. Compared to traditional human-operated stores, reduced labor and 24-h access are the advantages of using these devices, and the possibility of breakdowns, running out of products at the wrong time, or theft are disadvantages. This device can be equipped with a packaging press, which after consumption by the consumer, takes and presses the packaging, which takes up little space in the store and can be recycled in the end.

A_2: In addition to receiving the product through the purchase, buyers can increase their profit by benefiting from incentive schemes. These incentive schemes can be in line with the return of consumer plastic or glass; in return, the consumer is given credit, product, and gift. For example, if the consumer delivers five drinks, the consumer will be given a free drink.

A_3: One of humanity's significant problems in recent years is the excessive production and disposal of waste materials in the environment. This, regardless of the category of recycling and reuse of recycled materials, in addition to the transfer of capital, causes the loss of natural resources and causes irreparable damage to the environment. For this purpose, it is necessary to use effective ways of implementing the recycling program, and with the efforts of non-profit organizations, waste is received, recycled, and reused.

A_4: Cooperation with charities to return the product and spend the added value created to help the needy fulfill the company's social responsibility. By seeing the impact of product return and recycling on helping the needy, buyers will have a spiritual connection with the company, and the company's sales will increase. In this regard, the company has fulfilled its social responsibility. The company has become an active member of society, which will benefit society in addition to its profit.

A_5: Branding, the company, is the process of creating and strengthening the brand. A "brand" is a name, symbol, or distinguishing feature that helps the audience to identify a company or product from other similar ones. Today, the tangible product itself is not the only reason for people to buy; Rather, the product is only a part of the brand, and people buy it. In order to make a product stand out, it must be given an identity. Using things such as name, symbol or logo, special colors, and other components are in line with the product's identity. This way, an effort is made to give personality to the product to collect the waste of the sold products, help the environment, and create a special place for the waste collection in the customer's mind.

A_6: A by-product is a product that can be unintentionally produced alongside the main product. The by-product may be useful and salable,

or it may be considered waste. Here, after recycling the waste and using the company's by-products that are not used in the production of beverages, gifts can be considered to help collect product waste, and these gifts act as a driving force for collecting recycling.

4. Methodology

The purpose of this section is to provide a brief overview of the preliminary fuzzy Z-numbers, fuzzy Z extended numbers, and proposed extended approaches for each of the BCM and MABAC methods using fuzzy ZE-numbers.

4.1. Preliminary fuzzy ZE-numbers

Zadeh (1965) put forth the fuzzy set theory as a potent and adaptable concept for handling subjective and ambiguous information across diverse domains. Membership elements within fuzzy sets are determined within the range of [0, 1]. A variety of fuzzy sets were introduced, as well as fuzzy numbers, which can be used in a variety of fuzzy sets to accomplish various functions. A triangular fuzzy number (TFN) is conventionally represented by a trio (l, m, u), which represents the lower, mid, and upper values. TFN membership components are defined as follows.

$$\widetilde{\mu}_s(x) = \begin{cases} 0, x < l \\ \frac{x-l}{m-l}, l \le x \le m \\ \frac{u-x}{u-m}, m \le x \le u \\ 0, x > u \end{cases} \tag{1}$$

where $l < m < u$.

To consider the reliability of the judgment, fuzzy Z-numbers (Zadeh, 2011) were proposed and used successfully for developing decision-making models (Sarkar et al., 2023; Maleki et al., 2023). A fuzzy Z-number framework consists of two fuzzy numbers, $Z = (A,B)$; A represents the variable within the fuzzy constraint of the domain X and B refers to a reliability value of A. The $(R(X) : X \, is \, A)$ is a probabilistic limitation that signifies the potential distribution. This limitation can be defined using Eq. (2).

$$R(X) : X \text{ is } A \rightarrow Poss\ (X = u) = u_A(u) \tag{2}$$

in Eq. (3), u represents the overall value of X, while u_A serves as the membership function of the A. The u_A can be seen as a constraint linked to $R(X)$. Essentially, the degree to which u satisfies $u_A(u)$ indicates the level of compliance. Therefore, X acts as a random variable with the $R(X)$, assuming a potential constraint on X. The $R(X)$ is outlined as follows (Jia et al., 2021).

$$R(X) : X \text{ is } p \rightarrow Prob\ (u \le x \le u + du) = p(u)du \tag{3}$$

On the other hand, Eq. (4) is employed to transform the reliability of fuzzy numbers within Z-numbers into a precise, non-fuzzy numerical value.

$$\alpha = \frac{\int x\mu_B dx}{\int \mu_B dx} \tag{4}$$

For fuzzy Z-numbers, the B and A are governed by hidden probability. Eq. (5) shows mentioned restriction.

$$\sum_{i=1}^{n} \mu_A(x_i) \, . \, p_{x_A}(x_i) \rightarrow b_i \tag{5}$$

$$ZE = ((A,B),E) \tag{6}$$

Through the expansion of fuzzy Z-numbers, Tian et al. (2021) derived the reliability of group decision-making by employing fuzzy ZE-numbers. Fuzzy ZE-numbers are determined by using the voting approach to obtain the reliability of the group decision-making process. The fuzzy ZE-numbers are voted using Equation (7).

$$Evaluation - number = (Y, N, \theta) \tag{7}$$

As mentioned in the Introduction section, the fuzzy ZE-numbers framework provides an opportunity to consider the votes of the Experts in addition to the evaluations of the DMs. The Experts have an upper level than the DMs in the evaluation process. For this reason, the evaluation results of the DMs will voted on by the Experts. Based on the voting approach proposed in the fuzzy ZE-numbers, the experts agree with the DM's evaluations and disagree with them. Finally, the θ symbol uses to indicate the inactive votes of the experts to DM evaluations. According to Eq. (8), the credibility of a decision is calculated based on the sum of the experts' votes. The new reliability numbers are then calculated using Equation (9):

$$R = \frac{Y - N}{n - \theta} \tag{8}$$

$$M = \begin{cases} b_i^* = b_i * (1 + R) \quad . \quad R < 0 \\ b_i^* = b_i \quad . \quad R = 0 \\ b_i^* = 1 - (1 - b_i) * (1 - R) \quad . \quad R > 0 \end{cases} \tag{9}$$

where there will be three states for R values based on the sum of experts' votes. The new reliability values are calculated based on the value of the R according to Eq. (9). In this regard, If the value of R is zero, the value of the new reliability value (b_i^*) will be the same as the previous reliability value (b_i). If the value of R is greater than zero, the new reliability value will be increased. Also, if the value of R is less than zero, the reliability will decrease.

4.2. ZE-base criterion method

The fuzzy ZE-BCM is developed based on the fuzzy ZE-numbers in this section for use in group decision-making.

Step 1: Identify the experts DMs, and effective criteria for the decision problems.

In this step, the set of criteria $\{C_1, C_2, C_3, \ldots, C_n\}$ is determined. Also, defined the number of experts and DMs $\{DM_1, DM_2, \ldots, DM_n\}$ who will vote on DMs' evaluations.

Step 2: Choose a criterion as the base.

During this phase, a single criterion is chosen as the base (C_B) based on the preferences of the DM.

Step 3: Conduct pairwise comparisons.

The TFNs in Table 4 are used for pairwise comparisons in this step. Z-numbers incorporate the concept of reliability variables, and Table 5 presents these variables to indicate the level of confidence. Eq. (10) outlines the mathematical formula for calculating the value of a fuzzy Z-number, while, Eq. (4) illustrates the process for computing the α value.

$$Z - number\ \left(l_{Z(ij)}, m_{Z(ij)}, u_{Z(ij)}\right) = \left(l_j \times \sqrt{\alpha},\ m_j \times \sqrt{\alpha},\ u_j \times \sqrt{\alpha}\right) \tag{10}$$

Based on Eq. (11) we compute the pairwise comparison vector of the base-criterion to the other criteria under the Z-number.

$$\widetilde{A}_B = \left(\left(l_{Z(B1)}, m_{Z(B1)}, u_{Z(B1)}\right), \left(l_{Z(B2)}, m_{Z(B2)}, u_{Z(B2)}\right), \cdots, \left(l_{Z(Bn)}, m_{Z(Bn)}, u_{Z(Bn)}\right)\right) \tag{11}$$

here, $(l_{Z(Bj)}, m_{Z(Bj)}, u_{Z(Bj)})$ represents the degree of significance of the base criterion concerning the jth criterion, utilizing Z-numbers.

Table 4
Linguistic terms (Haseli et al., 2024a).

Linguistic terms	Abbriviations and values		Reverse	
Equally Important	EI	(1,1,1)	EI	(1,1,1)
Intermediate between Equally and Weakly Importance	IEWI	(1,2,3)	$IEWI^{-1}$	(1/3,1/2,1)
Weakly Important	WI	(2,3,4)	WI^{-1}	(1/4,1/3,1/2)
Intermediate between Weakly and Fairly Important	IWFI	(3,4,5)	$IWFI^{-1}$	(1/5,1/4,1/3)
Fairly Important	FI	(4,5,6)	FI^{-1}	(1/6,1/5,1/4)
Intermediate between Fairly and Very Important	IFVI	(5,6,7)	$IFVI^{-1}$	(1/7,1/6,1/5)
Very Important	VI	(6,7,8)	VI^{-1}	(1/8,1/7,1/6)
Intermediate between Very and Extremely Important	IVAI	(7,8,9)	$IVAI^{-1}$	(1/9,1/8,1/7)
Absolutly Important	AI	(8,9,9)	AI^{-1}	(1/9,1/9,1/8)

Assigning values to the pairwise comparisons should be done according to Equation (12). Employing Eq. (12) to determine these values helps maintain input control and eliminates inconsistencies. In this regard, the values of the membership variables for each pairwise comparison must be chosen in such a way that when we divide each of the values assigned to each of the pairwise comparisons, the result is according to Eq. (12) between $(8,9,9)$ and (1/9,1/9,1/8).

$$\left(l_{(ij)}, m_{(ij)}, u_{ij(ij)}\right) = \frac{\left(l_{(Bj)}, m_{(Bj)}, u_{(Bj)}\right)}{\left(l_{(Bj)}, m_{(Bj)}, u_{(Bj)}\right)} \tag{12}$$

$$(8,9,9) \leq \left(l_{(ij)}, m_{(ij)}, u_{ij(ij)}\right) \leq (1/9, 1/9, 1/8)$$

Step 4: By polling experts on the pairwise comparison preference vectors, obtain the fuzzy ZE-numbers.

During this phase, each expert votes on the preference vectors produced by the DMs for pairwise comparisons. Equations (8) and (9) are utilized in the computation of fuzzy ZE-numbers. As per Equation (9), there exist three regulations for R. The determination of the R regulation, used in the computation of new b_i, is influenced by the outcomes of expert voting.

According to fuzzy ZE-numbers concepts, the fuzzy ZE-numbers preferences of the base-to-others criteria are as follows.

$$\left(l_{Z^E(Bj)}, m_{Z^E(Bj)}, u_{Z^E(Bj)}\right) = \begin{cases} ZE = ((l_{B1}, m_{B1}, u_{B1}), (l_R, m_R, u_R), E_1) \\ ZE = ((l_{B2}, m_{B2}, u_{B2}), (l_R, m_R, u_R), E_2) \\ ZE = ((l_{B3}, m_{B3}, u_{B3}), (l_R, m_R, u_R), E_3) \\ \cdots \\ ZE = ((l_{Bn}, m_{Bn}, u_{Bn}), (l_R, m_R, u_R), E_n) \end{cases} \tag{13}$$

Step 5: Establish the most suitable criteria weighting.

Ultimately, the criteria weights are computed according to Eq. (13), taking into account the judgments of the experts and DMs.

$$\text{Min} \sum_{k=1}^{p} \lambda_k \xi_k \begin{cases} \left| \frac{\left(l_B^w, m_B^w, u_B^w\right)}{\left(l_j^w, m_j^w, u_j^w\right)} - \left(l_{Z^E(Bj)}, m_{Z^E(Bj)}, u_{Z^E(Bj)}\right) \right| \leq (\xi_k, \xi_k, \xi_k) \\ \sum_{j=1}^{n} \frac{\left(l_j^w + \left(4 * m_j^w\right) + u_j^w\right)}{6} = 1 \\ l_j^w \leq m_j^w \leq u_j^w \\ l_j^w \geq 0 \; for \; all \; j \end{cases} \tag{14}$$

4.3. ZE-MABAC method

MABAC is a powerful method for calculating the ranks of alternatives in MCDM. To accomplish this objective, the following steps should be performed by DMs in order to develop the MABAC method based on fuzzy ZE-numbers and apply it to calculating the ranks of case study strategies.

Step 1: Form the decision matrix by DMs.

Based on the criteria and alternatives, DMs should develop a decision matrix. Eq. (15) indicates the decision matrix by n criteria and m alternatives.

$$A = \begin{bmatrix} (l_{11}, m_{11}, u_{11}) & (l_{12}, m_{12}, u_{12}) & (l_{13}, m_{13}, u_{13}) & \cdots & (l_{1n}, m_{1n}, u_{1n}) \\ (l_{21}, m_{21}, u_{21}) & (l_{22}, m_{22}, u_{22}) & (l_{23}, m_{23}, u_{23}) & \cdots & (l_{2n}, m_{2n}, u_{2n}) \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ (l_{m1}, m_{m1}, u_{m1}) & (l_{m2}, m_{m2}, u_{m2}) & (l_{m3}, m_{m3}, u_{m3}) & \cdots & (l_{mn}, m_{mn}, u_{mn}) \end{bmatrix} \tag{15}$$

where (l_{11}, m_{11}, u_{11}) indicates the value of each criterion related to each alternative.

Step 2: Evaluation of each strategies based on the each criterion.

In this step, the DMs should be assigned the value of the membership function and reliability to each element according to the linguistics variables mentioned in Tables 4 and 5

Step 3: Each vector of the decision matrix should be voted on by experts.

After evaluations of the DMs and assigning the value for each decision matrix element, the experts should be voted to each vector of the decision matrix with the "Yes", "No", or "θ".

Step 4: Based on the fuzzy ZE-number framework, calculate the elements of the decision matrix.

The sum of the expert's votes for each decision matrix vector is calculated using Equation (8). The results are then divided into three groups according to Eq. (9), and the fuzzy ZE-numbers value is calculated for each element in the decision matrix.

Table 5
Linguistic reliability terms (Aboutorab et al., 2018).

Linguistic variables	Very High	High	Medium	Low	Very low
	VH	H	M	L	VL
TFNs	(0.7,1.0,1.0)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0,0,0.3)

$$A_{ZE} = \begin{bmatrix} (l_{Z^E(11)}, m_{Z^E(11)}, u_{Z^E(11)}) & (l_{Z^E(12)}, m_{Z^E(12)}, u_{Z^E(12)}) & \cdots & (l_{Z^E(1n)}, m_{Z^E(1n)}, u_{Z^E(1n)}) \\ (l_{Z^E(21)}, m_{Z^E(21)}, u_{Z^E(21)}) & (l_{Z^E(22)}, m_{Z^E(22)}, u_{Z^E(22)}) & \cdots & (l_{Z^E(2n)}, m_{Z^E(2n)}, u_{Z^E(2n)}) \\ \vdots & \vdots & \cdots & \vdots \\ (l_{Z^E(m1)}, m_{Z^E(m1)}, u_{Z^E(m1)}) & (l_{Z^E(m2)}, m_{Z^E(m2)}, u_{Z^E(m2)}) & \cdots & (l_{Z^E(mn)}, m_{Z^E(mn)}, u_{Z^E(mn)}) \end{bmatrix} \quad (16)$$

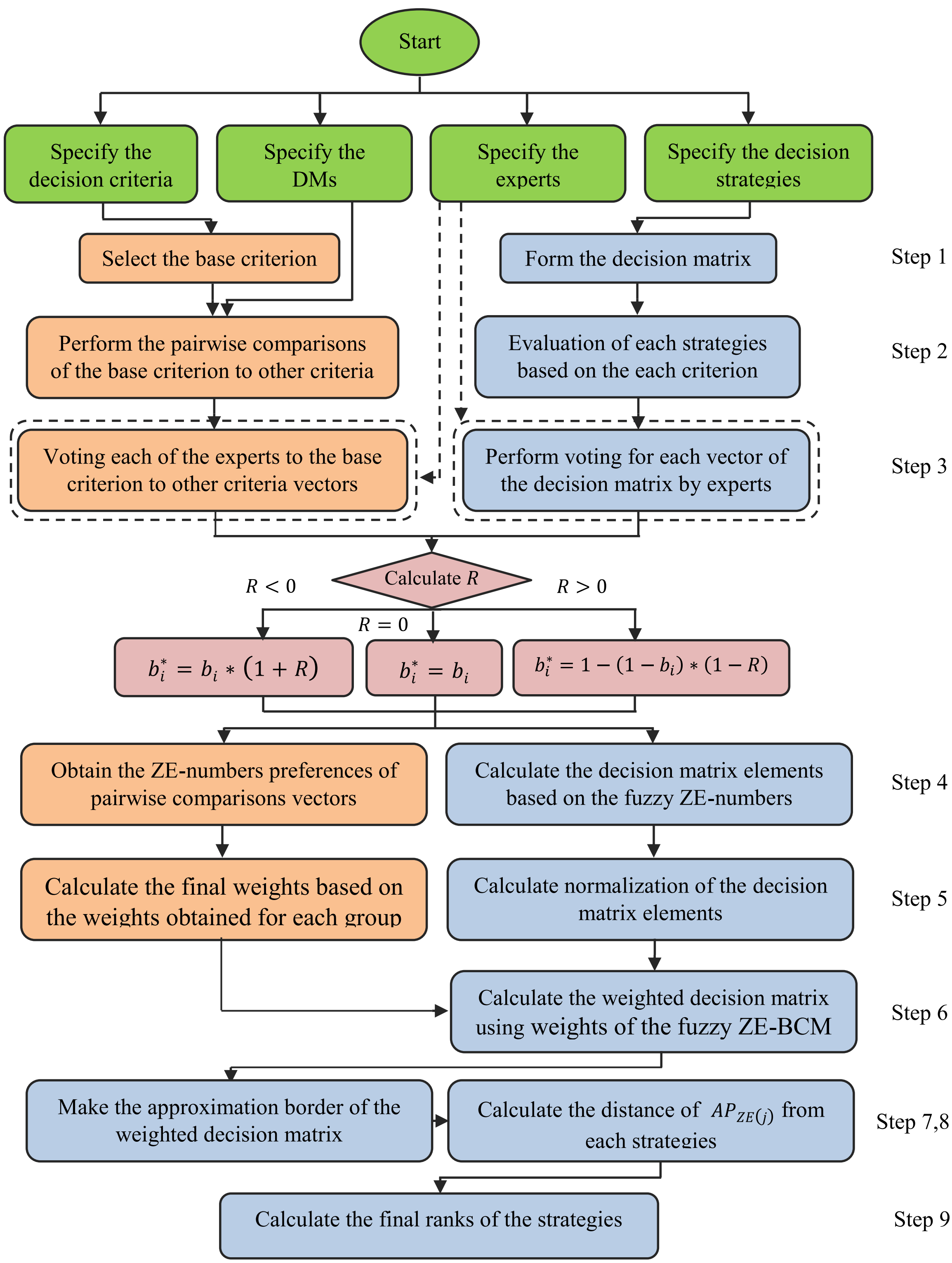


Fig. 1. An overview of the proposed approach, based on fuzzy ZE-BCMs and ZE-MABACs.

Step 5: Normalization of the decision matrix.

There are two types of criteria used in the normalization of the decision matrix; the elements of benefit criteria are used in equation (16) and the elements of cost criteria are used in equation (17).

$$\left(Nl_{Z^E(ij)}, Nm_{Z^E(ij)}, Nu_{Z^E(ij)}\right) = \left(\frac{l_{Z^E(ij)}}{\max Z^E(ij)}, \frac{m_{Z^E(ij)}}{\max Z^E(ij)}, \frac{u_{Z^E(11)}}{\max Z^E(ij)}\right) \text{ for benefit criteria} \tag{17}$$

$$\left(Nl_{Z^E(ij)}, Nm_{Z^E(ij)}, Nu_{Z^E(ij)}\right) = \left(\frac{\min Z^E(ij)}{u_{Z^E(11)}}, \frac{\min Z^E(ij)}{m_{Z^E(ij)}}, \frac{\min Z^E(ij)}{l_{Z^E(ij)}}\right) \text{ for cost criteria} \tag{18}$$

Step 6: Create a weighted decision matrix.

This step involves multiplying the criteria weights according to the fuzzy ZE-BCM with the elements of the alternative vectors in the normalized decision matrix. Equation (19) shows the weight of each criterion multiplied by the alternative index.

$$W_{ZE} = \begin{bmatrix} \left(l_{Z^E(w1)}, m_{Z^E(w1)}, u_{Z^E(w1)}\right) * \left(l_{Z^E(11)}, m_{Z^E(11)}, u_{Z^E(11)}\right) & \cdots & \left(l_{Z^E(wn)}, m_{Z^E(wn)}, u_{Z^E(wn)}\right) * \left(l_{Z^E(1n)}, m_{Z^E(1n)}, u_{Z^E(1n)}\right) \\ \left(l_{Z^E(w1)}, m_{Z^E(w1)}, u_{Z^E(w1)}\right) * \left(l_{Z^E(21)}, m_{Z^E(21)}, u_{Z^E(21)}\right) & \cdots & \left(l_{Z^E(wn)}, m_{Z^E(wn)}, u_{Z^E(wn)}\right) * \left(l_{Z^E(2n)}, m_{Z^E(2n)}, u_{Z^E(2n)}\right) \\ \vdots \quad \vdots \quad \vdots & \cdots & \vdots \\ \left(l_{Z^E(w1)}, m_{Z^E(w1)}, u_{Z^E(w1)}\right) * \left(l_{Z^E(m1)}, m_{Z^E(m1)}, u_{Z^E(m1)}\right) & \cdots & \left(l_{Z^E(wn)}, m_{Z^E(wn)}, u_{Z^E(wn)}\right) * \left(l_{Z^E(mn)}, m_{Z^E(mn)}, u_{Z^E(mn)}\right) \end{bmatrix} \tag{19}$$

Step 7: The weighted decision matrix approximation border should be made.

The approximation border area of the weighted decision matrix is obtained by Eq. (20).

$$AP_{Z^E} = \left[AP_{Z^E(1)}, AP_{Z^E(2),\dots,} AP_{Z^E(n)}\right] \text{ where } AP_{Z^E(j)} = \frac{1}{m}\left(\sum_{i=1}^{m} W_{Z^E(ij)}\right) \tag{20}$$

Step 8: Calculate the distance of $AP_{Z^E(j)}$ from each alternative.

The difference between the elements' values of the weighted matrix (W_{Z^E}) from the approximation border values (AP_{Z^E}) is determined as the distance of the alternatives from the approximation border.

$$Q_{ZE} = W_{Z^E}\text{-}A_{Z^E} \tag{21}$$

The alternatives could be placed in approximation border (Q), lower (Q^-), or upper (Q^+). The Q^- is the area that includes the anti-ideal alternative (A^-), while the Q^+ is the area that includes the ideal alternative (A^+).

Step 9: Calculate the rank of the alternatives.

The values of the criterion functions for the alternatives are calculated according to Eq. (21). According to Eq. (21), any alternative with a value close to 1 is ranked higher. Fig. 1 shows an overview of the proposed approach. As shown in Fig. 1, the proposed approach performed by experts and DMs with two non-similar ways.

5. Experimental results

According to the ZE-BCM, the affecting criteria weights, the strategy rank based on the ZE-MABAC, and the sensitive analysis based on the various outputs are provided in this section. As part of the evaluation of sustainable strategies, the weight of the influencing criteria must be determined. Therefore, the weights of the influencing criteria are derived as follows.

5.1. Criteria weights

As described in Section 4.3, the first step of the ZE-BCM is to specify experts, DMs, and effective criteria. Considering the opinions of the four DMs and the judgments of the 12 experts, the decision problem was solved. The pairwise comparisons results, as well as the experts' votes results for circular design criteria, are presented in Table 6 following the selection of the base criterion in step 2. For the membership function and reliability linguistic variables, the DMs assigned values for base pairwise comparisons. Also, the votes of the 12 experts on the 4 DMs evaluations are shown in Table 6 by "θ", "No", and "Yes". According to Eq. (8), the R values for each pairwise comparisons vector are calculated and inserted in the last column of Table 6. As previously stated, the value of R represents the level of consistency in pairwise comparisons made by decision-makers with the judgments provided by experts.

Tables A1, A3, A5, A7, and A9 of Appendix A provide the results of the base pairwise comparisons of 4 DMs and the votes of 12 experts for each pairwise comparison vector, as well as the calculated values of R for the sub-criteria of biodegradable packaging, product and manufacturer responsibility, critical success, corporate social responsibility, and main criteria, respectively.

For each pairwise comparisons of four DMs, the new extended reliability (E Reliability) and fuzzy ZE-numbers are shown in Table 7.

It is necessary to find the final criteria weights values in two stages due to the existence of the criteria. Therefore, to determine the final weight of a sub-criteria, similar steps must be followed in Tables 6 and 7.

Tables A2, A4, A6, A8, and A10 of Appendix A present the membership, ZE-numbers, and E reliability for the base pairwise comparison of four DMs based on the sub-criteria of biodegradable packaging, product and manufacturer responsibilities, critical success, corporate social responsibility, as well as the main criteria. Accordingly, the non-linear programming solution of Equation (14) of Appendix A is derived for each of the base pairwise comparisons vectors of Tables A2, A4, A6, A8, and A10 based on the fuzzy ZE-numbers determined for each pairwise comparisons. The obtained weight for each criterion is then multiplied by the corresponding weight for each sub-criteria. Table 8 shows the final value of each sub-criteria based on the fuzzy ZE-BCM step 5.

5.2. Strategies rank

It is possible to determine the rank of the sustainable strategies for the circular supply chain by following the steps of the fuzzy ZE-MABAC mentioned in section 4.3 once the sub-criteria weights are determined. The first step should be to form the decision matrix by the DMs. The DMs assigned the reliability values and membership functions based on the linguistic variables listed in Tables 5 and 4 The reliability values and membership functions for the elements of the decision matrix formed by DM1 are presented in Table B1 in Appendix B. As stated in section 4.3, the results of the experts' voting for each vector of the decision matrix

Table 6
The results for circular design criteria.

DM	Base criterion	Function	Pairwise comparisons				Experts votes			*R*
			C_{11}	C_{12}	C_{13}	C_{14}	*Yes*	*No*	θ	
DM_1	C_{14}	Membership	IFVI	WI	FI	EI	9	1	2	0.800
		Reliability	VL	VL	H	VH				
DM_2	C_{13}	Membership	WI	WI^{-1}	EI	WI^{-1}	7	3	2	0.400
		Reliability	L	M	VH	VL				
DM_3	C_{11}	Membership	EI	WI^{-1}	FI	VI	3	6	3	−0.333
		Reliability	VH	H	VL	L				
DM_4	C_{14}	Membership	FI	IWFI	IWFI	EI	5	5	2	0.000
		Reliability	H	VL	L	VH				

Table 7
ZE-numbers and new reliability for the circular design.

DM	C_1	C_{11}	C_{12}	C_{13}	C_{14}
DM_1	Membership	(5.0000,6.0000,7.0000)	(2.0000,3.0000,4.0000)	(4.0000,5.0000,6.0000)	(1.0000,1.0000,1.0000)
	E Reliability	(0.8000,0.8000,0.8600)	(0.8000,0.8000,0.8600)	(0.9000,0.9400,0.9800)	(1.0000,1.0000,1.0000)
	ZE-numbers	(1.8000,2.7000,3.6000)	(1.8000,2.7000,3.6000)	(3.8781,4.8477,5.8172)	(1.0000,1.0000,1.0000)
DM_2	Membership	(2.0000,3.0000,4.0000)	(0.2500,0.3333,0.5000)	(1.0000,1.0000,1.0000)	(0.2500,0.3333,0.5000)
	E Reliability	(0.4600,0.5800,0.7000)	(0.5800,0.7200,0.8200)	(1.0000,1.0000,1.0000)	(0.4000,0.4000,0.5800)
	ZE-numbers	(1.5232,2.2847,3.0463)	(0.2121,0.2828,0.4243)	(1.0000,1.0000,1.0000)	(0.1639,0.2186,0.3279)
DM_3	Membership	(1.0000,1.0000,1.0000)	(0.2500,0.3333,0.5000)	(0.1667,0.2000,0.2500)	(0.1250,0.1429,0.1667)
	E Reliability	(1.0000,1.0000,1.0000)	(0.3335,0.4669,0.6003)	(0.0000,0.0000,0.2001)	(0.0667,0.2001,0.3335)
	ZE-numbers	(1.0000,1.0000,1.0000)	(0.1708,0.2278,0.3417)	(0.0304,0.0365,0.0457)	(0.0559,0.0639,0.0746)
DM_4	Membership	(4.0000,5.0000,6.0000)	(3.0000,4.0000,5.0000)	(3.0000,4.0000,5.0000)	(1.0000,1.0000,1.0000)
	E Reliability	(0.5000,0.7000,0.9000)	(0.0000,0.0000,0.3000)	(0.3000,0.5000,0.7000)	(1.0000,1.0000,1.0000)
	ZE-numbers	(3.3466,4.1833,5.0200)	(0.6708,0.8944,1.1180)	(2.1213,2.8284,3.5355)	(1.0000,1.0000,1.0000)

Table 8
The final criteria weights.

Sub-criteria	ZE-BCM weight			Sub-criteria	ZE-BCM weight		
	l	m	u		l	m	u
C_{11}	0.0060	0.0083	0.0151	C_{35}	0.0131	0.0181	0.0282
C_{12}	0.0165	0.0263	0.0507	C_{41}	0.0413	0.0709	0.1318
C_{13}	0.0120	0.0204	0.0350	C_{42}	0.0786	0.1208	0.1752
C_{14}	0.0271	0.0402	0.0705	C_{43}	0.1303	0.1430	0.1912
C_{21}	0.0122	0.0164	0.0247	C_{44}	0.0495	0.0587	0.0825
C_{22}	0.0177	0.0195	0.0250	C_{45}	0.0261	0.0331	0.0481
C_{23}	0.0135	0.0168	0.0247	C_{46}	0.0294	0.0399	0.0546
C_{24}	0.0064	0.0083	0.0132	C_{51}	0.0208	0.0303	0.0407
C_{31}	0.0345	0.0853	0.1446	C_{52}	0.0296	0.0420	0.0696
C_{32}	0.0392	0.0617	0.0958	C_{53}	0.0084	0.0097	0.0127
C_{33}	0.0187	0.0303	0.0582	C_{54}	0.0204	0.0308	0.0454
C_{34}	0.0118	0.0167	0.0254	C_{55}	0.0203	0.0295	0.0462

According to Table 8, the most important sub-criterion is C_{43}, whereas the least important is C_{11}.

derived by DM_1 are presented in Table B1 in Appendix B.

For this purpose, the DMs assigned membership functions and reliability values to each element. Similar to Table B1 in Appendix B, the results of the formed decision matrix and experts' voting for each vector of the decision matrix formed By DM_2, DM_3, and DM_4 are presented in Tables B2, B3, and B4 in Appendix B.

According to step 3, after calculating the new reliability and fuzzy ZE-numbers for each element of the formed decision matrix by DMs, the group decision matrix is calculated in accordance with the average of the obtained fuzzy ZE-numbers decision matrix of the DMs. Based on DMs fuzzy ZE-number decision matrix, the results of the fuzzy ZE-numbers decision matrix for the group are shown in Table B5 in Appendix B.

Table B6 in Appendix B presents the normalized matrix results according to step 4. Also, according to the step 5, the results for weighted matrix are calculated and presented in Table B7 in Appendix B. Finally, the results of the obtained distance of $AP_{Z^E(j)}$ from each sustainable strategy for the circular supply chain are presented in Table B8 in Appendix B.

According to Eq. (21), the S_i of any strategy with a value close to 1 is ranked higher. Table 9 shows the results of the final strategies' rank based on the fuzzy ZE-MABAC methods.

Table 9
Final rank of the strategies based on the fuzzy ZE-MABAC.

Strategies	*Si*	Crisp	Rank
A_1	(-1.4616, 0.0750, 1.6480)	0.0871	4
A_2	(-1.4442, 0.0874, 1.6410)	0.0947	3
A_3	(-1.4412, 0.0913, 1.6510)	0.1004	2
A_4	(-1.4030, 0.1449, 1.7423)	0.1614	1
A_5	(-1.6125, −0.1717, 1.2171)	−0.1891	6
A_6	(-1.6030, −0.0935, 1.3540)	−0.1142	5

As can be seen in the results provided in Table 9, strategy A_4 is determined as the best strategy, and A_5 and A_6 are determined as the least important strategies.

5.3. Sensitivity analysis

As described above, the identified criteria have both costs and benefits; therefore, they have a significant impact on the rankings of the

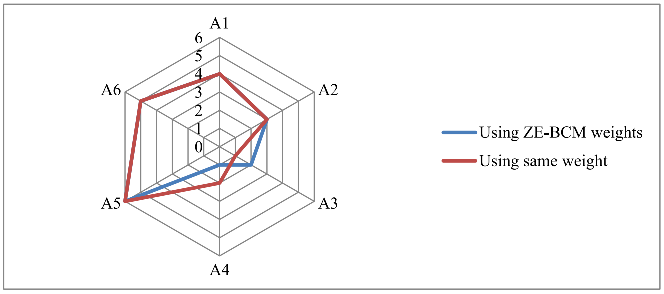


Fig. 2. Sensitivity analysis for the ranks of the sustainable strategies.

strategies. It follows, therefore, that a change in the weight of some criteria can affect the rank of a strategy. This can be achieved by calculating the ranking of the strategies using different weights for each criterion to gain a better understanding of the importance of the weights derived from ZE-BCM. To analyze the sensitivity of the circular supply chain ranking, different weights for the criteria of sustainability are used.

The ranking of the strategies has been determined by applying the same weights to all of the sub-criteria, as shown in Fig. 2. This means that the weight of 1 is divided into 19 sub-criteria, and the result is used as the weight for the sub-criteria. The comparison results in Fig. 2 show differences between the ranking of strategies using the ZE-BCM criteria weights and the ranking of strategies using the same weights conditions. To obtain more accurate rankings for CSCM, it is necessary to weigh the criteria using the fuzzy ZE-BCM.

After weighing the criteria, results showed that A_4 stands out as the best strategy, followed by A_3, A_2, A_1, A_6, and A_5, respectively. Based on ZE-BCM weighting, the difference between the strategies is less scattered. When the weighting of all sub-criteria is considered equal, the ranking of the strategies does not change. However, their distance from each other increases. As demonstrated in Fig. 2, strategy A_4 occupies the first place by a great margin. The A_6 and A_5 are far behind the top 4 strategies, and A_5, as the last strategy, is the least desirable for implementation.

Moreover, it is also very important to understand how each strategy ranks and values based on the sub-criteria that make up each main criterion to be able to evaluate its performance accordinglyThe results

Table 10
Comparative rank results of the strategies based on the different fuzzy types.

Strategies	Fuzzy MABAC		Fuzzy Z-MABAC		Fuzzy ZE-MABAC	
	Si	Rank	Si	Rank	Si	Rank
A_1	0.1520	1	0.1953	1	0.0871	4
A_2	0.1448	2	0.1114	3	0.0947	3
A_3	0.0937	3	0.0206	4	0.1004	2
A_4	0.0738	4	0.1173	2	0.1614	1
A_5	−0.1603	6	−0.1677	6	−0.1891	6
A_6	−0.1578	5	−0.1184	5	−0.1142	5

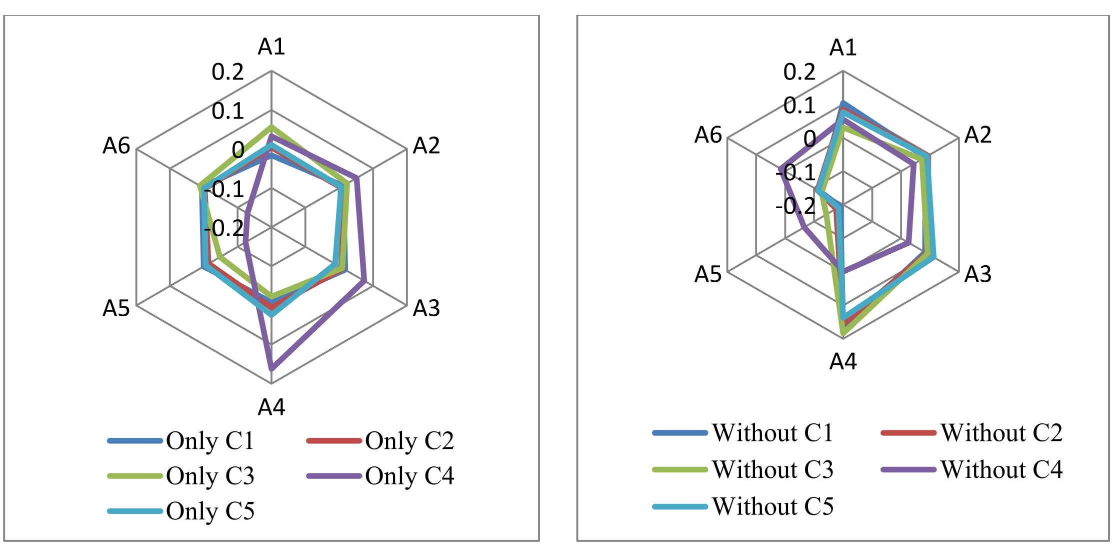
are shown in the table below and it is easy to see which strategy ranks higher in terms of the sub-criteria of each main criterion in the ranking process. By analyzing the proposed strategies rankings for the CSCM without taking into consideration the subcriteria of each main criterion at each step, we can predict the results for final ranking when the sub-criteria are removed from each main criterion. In Fig. 3, parts (a) and (b), we show the ranking results by considering "without" and "only" effects of the sub-criteria of each criterion.

The ranking of strategies based on actions is only one of the main criteria Fig. 3(a). For example, the "only C_3" output has been ranked based on the product and producer responsibility criteria (C_3) and its sub-criteria. In C_3, strategy A_1 has the best rating. In C_4, strategy A_4 has the best rating. In Fig. 3(b), the ranking of strategies is based on applying indicators without one of the main indicators. For example, the output of the "Without C_3" shows the ranking of strategies without considering the product index and producer responsibility (C_3) and its sub-criteria. In the review of the "Without C_3", strategy A_4 has the best rating. Also, in the review of the "Without C_4", strategy A_1 has the best rating.

An important point that can be taken from the sensitivity analysis presented in Fig. 3 is the significant impact of critical success factors (C_4). The results show that the presence or absence of **sub**-criteria of this criterion can cause significant changes in the ranking results of strategies. So that there is convergence in the results of ranking strategies among the influence of the presence or absence of other criteria, but the critical success factors (C_4) criterion has a decisive role.

5.4. Comparative analysis

We compare the results of this research with other MCDM methods as



(a). Only the sub-criteria of each criterion (b). Without the sub-criteria of each criterion

Fig. 3. Ranks the sub-criteria of each main criterion with "only" and "without" impacts.

well as with different fuzzy extensions of the MABAC method in order to better understand the advantages of the used methodology. A preliminary comparison is made between the fuzzy ZE-MABAC methods and the two previous fuzzy extensions.

As seen in Table 10, strategy A_1 emerges as the best choice in all methods except fuzzy ZE-MABAC. Additionally, strategy A_4 secures the 1st rank in fuzzy ZE-MABAC, while it ranks 2nd and 4th in fuzzy Z-MABAC and fuzzy MABAC, respectively. The weighted Spearman's rank correlation coefficient for strategy A_1 among the three mentioned methods exceeds 0.700, indicating a good correlation between fuzzy MABAC, fuzzy Z-MABAC, and fuzzy ZE-MABAC.

It is also evident that strategy A_5 performs the poorest in all three methods, ranking 6th. Another commonality across all three methods is observed in strategy A_6, which holds the 5th rank in each. The weighted Spearman's rank correlation coefficient for strategies A_5 and A_6 is 1.000, indicating a strong correlation among all three methods.

Further analysis within the realm of Spearman's correlation involves examining the overall correlation among fuzzy MABAC, fuzzy Z-MABAC, and fuzzy ZE-MABAC simultaneously. The Spearman's correlation between fuzzy MABAC and fuzzy ZE-MABAC is 0.429, signifying an average correlation between the results of these two decision-making methods. A strong correlation exists between fuzzy Z-MABAC and fuzzy ZE-MABAC, as indicated by the correlation coefficient of 0.600.

The results of the weighted Spearman's rank correlation coefficient demonstrate an increasing correlation with the progression from fuzzy MABAC to fuzzy Z-MABAC. This underscores the impact of considering reliability in decisions. When the reliability of decisions is not factored into the fuzzy MABAC method, the noticeable divergence in results highlights its significance. Furthermore, comparing fuzzy Z-MABAC and fuzzy ZE-MABAC, it becomes evident that the inclusion of expert judgments contributes to more reliable results, explaining the variation in outcomes.

In addition to comparing the results of strategies using the fuzzy expansions of the MABAC method, more comprehensive comparisons were conducted with other MCDM methods such as VIKOR, TOPSIS, COPRAS, and a novel MCDM method called the Root Assessment Method (RAM) (Sotoudeh-Anvari, 2023) in Table 11. In this context, the A_4 strategy was again identified as the best choice in all methods except the VIKOR method. The weighted Spearman's rank correlation coefficient for the A_4 strategy among the five methods is 0.750, indicating a strong correlation across all methods. Furthermore, the A_3 strategy secured the first rank in the VIKOR method, while it ranked 2nd to 4th in the remaining methods. Strategy A_1 also obtained the 4th rank in RAM and MABAC, and it secured the 2nd and 3rd ranks in other methods, highlighting the high correlation in the ranking among these methods.

Another analysis in this domain involves the overall correlation of TOPSIS, VIKOR, COPRAS, RAM, and MABAC methods simultaneously. According to the weighted Spearman's rank correlation coefficient, MABAC is 0.829 of the time, 0.886 of the time, 0.771 of the time, and 0.943 of the time, compared with other methodologies, such as TOPSIS, VIKOR, COPRAS, and RAM. According to the results, the ranking

Table 11
Priority of choices by different MCDM methods.

Priority of Strategies	TOPSIS	VIKOR	COPRAS	RAM	MABAC
1	A_4	A_3	A_4	A_4	A_4
2	A_2	A_4	A_1	A_2	A_3
3	A_1	A_1	A_2	A_3	A_2
4	A_3	A_2	A_3	A_1	A_1
5	A_6	A_6	A_6	A_6	A_6
6	A_5	A_5	A_5	A_5	A_5

Additionally, the A_5 and A_6 strategies are among the least favorable choices in all five MCDM methods, ranking 6th and 5th, respectively. The weighted Spearman's rank correlation coefficient for strategies A5 and A6 across all MCDM methods is equal to 1, indicating that A_5 and A_6 hold the same position in all mentioned methods.

correlation between MABAC and other MCDM methods is notably high. In the next section, provided more detailed discussion about the results.

6. Discussion

Taking into account the concept of corporate social responsibility, it is important to acknowledge that products must be produced in a manner that minimizes waste, including that resulting from human and environmental activities. The CSCMs should be implemented in the beverage industry, but before implementing CSCM in the beverage industry, the most important issue is choosing an appropriate strategy, the lack of which increases the probability of CSCM failure. Despite the importance of choosing the right strategy for the effectiveness of CSCM, research in the direction of choosing a strategy considering biodegradable packaging, corporate social responsibility, and their sub-criteria has not been done in the beverage industry. As seen in Fig. 4, the waste recycling rate in the world is 2.5 times that of Iran. In this regard, the company's social responsibility requires this research to focus on reducing waste and preserving the environment. In addition, it can positively impact the integrity of the CSCM cycle and the performance of the beverage industry.

The six strategies considered in Table 3 were investigated in companies active in the beverage industry. Each strategy was examined separately with all the criteria to measure the strategies. The difference in strategies affected the amount of each criterion and produced different results. One of the most important criteria is corporate social responsibility (C_5), which measures companies' performance in complying with society's expediency and interests by accepting responsibility for their activities' effects on consumers, society, and most importantly, on the environment. This commitment goes beyond legal requirements to comply with regulations and shows how companies voluntarily strive to improve corporate social responsibility. Companies can improve corporate social responsibility by involving consumers in social responsibility (C_{52}). One of the most important criteria is biodegradable packaging (C_2), which has become a suitable strategy for Beverage packaging compared to oil derivatives to reduce environmental pollution. In this regard, with environmental regulations (C_{22}), it is possible to purposefully control the amount of use of all types of packaging, and with the recyclability of packaging (C_{24}), recycled materials can be used again. This has formed a circular cycle. With the optimal design (C_{13}), many costs (C_{42}) and materials are reused. Recycling greatly reduces waste, establishing an optimal environmental safety level (C_{21}). In the next section, provided the managerial implications about the results for a more comprehensive view of the discussion.

7. Managerial implications

Analyzing the strategies results shows that the A_4 strategy has been chosen best. In A_4, incentive and charity schemes have been utilized, and customers can get a new product by returning the packaging, or according to the charity plan, the benefits of returning the packaging can be used for humanitarian projects (supporting children, donations from the company to charities, helping injured people use natural events, etc). Corporate social responsibility also requires that companies take responsibility for society and the environment in which they operate and, in this regard, make efforts to support humanitarian projects. One of the advantages of A_4 is that the philanthropic schemes help establish cooperation between consumers, companies, and distributors towards the successful establishment of the strategy. The A_4 can also be considered for certain types of sales network development, the driving force of which is people's empathy, but it needs much time to be implemented. Strategy A_3, chosen as the second priority, implements the return plan for consumers to return plastic or bottle to non-profits such as municipalities.

Since existing non-profit organizations can be utilized for help, the

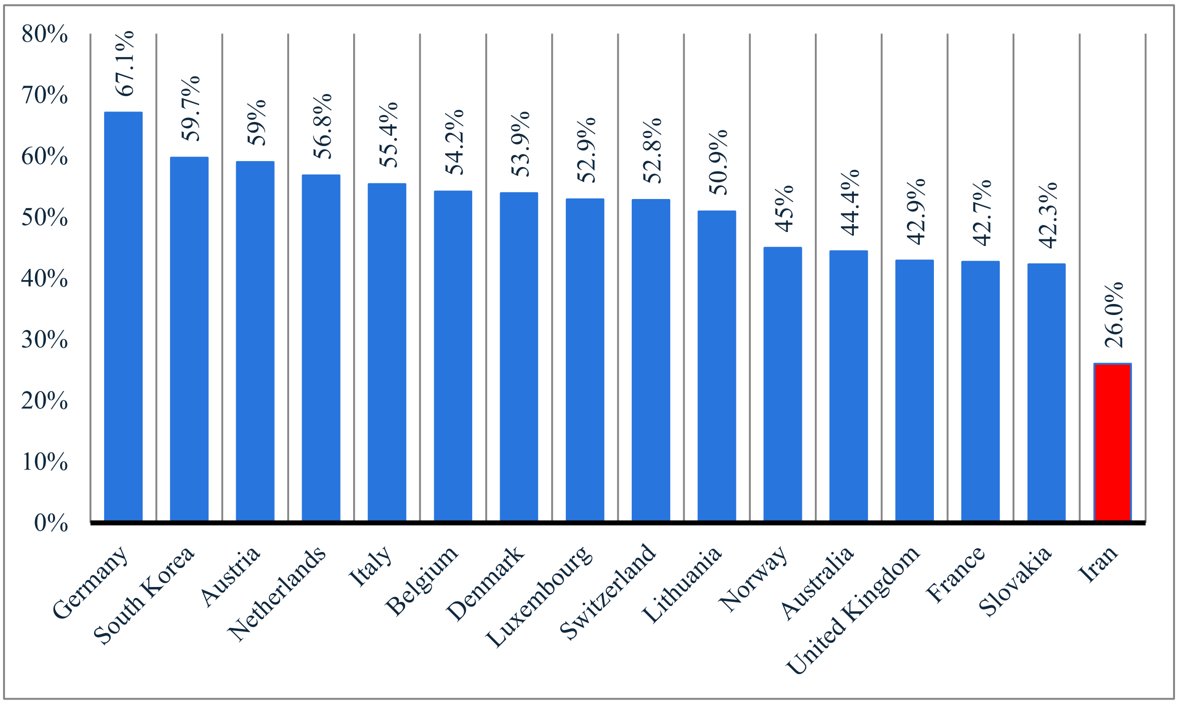


Fig. 4. Municipal solid waste material recovery rates worldwide in 2020, by select country (OECD; ID 1052439).

cost of collection is greatly reduced, and most non-profit organizations have the ability and strength to implement such plans. Based on these relationships, companies can access a network of various organizations and increase product sales while reducing implantation costs of the return packaging plan. Companies can sell their products to organizations with tools such as gift cards, discount codes, and bulk sales, which makes them more profitable. The weakness of A_3 is that it needs a wide network for implementation, which makes it difficult to manage.

Strategy A_2, chosen as the third priority, shows that incentive plans can be used to advance companies' goals. Incentive plans are plans that are formed based on the performance of consumers. The more consumers buy, the more benefits they will receive. For example, consumers get a new product by returning five packages of used products in a plan. In another scheme, the consumer uses an exponential discount by returning more waste. This strategy can be one of the company's goals to increase sales because previous customers are encouraged to buy again. Instead of attracting new customers, which costs much marketing, the company encourages existing customers to buy again. Strategy A_1, which was chosen as the fourth priority, is the use of vending machines. In addition to selling, these machines are responsible for receiving and pressing the packaging of products. Although this strategy is the 4th, it is cost-effective due to its low cost, no need for a salesperson, and the availability of sales machines. Vending machines are used in chain stores, and one of their advantages is more time for sales. The weakness of A_1 is that it needs a safe and suitable place to sell, sometimes, the vending machines are broken, or the product is out of stock, and they need to be constantly maintained.

The A_6 and A_5 strategies were ranked 5th and 6th among the strategies and are far away from other strategies. These strategies are less attractive to implement than those ranked 1 to 4 because of the low rating derived from the analysis of all criteria. In this regard, the A6 strategy, chosen as the fifth strategy, shows that the products produced next to the original product can be turned into gifts and recycled waste. These gifts should be given to collect waste products. It seems that spending energy to convert products into gifts is not cost-effective, and there are more meaningful ways to increase company productivity. This strategy is not as effective as needed. A_5 strategy, which was chosen as the sixth strategy, focused on branding the company and choosing a logo to collect the waste of sold products to help the environment. It can be said that actions with better executive support can be done in Iran. Spending money on branding for waste collection is not cost-effective and needs to increase the infrastructure with more practical measures. Increasing the infrastructure for waste return has created an active cycle that increases the company's strength by reducing costs and less need for raw materials.

8. Conclusions

In this research, 24 sub-criteria were identified in 5 main criteria categories to provide sustainable strategies based on the social responsibility of the beverage industry companies for the circular supply chain. Five main criteria include circular design (C_1), biodegradable packaging (C_2), product and producer responsibility (C_3), critical success factors (C_4), and corporate social responsibility (C_5). Then six strategies were selected to implement CSCM in active companies in the beverage industry. The results show that the most important criteria are economic benefit from the implementation of each strategy (C_{43}), cost reduction (C_{42}), and research and development (C_{31}), respectively. The least important criteria are recyclability or reusability (C_{24}), ecological effects of the product life cycle (C_{11}), and involving consumers in social responsibility (C_{53}). The review of the strategies in the criteria also showed that strategy (A_4) was chosen as the best strategy. The prioritization of other strategies showed that the next priorities are A_3, A_2, A_1, $A_{6,}$ and $A_{5,}$ respectively. Strategies A_6 and A_5 are less attractive to implement due to their low ranking.

Also, some analysis was performed to show the impact of the sub-criteria of each criterion in choosing the best strategies that show how effective is the presence or absence of each of the criteria in choosing the best strategies. All performed sensitivity analyses are used as the guide for the managers to analyze all statuses in calculating the scores of the strategies.

The results of the analysis for the applied methodology show that the fuzzy ZE-numbers with the BCM and MABAC offer valuable advantages. The results show that the criteria weights and scores of the sustainable strategies are more reliable than results obtained from the same methods under the classic fuzzy set or fuzzy set with the Z-number concept. Also, the results show that the used methodology has an overall correlation with other similar MCDM methods.

In order to the limitations of the research, in situations where access to the experts and DMs is difficult, the applicability of used methods may be limited. Also, the implementation of fuzzy ZE-numbers is complex, especially for individuals not familiar with fuzzy concepts. This complexity can pose challenges in both application and interpretation. Additionally, reliability is a subjective measure in fuzzy ZE-numbers. It is therefore difficult to objectively determine reliability, and subjective assessments may introduce errors and biases into the decision-making process.

In addition to the limitations of fuzzy ZE-numbers, the main limitation in precess of this research is the hardness of collecting decision data from experts and DMs. Providing strategies at the macro level requires coordination to conduct interviews with middle and senior managers of organizations. Due to the difference in the manager's views, which is caused by the difference in the management levels and their field of activity, it is not easy to reach a comprehensive, optimal decision. In this research, a novel group decision-making method is applied, which uses two different approaches to collect the judgments of DMs and experts so that the final decision is obtained based on the opinions of a wide range of managers.

Another limitation is the lack of a simulation system to evaluate the effects of each sustainable strategy for the circular supply chain if implemented in the real world. This limitation causes the accuracy of final decisions for sustainable strategies uncertain until full implementation. Although this research tried to provide more reliable decisions by considering reliability, it is a fact that before the full implementation of strategies in the beverage industry and the passage of time, it is impossible to understand some of its hidden problems.

For the future direction, the integration of advanced AI techniques, such as machine learning and deep learning, with fuzzy MCDM methods can enhance the decision-making process by learning from historical data and adapting to changing conditions in the CSCM. Also, developing new MCDM methods like RAM will be attractive for future research. Evaluation of sustainable strategies for circular supply chains in other industries, such as the food industry, can be another attractive topic for future research. Also, the evaluation of sustainable strategies from the point of view of macro policies of countries can create a new vision for the success of implementing circular supply chains for industries. Therefore, one of the suggestions for future research is to design a system to simulate the impact of implementing each of the sustainable strategies for the circular supply chain in the beverage industry.

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CRediT authorship contribution statement

Gholamreza Haseli: Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Javad Nazarian-Jashnabadi:** Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Behnaz Shirazi:** Writing – original draft, Methodology, Investigation. **Mostafa Hajiaghaei-Keshteli:** Writing – review & editing, Supervision. **Sarbast Moslem:** Writing – review & editing.

Declaration of competing interest

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

Data availability

No data was used for the research described in the article.

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Appendix A

Table A1
The results of pairwise comparisons and votes for biodegradable packaging criteria.

DMs	Base criterion	Function	Sub-criteria				Experts votes			R
			C_{21}	C_{22}	C_{23}	C_{24}	*Yes*	*No*	θ	
DM_1	C_{22}	Membership	WI	EI	FI	WI	10	2	0	0.667
		Reliability	M	VH	VL	M				
DM_2	C_{22}	Membership	EI	EI	IWFI	IWFI	3	5	4	−0.111
		Reliability	VH	VH	VL	L				
DM_3	C_{24}	Membership	FI^{-1}	WI	VI	EI	3	6	3	−0.333
		Reliability	L	VL	L	VH				
DM_4	C_{21}	Membership	EI	IWFI	IWFI	FI	4	4	4	0.000
		Reliability	VH	M	VL	L				

Table A2
ZE-numbers and new reliability for the biodegradable packaging.

DM	C_2	C_{21}	C_{22}	C_{23}	C_{24}
DM_1	Membership	(2.0000,3.0000,4.0000)	(1.0000,1.0000,1.0000)	(4.0000,5.0000,6.0000)	(2.0000,3.0000,4.0000)
	E Reliability	(0.7669,0.8335,0.9001)	(1.0000,1.0000,1.0000)	(0.6670,0.6670,0.7669)	(0.7669,0.8335,0.9001)
	ZE-numbers	(1.8259,2.7389,3.6518)	(1.0000,1.0000,1.0000)	(3.3073,4.1342,4.9610)	(1.8259,2.7389,3.6518)
DM_2	Membership	(1.0000,1.0000,1.0000)	(1.0000,1.0000,1.0000)	(3.0000,4.0000,5.0000)	(3.0000,4.0000,5.0000)
	E Reliability	(1.0000,1.0000,1.0000)	(1.0000,1.0000,1.0000)	(0.0000,0.0000,0.2250)	(0.07500,0.2250,0.3750)

(continued on next page)

Table A2 (*continued*)

DM	C_2	C_{21}	C_{22}	C_{23}	C_{24}
	ZE-numbers	(1.0000,1.0000,1.0000)	(1.0000,1.0000,1.0000)	(0.5809,0.7746,0.9682)	(1.4230,1.8974,2.3717)
DM_3	Membership	(0.1667,0.2000,0.2500)	(0.2500,0.3333,0.5000)	(0.1250,0.1429,0.1667)	(1.0000,1.0000,1.0000)
	E Reliability	(0.0667,0.2001,0.3335)	(0.0000,0.0000,0.2001)	(0.0667,0.2001,0.3335)	(1.0000,1.0000,1.0000)
	ZE-numbers	(0.0746,0.0895,0.1118)	(0.0457,0.0609,0.0913)	(0.0559,0.0639,0.0746)	(1.0000,1.0000,1.0000)
DM_4	Membership	(1.0000,1.0000,1.0000)	(3.0000,4.0000,5.0000)	(3.0000,4.0000,5.0000)	(4.0000,5.0000,6.0000)
	E Reliability	(1.0000,1.0000,1.0000)	(0.3000,0.5000,0.7000)	(0.0000,0.0000,0.3000)	(0.1000,0.3000,0.5000)
	ZE-numbers	(1.0000,1.0000,1.0000)	(2.1213,2.8284,3.5355)	(0.6708,0.8944,1.1180)	(2.1909,2.7386,3.2863)

Table A3
The pairwise comparisons results and votes for product and manufacturer's responsibility criteria.

DM	Base criterion	Function	Sub-criteria					Experts votes			R
			C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	*Yes*	*No*	θ	
DM_1	C_{32}	Membership	WI	EI	FI	VI	AI	8	3	1	0.727
		Reliability	VL	VH	H	L	M				
DM_2	C_{33}	Membership	$IEWI^{-1}$	$IEWI^{-1}$	EI	WI	IWFI	3	3	6	0.000
		Reliability	VL	H	VH	M	M				
DM_3	C_{35}	Membership	FI^{-1}	AI^{-1}	$IFVI^{1-}$	FI^{-1}	EI	7	3	2	0.400
		Reliability	L	H	VL	VL	VH				
DM_4	C_{32}	Membership	FI	EI	IEWI	VI	FI	5	5	2	0.000
		Reliability	L	VH	M	H	VL				

Table A4
ZE-numbers and new reliability for the product and manufacturer's responsibility.

DM	C_3	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}
DM_1	Membership	(1.0000,2.0000,3.0000)	(1.0000,1.0000,1.0000)	(4.0000,5.0000,6.0000)	(6.0000,7.0000,8.0000)	(8.0000,9.0000,9.0000)
	E Reliability	(0.7270,0.7270,0.8089)	(1.0000,1.0000,1.0000)	(0.8635,0.9181,0.9727)	(0.7543,0.8089,0.8635)	(0.8089,0.8635,0.9181)
	ZE-numbers	(1.7212,2.5818,3.4424)	(1.0000,1.0000,1.0000)	(3.8327,4.7909,5.7491)	(5.3963,6.2957,7.1951)	(7.4340,8.3632,8.3632)
DM_2	Membership	(0.3333,0.5000,1.0000)	(0.3333,0.5000,1.0000)	(1.0000,1.0000,1.0000)	(1.0000,2.0000,3.0000)	(3.0000,4.0000,5.0000)
	E Reliability	(0.0000,0.0000,0.3000)	(0.5000,0.7000,0.9000)	(1.0000,1.0000,1.0000)	(0.3000,0.5000,0.7000)	(0.3000,0.5000,0.7000)
	ZE-numbers	(0.0745,0.1118,0.2236)	(0.2789,0.4183,0.8367)	(1.0000,1.0000,1.0000)	(1.4142,2.1213,2.8284)	(2.1213,2.8284,3.5353)
DM_3	Membership	(0.1667,0.2000,0.2500)	(0.1111,0.1111,0.1250)	(0.1429,0.1667,0.2000)	(0.1667,0.2000,0.2500)	(1.0000,1.0000,1.0000)
	E Reliability	(0.4600,0.5800,0.7000)	(0.7000,0.8200,0.9400)	(0.4000,0.4000,0.5800)	(0.4000,0.4000,0.5800)	(1.0000,1.0000,1.0000)
	ZE-numbers	(0.1269,0.1523,0.1904)	(0.1006,0.1006,0.1132)	(0.0937,0.1093,0.1311)	(0.1093,0.1311,0.1639)	(1.0000,1.0000,1.0000)
DM_4	Membership	(4.0000,5.0000,6.0000)	(1.0000,1.0000,1.0000)	(1.0000,2.0000,3.0000)	(6.0000,7.0000,8.0000)	(4.0000,5.0000,6.0000)
	E Reliability	(0.1000,0.3000,0.5000)	(1.0000,1.0000,1.0000)	(0.3000,0.5000,0.7000)	(0.5000,0.7000,0.9000)	(0.0000,0.0000,0.3000)
	ZE-numbers	(2.1909,2.7386,3.2863)	(1.0000,1.0000,1.0000)	(0.7071,1.4142,2.1213)	(5.0200,5.8566,6.6933)	(0.8944,1.1180,1.3416)

Table A5
The pairwise comparisons results and experts' votes for critical success factors criteria.

DM	Base criterion	Function	Sub-criteria						Experts votes			R
			C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	C_{46}	*Yes*	*No*	θ	
DM_1	C_{42}	Membership	IEWI	EI	IEWI	WI	IWFI	FI	10	1	1	0.818
		Reliability	L	VH	H	L	VH	H				
DM_2	C_{43}	Membership	$IEWI^{-1}$	WI^{-1}	EI	IEWI	IEWI	WI	10	0	2	1.000
		Reliability	VL	M	VH	L	H	H				
DM_3	C_{45}	Membership	$IEWI^{-1}$	$IEWI^{-1}$	FI^{-1}	$IWFI^{-1}$	EI	$IEWI^{-1}$	3	9	1	−0.454
		Reliability	VH	VH	VL	M	VH	M				
DM_4	C_{42}	Membership	IEWI	EI	WI	IWFI	IWFI	WI	6	3	3	0.333
		Reliability	VH	VH	VH	L	L	H				

Table A6
ZE-numbers and new reliability for the critical success factors.

DM	C_4	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	C_{46}
DM_1	Membership	(1.0000,2.0000,3.0000)	(1.0000,1.0000,1.0000)	(1.0000,2.0000,3.0000)	(2.0000,3.0000,4.0000)	(3.0000,4.0000,5.0000)	(4.0000,5.0000,6.0000)
	E Reliability	(0.8362,0.8726,0.9090)	(1.0000,1.0000,1.0000)	(0.9090,0.9454,0.9818)	(0.8362,0.8726,0.9090)	(0.9454,1.0000,1.0000)	(0.9090,0.9454,0.9818)
	ZE-numbers	(0.9341,1.8683,2.8024)	(1.0000,1.0000,1.0000)	(0.9723,1.9446,2.9170)	(1.8683,2.8024,3.7365)	(2.9863,3.9818,4.9772)	(3.8893,4.8616,5.8339)
DM_2	Membership	(0.3333,0.5000,1.0000)	(0.2500,0.3333,0.5000)	(1.0000,1.0000,1.0000)	(1.0000,2.0000,3.0000)	(1.0000,2.0000,3.0000)	(2.0000,3.0000,4.0000)

(*continued on next page*)

Table A6 (*continued*)

DM	C_4	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	C_{46}
	E Reliability	(1.0000,1.0000,1.0000)	(1.0000,1.0000,1.0000)	(1.0000,1.0000,1.0000)	(1.0000,1.0000,1.0000)	(1.0000,1.0000,1.0000)	(1.0000,1.0000,1.0000)
	ZE-numbers	(0.3333,0.5000,1.0000)	(0.2500,0.3333,0.5000)	(1.0000,1.0000,1.0000)	(1.0000,2.0000,3.0000)	(1.0000,2.0000,3.0000)	(2.0000,3.0000,4.0000)
DM_3	Membership	(0.3333,0.5000,1.0000)	(0.3333,0.5000,1.0000)	(0.1667,0.2000,0.2500)	(0.2000,0.2500,0.3333)	(1.0000,1.0000,1.0000)	(0.3333,0.5000,1.0000)
	E Reliability	(0.3822,1.0000,1.0000)	(0.3822,1.0000,1.0000)	(0.0000,0.0000,0.1638)	(0.1638,0.2730,0.3822)	(1.0000,1.0000,1.0000)	(0.1638,0.2730,0.3822)
	ZE-numbers	(0.3157,0.4736,0.9471)	(0.3157,0.4736,0.9471)	(0.0275,0.0330,0.0413)	(0.1045,0.1306,0.1742)	(1.0000,1.0000,1.0000)	(0.1742,0.2612,0.5225)
DM_4	Membership	(1.0000,2.0000,3.0000)	(1.0000,1.0000,1.0000)	(2.0000,3.0000,4.0000)	(3.0000,4.0000,5.0000)	(3.0000,4.0000,5.0000)	(2.0000,3.0000,4.0000)
	E Reliability	(0.7999,1.0000,1.0000)	(1.0000,1.0000,1.0000)	(0.7999,1.0000,1.0000)	(0.3997,0.5331,0.6665)	(0.3997,0.5331,0.6665)	(0.6665,0.7999,0.9333)
	ZE-numbers	(0.9832,1.9664,2.9496)	(1.0000,1.0000,1.0000)	(1.9664,2.9496,3.9327)	(2.1904,2.9205,3.6507)	(2.1904,2.9205,3.6507)	(1.7887,2.6831,3.5775)

Table A7
The pairwise comparisons results and experts' votes for corporate social responsibility criteria.

DM	Base criterion	Function	Sub-criteria					Experts votes			R
			C_{51}	C_{52}	C_{53}	C_{54}	C_{55}	*Yes*	*No*	θ	
DM_1	C_{52}	Membership	VI	EI	IVAI	WI	IWFI	9	1	2	0.800
		Reliability	VL	VH	VL	H	H				
DM_2	C_{55}	Membership	IEWI	WI	IWFI	IEWI	EI	7	1	4	0.750
		Reliability	VH	L	VL	L	VH				
DM_3	C_{53}	Membership	$IFVI^{-1}$	$IEWI^{-1}$	EI	$IWFI^{-1}$	$IWFI^{-1}$	4	6	2	−0.200
		Reliability	H	VL	VH	M	VL				
DM_4	C_{52}	Membership	IWFI	EI	VI	WI	IWFI	5	4	1	0.125
		Reliability	VL	VH	VL	VH	H				

Table A8
ZE-numbers and new reliability for the corporate social responsibility.

DM	C_5	C_{51}	C_{52}	C_{53}	C_{54}	C_{55}
DM_1	Membership	(6.0000,7.0000,8.0000)	(1.0000,1.0000,1.0000)	(7.0000,8.0000,9.0000)	(2.0000,3.0000,4.0000)	(3.0000,4.0000,5.0000)
	E Reliability	(0.8000,0.8000,0.8600)	(1.0000,1.0000,1.0000)	(0.8200,0.8600,0.9000)	(0.9000,0.9400,0.9800)	(0.9000,0.9400,0.9800)
	ZE-numbers	(5.4000,6.3000,7.2000)	(1.0000,1.0000,1.0000)	(6.4915,7.4189,8.3463)	(1.9391,2.9086,3.8781)	(2.9086,3.8781,4.8477)
DM_2	Membership	(0.3333,0.5000,1.0000)	(2.0000,3.0000,4.0000)	(3.0000,4.0000,5.0000)	(0.3333,0.5000,1.0000)	(1.0000,1.0000,1.0000)
	E Reliability	(0.9250,1.0000,1.0000)	(0.7750,0.8250,0.8750)	(0.7500,0.7500,0.8250)	(0.7750,0.8250,0.8750)	(1.0000,1.0000,1.0000)
	ZE-numbers	(0.3312,0.4969,0.9937)	(1.8166,2.7249,3.6332)	(2.6196,3.4928,4.3661)	(0.3028,0.4541,0.9083)	(1.0000,1.0000,1.0000)
DM_3	Membership	(0.1429,0.1667,0.2000)	(0.3333,0.5000,1.0000)	(1.0000,1.0000,1.0000)	(0.2000,0.2500,0.3333)	(0.2000,0.2500,0.3333)
	E Reliability	(0.4000,0.5600,0.7200)	(0.0000,0.0000,0.2400)	(1.0000,1.0000,1.0000)	(0.2400,0.4000,0.5600)	(0.0000,0.0000,0.2400)
	ZE-numbers	(0.1069,0.1247,0.1497)	(0.6670,0.1000,0.2000)	(1.0000,1.0000,1.0000)	(0.1265,0.1581,0.2108)	(0.0400,0.0500,0.6670)
DM_4	Membership	(3.0000,4.0000,5.0000)	(1.0000,1.0000,1.0000)	(6.0000,7.0000,8.0000)	(2.0000,3.0000,4.0000)	(3.0000,4.0000,5.0000)
	E Reliability	(0.1250,0.1250,0.3875)	(1.0000,1.0000,1.0000)	(0.1250,0.1250,0.3875)	(0.7375,1.0000,1.0000)	(0.5625,0.7375,0.9125)
	ZE-numbers	(1.2324,1.6432,2.0540)	(1.0000,1.0000,1.0000)	(2.4648,2.8755,3.2863)	(1.9558,2.9336,3.9115)	(2.5763,3.4351,4.2939)

Table A9
The pairwise comparisons results and experts' votes for main criteria.

DM	Base criterion	Function	Sub-criteria					Experts votes			R
			C_1	C_2	C_3	C_4	C_5	*Yes*	*No*	θ	
DM_1	C_4	Membership	FI	IFVI	WI	EI	WI	11	0	1	1.000
		Reliability	L	H	H	VH	H				
DM_2	C_5	Membership	IEWI	IWFI	$IEWI^{-1}$	$IEWI^{-1}$	EI	8	2	2	0.600
		Reliability	L	M	L	VH	VH				
DM_3	C_2	Membership	$IEWI^{-1}$	EI	FI	$IFVI^{-1}$	WI	4	4	4	0.000
		Reliability	L	VH	H	VL	L				
DM_4	C_4	Membership	FI	IFVI	WI	EI	IWFI	9	2	1	0.636
		Reliability	L	H	H	VH	H				

Table A10
New reliability and ZE-numbers for the main criteria base pairwise comparisons.

DM	C_5	C_1	C_2	C_3	C_4	C_5
DM_1	Membership	(4.0000,5.0000,6.0000)	(5.0000,6.0000,7.0000)	(2.0000,3.0000,4.0000)	(1.0000,1.0000,1.0000)	(2.0000,3.0000,4.0000)
	E Reliability	(1.0000,1.0000,1.0000)	(1.0000,1.0000,1.0000)	(1.0000,1.0000,1.0000)	(1.0000,1.0000,1.0000)	(1.0000,1.0000,1.0000)
	ZE-numbers	(4.0000,5.0000,6.0000)	(4.0000,5.0000,6.0000)	(2.0000,3.0000,4.0000)	(1.0000,1.0000,1.0000)	(2.0000,3.0000,4.0000)
DM_2	Membership	(1.0000,2.0000,3.0000)	(3.0000,4.0000,5.0000)	(0.3333,0.5000,1.0000)	(0.3333,0.5000,1.0000)	(1.0000,1.0000,1.0000)
	E Reliability	(0.6400,0.7200,0.8000)	(0.7200,0.8000,0.8800)	(0.6400,0.7200,0.8000)	(0.8800,1.0000,1.0000)	(1.0000,1.0000,1.0000)
	ZE-numbers	(0.8485,1.6971,2.5456)	(2.6833,3.5778,4.4721)	(0.2828,0.4243,0.8485)	(0.3300,0.5000,0.9900)	(1.0000,1.0000,1.0000)
DM_3	Membership	(0.3333,0.5000,1.0000)	(1.0000,1.0000,1.0000)	(0.1667,0.2000,0.2500)	(0.1429,0.1667,0.2000)	(0.2500,0.3333,0.5000)
	E Reliability	(0.1000,0.3000,0.5000)	(1.0000,1.0000,1.0000)	(0.5000,0.7000,0.9000)	(0.0000,0.0000,0.3000)	(0.1000,0.3000,0.5000)
	ZE-numbers	(0.1826,0.2739,0.5477)	(1.0000,1.0000,1.0000)	(0.1394,0.1673,0.2092)	(0.0319,0.0373,0.0447)	(0.1369,0.1826,0.2739)
DM_4	Membership	(4.0000,5.0000,6.0000)	(5.0000,6.0000,7.0000)	(2.0000,3.0000,4.0000)	(1.0000,1.0000,1.0000)	(3.0000,4.0000,5.0000)
	E Reliability	(0.6724,0.7452,0.8180)	(0.8180,0.8908,0.9636)	(0.8180,0.8908,0.9636)	(1.0000,1.0000,1.0000)	(0.8180,0.8908,0.9636)
	ZE-numbers	(3.4530,4.3162,5.1795)	(4.7191,5.6629,6.6068)	(1.8876,2.8315,3.7753)	(1.0000,1.0000,1.0000)	(2.8315,3.7753,4.7191)

Appendix B

Table B1
Decision matrix of DM_1 based on the six strategies.

Alt.	Criterion	Circular design				Biodegradable packaging				Product responsibility					Critical success factors					
	Sub-criteria	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	C_{46}
A_1	Membership	IWFI	VI	FI	IEWI	IFVI	IEWI	IVAI	IVAI	VI	VI	IVAI	IFVI	IVAI	IVAI	IWFI	IWFI	IFVI	WI	IFVI
	Reliability	L	H	M	L	VL	M	H	L	M	H	H	VL	L	H	M	L	M	M	VL
A_2	Membership	IVAI	IWFI	VI	WI	IFVI	IEWI	IVAI	IVAI	IWFI	IWFI	VI	IVAI	IVAI	IWFI	FI	FI	VI	IWFI	IFVI
	Reliability	H	H	VL	M	L	VL	VL	H	VL	L	VL	H	VH	M	M	M	VL	VL	L
A_3	Membership	IVAI	IFVI	VI	IWFI	FI	IEWI	AI	IVAI	IEWI	IWFI	VI	IVAI	IVAI	IWFI	FI	FI	VI	WI	FI
	Reliability	H	VL	H	M	VL	L	VH	VL	M	L	L	VH	H	L	L	VL	H	L	VL
A_4	Membership	FI	FI	IWFI	IWFI	IFVI	IEWI	FI	VI	IEWI	WI	VI	VI	VI	FI	FI	FI	VI	FI	WI
	Reliability	VL	M	L	VL	L	VL	M	L	L	H	L	H	M	M	L	VL	H	VL	H
A_5	Membership	IFVI	IEWI	WI	EI	WI	WI	FI	IFVI	FI	WI	IWFI	IWFI	IWFI	IFVI	EI	EI	WI	WI	WI
	Reliability	L	M	M	VL	VL	M	L	VL	M	L	VL	M	VL	M	VH	VL	M	L	M
A_6	Membership	IVAI	EI	FI	IEWI	IEWI	FI	IWFI	FI	VI	IWFI	FI	WI	WI	IFVI	EI	EI	IEWI	WI	IEWI
	Reliability	L	L	VL	VL	L	M	VL	L	L	VL	H	M	M	L	VL	VH	M	M	M

Alt.	Criterion	Corporate social responsibility					Experts votes			R
	Sub-criteria	C_{51}	C_{52}	C_{53}	C_{54}	C_{55}	*Yes*	*No*	θ	
A_1	Membership	VI	IFVI	IWFI	IWFI	IVAI	10	1	1	0.818
	Reliability	L	M	VL	M	L				
A_2	Membership	VI	VI	VI	WI	IVAI	6	3	3	0.333
	Reliability	VL	H	L	M	M				
A_3	Membership	VI	AI	AI	IWFI	AI	12	0	0	1.000
	Reliability	M	VH	VH	L	VH				
A_4	Membership	IVAI	IVAI	IVAI	WI	AI	11	0	1	1.000
	Reliability	VL	VH	VH	L	VH				
A_5	Membership	AI	AI	IFVI	FI	IFVI	10	2	0	0.667
	Reliability	VH	VH	L	VL	H				
A_6	Membership	IFVI	VI	AI	FI	IWFI	6	2	4	0.500
	Reliability	L	H	VH	VL	L				

Table B2
Decision matrix of DM_2 based on the six strategies.

	Criterion	Circular design				Biodegradable packaging				Product responsibility					Critical success factors					
	Sub-criteria	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	C_{46}
A_1	Membership	IFVI	VI	FI	WI	IVAI	IEWI	FI	WI	VI	VI	IVAI	IWFI	IVAI	IVAI	IWFI	IWFI	IFVI	FI	IFVI
	Reliability	VL	VL	M	L	VH	M	L	M	VL	L	VH	VL	M	H	L	H	VL	L	VL
A_2	Membership	IVAI	FI	VI	WI	IVAI	FI	IFVI	WI	FI	IWFI	IWFI	VI	VL	IWFI	FI	FI	VI	WI	WI
	Reliability	H	VL	H	L	VL	L	M	L	VH	M	L	VL	H	L	H	VL	VL	L	H
A_3	Membership	VI	VI	VI	IWFI	IVAI	EI	IVAI	FI	WI	IWFI	IVAI	VI	VI	IVAI	FI	FI	VI	WI	WI
	Reliability	VH	H	H	L	L	H	VH	VL	M	H	VH	M	VL	H	VL	L	VH	L	H
A_4	Membership	WI	FI	IWFI	WI	IVAI	IEWI	WI	FI	IEWI	IEWI	VI	VI	IWFI	IFVI	FI	FI	VI	FI	EI
	Reliability	L	H	H	VL	H	L	M	M	VH	L	M	VL	M	L	M	VL	M	VL	M
A_5	Membership	IFVI	IEWI	WI	IEWI	WI	WI	IFVI	WI	FI	WI	FI	WI	WI	FI	IWFI	WI	WI	WI	FI
	Reliability	H	L	H	L	M	VL	H	VL	VL	M	VH	L	VL	H	M	L	VL	H	M
A_6	Membership	IVAI	WI	FI	IEWI	IEWI	FI	IWFI	FI	VI	IEWI	IWFI	FI	WI	IFVI	WI	EI	IEWI	WI	IEWI
	Reliability	VL	VL	M	L	L	H	H	VL	VH	H	M	L	L	VL	H	L	H	VL	L

	Criterion	Corporate social responsibility	Experts votes	R

(continued on next page)

Table B2 (*continued*)

	Criterion	Corporate social responsibility					Experts votes			R
	Sub-criteria	C_{51}	C_{52}	C_{53}	C_{54}	C_{55}	*Yes*	*No*	θ	
	Sub-criteria	C_{51}	C_{52}	C_{53}	C_{54}	C_{55}	*Yes*	*No*	θ	
A_1	Membership	VI	IFVI	IWFI	IWFI	AI	5	5	2	0.000
	Reliability	H	M	L	VL	VH				
A_2	Membership	VI	VI	VI	WI	AI	7	3	2	0.400
	Reliability	L	H	VL	L	H				
A_3	Membership	VI	AI	AI	IWFI	AI	5	4	3	0.111
	Reliability	VL	VH	VH	L	VL				
A_4	Membership	IVAI	IVAI	AI	WI	AI	7	2	3	0.555
	Reliability	VH	VH	VL	L	VH				
A_5	Membership	AI	AI	IFVI	FI	FI	4	4	4	0.000
	Reliability	VH	VH	L	VH	M				
A_6	Membership	IFVI	VI	VI	FI	FI	6	4	2	0.200
	Reliability	VL	H	VH	VL	H				

Table B3
Decision matrix of DM_3 based on the six strategies.

	Criterion	Circular design				Biodegradable packaging				Product responsibility					Critical success factors					
	Sub-criteria	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	C_{46}
A_1	Membership	IWFI	VI	FI	WI	IFVI	IEWI	IVAI	IVAI	VI	VI	IVAI	IFVI	IVAI	IVAI	IWFI	IWFI	IFVI	WI	IFVI
	Reliability	M	VH	M	M	M	H	VH	VH	VH	H	VH	M	M	VH	M	M	H	M	H
A_2	Membership	AI	FI	VI	EI	AI	IEWI	VI	IVAI	VI	FI	VI	IVAI	VI	IWFI	IWFI	FI	IVAI	IWFI	IFVI
	Reliability	VH	M	M	L	VH	VL	M	VH	L	VL	H	VH	M	VL	VL	M	VH	VL	L
A_3	Membership	FI	VI	VI	FI	IFVI	IEWI	IVAI	IVAI	IEWI	IWFI	VI	IVAI	VI	FI	FI	FI	VI	WI	FI
	Reliability	H	H	M	VL	M	L	L	H	VL	H	H	M	M	VL	VL	L	VH	H	H
A_4	Membership	IFVI	IFVI	IWFI	EI	AI	EI	AI	VI	EI	WI	VI	VI	VI	FI	FI	FI	IVAI	IFVI	WI
	Reliability	H	M	VL	H	VH	M	L	M	H	VL	M	VH	H	H	H	H	VH	VL	M
A_5	Membership	IWFI	IEWI	WI	EI	FI	FI	IFVI	IFVI	FI	WI	IWFI	IFVI	FI	IWFI	EI	EI	IWFI	WI	WI
	Reliability	M	L	VL	M	M	M	VL	L	VL	VL	VL	VH	H	VL	L	L	H	VL	VL
A_6	Membership	AI	IEWI	FI	IEWI	IEWI	FI	IWFI	FI	IVAI	WI	FI	WI	EI	IFVI	EI	EI	IEWI	IEWI	IEWI
	Reliability	VH	VL	L	VL	M	L	M	H	VH	M	H	VL	L	H	L	L	VL	M	L

	Criterion	Corporate social responsibility					Experts votes			R
	Sub-criteria	C_{51}	C_{52}	C_{53}	C_{54}	C_{55}	*Yes*	*No*	θ	
A_1	Membership	VI	IFVI	IWFI	IWFI	IVAI	3	6	3	−0.333
	Reliability	H	VH	M	M	VH				
A_2	Membership	IVAI	VI	VI	WI	IVAI	4	6	2	−0.200
	Reliability	VH	M	L	VL	VH				
A_3	Membership	IVAI	AI	IVAI	WI	AI	5	5	2	0.000
	Reliability	L	VH	H	M	VH				
A_4	Membership	IVAI	IVAI	AI	IWFI	AI	4	4	4	0.000
	Reliability	H	H	VH	L	VH				
A_5	Membership	AI	IVAI	FI	FI	FI	3	5	4	−0.250
	Reliability	VH	VH	VL	VL	VL				
A_6	Membership	IFVI	FI	IVAI	FI	WI	7	3	2	0.400
	Reliability	H	VL	H	M	VL				

Table B4
Decision matrix of DM_4 based on the six strategies.

	Criterion	Circular design				Biodegradable packaging				Product responsibility					Critical success factors					
	Sub-criteria	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	C_{46}
A_1	Membership	FI	AI	IWFI	WI	IVAI	IEWI	IWFI	IVAI	WI	VI	IVAI	IFVI	IVAI	IWFI	WI	IWFI	VI	WI	IFVI
	Reliability	VL	VH	VL	L	L	L	M	VH	VL	H	VH	M	VH	M	VL	M	H	M	H
A_2	Membership	VI	FI	IVAI	WI	IWFI	IEWI	IVAI	IWFI	IWFI	IVAI	VI	IVAI	IVAI	FI	FI	FI	VI	IFVI	IFVI
	Reliability	L	L	H	VL	H	L	M	M	VL	VH	H	VH	VH	M	H	VL	H	M	M
A_3	Membership	IVAI	VI	IVAI	WI	IEWI	FI	AI	IVAI	IEWI	VI	WI	IVAI	IVAI	IWFI	FI	IWFI	VI	IEWI	FI
	Reliability	VH	L	VH	VL	VL	M	VH	VH	VL	H	VL	H	VH	H	L	VL	L	L	VH
A_4	Membership	VI	IWFI	IWFI	IEWI	IWFI	IEWI	AI	VI	IEWI	WI	VI	VI	VI	FI	FI	VI	AI	VI	WI
	Reliability	M	VL	H	M	M	L	VH	H	L	L	H	H	H	M	M	VH	VH	VH	L
A_5	Membership	VI	WI	IEWI	FI	WI	WI	FI	IWFI	FI	WI	IWFI	IWFI	IWFI	IFVI	IEWI	IEWI	WI	WI	WI
	Reliability	H	VL	L	H	VL	VL	L	L	VL	L	M	M	L	M	L	VL	M	M	VL
A_6	Membership	AI	IEWI	IFVI	FI	FI	FI	IWFI	VI	WI	IWFI	FI	WI	WI	IFVI	IEWI	WI	WI	IEWI	IEWI
	Reliability	VH	VL	H	L	VL	VL	L	H	VL	M	H	VL	L	VH	L	L	M	VL	VL

(*continued on next page*)

Table B4 (*continued*)

	Criterion	Corporate social responsibility					Experts votes			*R*
	Sub-criteria	*C51*	*C52*	*C53*	*C54*	*C55*	*Yes*	*No*	*θ*	
	Criterion	Corporate social responsibility					Experts votes			*R*
	Sub-criteria	*C51*	*C52*	*C53*	*C54*	*C55*	*Yes*	*No*	*θ*	
A_1	Membership	VI	IFVI	IWFI	IWFI	IVAI	6	4	2	0.200
	Reliability	H	H	L	L	VL				
A_2	Membership	VI	VI	VI	FI	IFVI	8	2	2	0.600
	Reliability	M	H	VL	M	M				
A_3	Membership	VI	AI	AI	IWFI	FI	12	0	0	1.000
	Reliability	M	VH	VH	VL	H				
A_4	Membership	AI	IVAI	AI	FI	IVAI	10	1	1	0.818
	Reliability	VH	H	VH	VL	VH				
A_5	Membership	VI	AI	FI	FI	IFVI	6	2	4	0.500
	Reliability	H	VH	M	M	H				
A_6	Membership	IFVI	IVAI	AI	FI	IWFI	8	2	2	0.600
	Reliability	M	H	VH	L	L				

Table B5
Calculated ZE-numbers for decision matrix.

Alt.	*C11*	*C12*	*C13*	*C14*	*C21*	*C22*
A_1	(1.9110,2.4607,3.0173)	(4.9475,5.6904,6.1885)	(2.6075,3.2891,3.9714)	(1.1284,1.8095,2.4905)	(4.7227,5.5026,6.2841)	(0.7518,1.5036,2.2554)
A_2	(6.1662,7.0463,7.7083)	(2.8075,3.5653,4.3231)	(4.7853,5.5437,6.3022)	(1.3052,1.8965,2.4879)	(4.5073,5.3063,5.8873)	(1.1631,1.7551,2.3471)
A_3	(5.8029,6.7565,7.7100)	(5.2895,6.2127,7.1360)	(5.5952,6.4860,7.3769)	(1.9345,2.6441,3.3536)	(3.2094,4.0398,4.8702)	(1.6010,2.2372,2.8741)
A_4	(3.8908,4.1735,4.9507)	(3.4943,4.3803,5.2664)	(2.3451,3.1268,3.9085)	(1.0774,1.7557,2.4340)	(5.5434,6.5082,7.2292)	(0.8678,1.5587,2.2497)
A_5	(3.9827,4.7944,5.6061)	(0.8460,1.5109,2.1759)	(1.1732,1.8606,2.5479)	(1.4187,1.7861,2.1535)	(1.7416,2.4594,3.1771)	(1.5429,2.1613,2.7797)
A_6	(6.2179,7.0356,7.3597)	(0.8074,1.2906,1.7738)	(3.1487,3.8772,4.6057)	(1.3594,2.0825,2.8055)	(1.3640,2.1374,2.9108)	(3.2868,4.1085,4.9302)
Alt.	*C23*	*C24*	*C31*	*C32*	*C33*	*C34*
A_1	(4.2233,4.9959,5.7689)	(5.0962,5.9505,6.8047)	(3.2045,3.8202,4.4360)	(4.6127,5.3815,6.1502)	(6.5149,7.4449,8.3766)	(2.9921,3.6129,4.2336)
A_2	(4.6194,5.3617,6.1039)	(4.1424,4.9979,5.8534)	(2.7644,3.4813,4.1983)	(3.1075,3.7967,4.4859)	(4.0091,4.7724,5.5358)	(5.8068,6.6598,7.3488)
A_3	(6.6692,7.5505,7.9318)	(5.3584,6.1662,6.9739)	(0.9286,1.6708,2.4130)	(3.5198,4.8662,4.9430)	(4.9657,5.9192,6.8728)	(5.8554,6.7185,7.6491)
A_4	(3.9795,4.8357,5.4431)	(4.9009,5.7912,6.6815)	(0.9399,1.6707,2.4014)	(1.2863,2.0332,2.7801)	(5.3418,6.2321,7.1224)	(5.5602,6.4869,7.4128)
A_5	(2.7683,3.6479,4.3260)	(2.3430,2.7241,3.5084)	(2.0548,2.5685,3.0822)	(1.4317,2.1476,2.8634)	(2.3896,3.1049,3.8202)	(2.6287,3.4145,4.2003)
A_6	(2.4612,3.2815,4.1019)	(3.6088,4.3937,5.1787)	(4.7963,5.6859,6.5755)	(1.8505,2.6824,3.5142)	(3.3465,4.2316,4.6166)	(1.8179,2.5610,3.3042)
Alt.	*C35*	*C41*	*C42*	*C43*	*C44*	*C45*
A_1	(5.7826,6.3587,7.4348)	(5.1397,5.9846,6.8298)	(1.8299,2.4474,3.0898)	(2.3432,3.1242,3.9053)	(3.6331,4.3161,4.9991)	(1.7011,2.4148,3.1284)
A_2	(5.7600,6.6378,7.5155)	(2.2279,2.8960,3.5641)	(2.8100,3.5250,4.2400)	(2.8920,3.6150,4.3380)	(4.8246,5.5924,6.1962)	(2.1030,2.7183,3.3337)
A_3	(5.1521,5.9274,6.7028)	(3.2222,3.9922,4.7622)	(2.6179,3.2724,3.9268)	(2.9123,3.7029,4.4934)	(5.9283,6.9164,7.9036)	(1.4756,2.3384,3.2012)
A_4	(4.8748,5.7966,6.7202)	(3.8273,4.7323,5.6372)	(3.6718,4.5898,5.5076)	(4.0907,4.9889,5.8871)	(6.5192,7.4814,8.1963)	(3.5336,4.2785,5.0234)
A_5	(2.0612,2.7065,3.3518)	(3.2056,3.9080,4.6103)	(1.0984,1.4767,1.8550)	(0.7803,1.0984,1.4164)	(1.5447,2.2265,2.9083)	(1.3861,2.0791,2.7721)
A_6	(1.3794,1.9738,2.5683)	(0.0000,4.7874,5.5853)	(1.0196,1.4497,1.8797)	(1.0274,1.2395,1.4516)	(1.0456,1.8676,2.6896)	(1.0840,1.8290,2.5740)
Alt.	*C46*	*C51*	*C52*	*C53*	*C54*	*C55*
A_1	(3.3560,4.0272,4.6984)	(4.9888,5.8203,6.6517)	(4.1604,4.9925,5.8246)	(2.0220,2.6960,3.3699)	(1.8394,2.4192,3.0239)	(5.8344,6.6331,7.1884)
A_2	(2.9384,3.8509,4.6059)	(4.9179,5.7012,6.4845)	(5.0557,5.8983,6.7409)	(3.9948,4.6606,5.1624)	(1.7834,2.4515,3.1196)	(5.8834,6.7555,7.4011)
A_3	(3.2648,4.1881,5.1113)	(4.5499,5.2854,6.0209)	(7.9044,8.8925,8.8925)	(7.4192,8.3728,8.5819)	(2.3145,3.1449,3.9753)	(5.7379,6.5801,6.8301)
A_4	(1.3643,2.0246,2.6849)	(6.9355,7.8907,8.5971)	(6.6461,7.5956,8.5450)	(7.4598,8.3923,8.3923)	(2.2318,3.0527,3.8736)	(7.6690,8.6587,8.9076)
A_5	(1.6406,2.2841,2.9276)	(6.9486,7.8748,8.1053)	(7.3364,8.2789,8.4831)	(2.8390,3.4598,4.0806)	(2.8612,3.5765,4.2918)	(3.1716,3.9320,4.6249)
A_6	(0.7696,1.5392,2.3088)	(3.8701,3.2859,5.4182)	(4.9880,5.8349,6.6820)	(7.0092,7.9748,8.4461)	(2.8997,3.6246,4.3495)	(2.4937,3.3157,4.1377)

Table B6
Normalized values for the strategies.

	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}
A_1	(0.0000,0.0948,0.1908)	(0.1506,0.2298,0.3479)	(0.2312,0.3411,0.4510)	(0.0224,0.3216,0.6208)	(0.5726,0.7056,0.8389)	(0.0000,0.1799,0.3598)
A_2	(0.7338,0.8855,0.9997)	(0.4472,0.5677,0.6882)	(0.5822,0.7045,0.8268)	(0.1001,0.3599,0.6196)	(0.5359,0.6721,0.7712)	(0.0984,0.2401,0.3818)
A_3	(0.6711,0.8218,1.0000)	(0.0000,0.1468,0.2936)	(0.7128,0.8564,1.0000)	(0.3766,0.6883,1.0000)	(0.3146,0.4562,0.5978)	(0.2032,0.3555,0.5079)
A_4	(0.3414,0.3901,0.5242)	(0.2972,0.4381,0.5790)	(0.1889,0.3149,0.4409)	(0.0000,0.2980,0.5960)	(0.7126,0.8771,1.0000)	(0.0278,0.1931,0.3585)
A_5	(0.3572,0.4972,0.6372)	(0.7886,0.8943,1.0000)	(0.0000,0.1108,0.2216)	(0.1499,0.3113,0.4728)	(0.0644,0.1868,0.3091)	(0.1893,0.3373,0.4853)
A_6	(0.7427,0.8837,0.9396)	(0.8525,0.9293,0.1475)	(0.3184,0.4359,0.5533)	(0.1239,0.4415,0.7592)	(0.0000,0.1319,0.2637)	(0.6067,0.8033,1.0000)
	C23	*C24*	*C31*	*C32*	*C33*	*C34*
A_1	(0.3221,0.4633,0.6046)	(0.5945,0.7790,0.9635)	(0.4030,0.5121,0.6211)	(0.6839,0.8419,1.0000)	(0.6890,0.8444,1.0000)	(0.2014,0.3078,0.4143)
A_2	(0.3945,0.5302,0.6659)	(0.3886,0.5733,0.7581)	(0.3251,0.4521,0.5790)	(0.3744,0.5161,0.6578)	(0.2705,0.3980,0.5255)	(0.6841,0.8303,0.9485)
A_3	(0.7692,0.9303,1.0000)	(0.6512,0.8256,1.0000)	(0.0000,0.1314,0.2629)	(0.4592,0.7360,0.7518)	(0.4303,0.5895,0.7488)	(0.6924,0.8404,1.0000)
A_4	(0.2775,0.4341,0.5451)	(0.5524,0.7446,0.9369)	(0.0020,0.1314,0.2608)	(0.0000,0.1535,0.3071)	(0.4931,0.6418,0.7905)	(0.6418,0.8007,0.9595)

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Table B6 (*continued*)

	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}
A_5	(0.0561,0.2169,0.3409)	(0.0000,0.0823,0.2517)	(0.1994,0.2904,0.3814)	(0.0299,0.1771,0.3242)	(0.0000,0.1195,0.2389)	(0.1390,0.2738,0.4086)
A_6	(0.0000,0.1500,0.2999)	(0.2733,0.4428,0.6123)	(0.6849,0.8425,1.0000)	(0.1160,0.2870,0.4580)	(0.1598,0.3077,0.3720)	(0.0000,0.1274,0.2549)

	C_{35}	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}
A_1	(0.7176,0.8115,0.9868)	(0.7525,0.8763,1.0000)	(0.1806,0.3181,0.4613)	(0.3060,0.4590,0.6119)	(0.3618,0.4574,0.5529)	(0.1567,0.3378,0.5190)
A_2	(0.7139,0.8570,1.0000)	(0.3262,0.4240,0.5219)	(0.3989,0.5582,0.7176)	(0.4135,0.5551,0.6967)	(0.5285,0.6359,0.7203)	(0.2587,0.4149,0.5711)
A_3	(0.6148,0.7412,0.8675)	(0.4718,0.5845,0.6973)	(0.3561,0.5019,0.6478)	(0.4175,0.5723,0.7271)	(0.6828,0.8210,0.9591)	(0.0994,0.3184,0.5375)
A_4	(0.5696,0.7199,0.8704)	(0.5604,0.6929,0.8254)	(0.5910,0.7955,1.0000)	(0.6482,0.8241,1.0000)	(0.7655,0.9000,1.0000)	(0.6218,0.8109,1.0000)
A_5	(0.1111,0.2163,0.3214)	(0.4694,0.5722,0.6750)	(0.0176,0.1019,0.1861)	(0.0000,0.0623,0.1246)	(0.0698,0.1651,0.2605)	(0.0767,0.2526,0.4285)
A_6	(0.0000,0.0969,0.1938)	(0.0000,0.7010,0.8178)	(0.0000,0.0958,0.1917)	(0.0484,0.0899,0.1315)	(0.0000,0.1150,0.2299)	(0.0000,0.1891,0.3782)

	C_{46}	C_{51}	C_{52}	C_{53}	C_{54}	C_{55}
A_1	(0.5957,0.7503,0.9049)	(0.2367,0.4126,0.5885)	(0.6483,0.8242,1.0000)	(0.0000,0.1027,0.2055)	(0.0218,0.2477,0.4834)	(0.5209,0.6454,0.7320)
A_2	(0.4995,0.7097,0.8836)	(0.2217,0.3874,0.5531)	(0.4547,0.6327,0.8108)	(0.3007,0.4022,0.4787)	(0.0000,0.2603,0.5207)	(0.5285,0.6645,0.7651)
A_3	(0.5747,0.7874,1.0000)	(0.1438,0.2994,0.4550)	(0.0000,0.0000,0.2088)	(0.8228,0.9681,1.0000)	(0.2070,0.5306,0.8542)	(0.5058,0.6371,0.6761)
A_4	(0.1370,0.2891,0.4411)	(0.6485,0.8506,1.0000)	(0.0734,0.2741,0.4747)	(0.8289,0.9711,0.9711)	(0.1747,0.4946,0.8145)	(0.8069,0.9612,1.0000)
A_5	(0.2006,0.3488,0.4970)	(0.6513,0.8472,0.8960)	(0.0865,0.1297,0.3288)	(0.1245,0.2192,0.3138)	(0.4200,0.6988,0.9775)	(0.1057,0.2242,0.3323)
A_6	(0.0000,0.1773,0.3545)	(0.0000,-0.1236,0.3275)	(0.4671,0.6461,0.8251)	(0.7602,0.9075,0.9793)	(0.4350,0.7175,1.0000)	(0.0000,0.1282,0.2563)

Table B7
Weighted values for the strategies.

	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}
A_1	(0.0060,0.0091,0.0180)	(0.0190,0.0323,0.0683)	(0.0148,0.0274,0.0508)	(0.0277,0.0531,0.1143)	(0.0192,0.0280,0.0454)	(0.0177,0.0230,0.0340)
A_2	(0.0104,0.0156,0.0302)	(0.0239,0.0412,0.0856)	(0.0190,0.0348,0.0639)	(0.0298,0.0547,0.1142)	(0.0187,0.0274,0.0437)	(0.0194,0.0242,0.0345)
A_3	(0.0100,0.0151,0.0302)	(0.0165,0.0302,0.0656)	(0.0206,0.0379,0.0700)	(0.0373,0.0679,0.1410)	(0.0160,0.0239,0.0395)	(0.0213,0.0264,0.0377)
A_4	(0.0080,0.0115,0.0230)	(0.0214,0.0378,0.0801)	(0.0143,0.0268,0.0504)	(0.0271,0.0522,0.1125)	(0.0209,0.0308,0.0494)	(0.0182,0.0233,0.0340)
A_5	(0.0081,0.0124,0.0247)	(0.0295,0.0498,0.1014)	(0.0120,0.0227,0.0428)	(0.0312,0.0527,0.1038)	(0.0130,0.0195,0.0323)	(0.0211,0.0261,0.0371)
A_6	(0.0105,0.0156,0.0293)	(0.0306,0.0507,0.0582)	(0.0158,0.0293,0.0544)	(0.0305,0.0580,0.1240)	(0.0122,0.0186,0.0312)	(0.0284,0.0352,0.0500)

	C_{23}	C_{24}	C_{31}	C_{32}	C_{33}	C_{34}
A_1	(0.0178,0.0246,0.0396)	(0.0102,0.0148,0.0259)	(0.0484,0.1290,0.2344)	(0.0660,0.1136,0.1916)	(0.0316,0.0559,0.1164)	(0.0142,0.0218,0.0359)
A_2	(0.0188,0.0257,0.0411)	(0.0089,0.0131,0.0232)	(0.0457,0.1239,0.2283)	(0.0539,0.0935,0.1588)	(0.0238,0.0424,0.0888)	(0.0199,0.0306,0.0495)
A_3	(0.0239,0.0324,0.0494)	(0.0106,0.0152,0.0264)	(0.0345,0.0965,0.1826)	(0.0572,0.1071,0.1678)	(0.0267,0.0482,0.1018)	(0.0200,0.0307,0.0508)
A_4	(0.0172,0.0241,0.0382)	(0.0099,0.0145,0.0256)	(0.0346,0.0965,0.1823)	(0.0392,0.0712,0.1252)	(0.0279,0.0497,0.1042)	(0.0194,0.0301,0.0498)
A_5	(0.0143,0.0204,0.0331)	(0.0064,0.0090,0.0165)	(0.0414,0.1101,0.1997)	(0.0404,0.0726,0.1269)	(0.0187,0.0339,0.0721)	(0.0134,0.0213,0.0358)
A_6	(0.0135,0.0193,0.0321)	(0.0081,0.0120,0.0213)	(0.0581,0.1572,0.2892)	(0.0437,0.0794,0.1397)	(0.0217,0.0396,0.0798)	(0.0118,0.0188,0.0319)

	C_{35}	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}
A_1	(0.0225,0.0328,0.0560)	(0.0724,0.1330,0.2636)	(0.0928,0.1592,0.2560)	(0.1702,0.2086,0.3082)	(0.0674,0.0855,0.1281)	(0.0302,0.0443,0.0731)
A_2	(0.0225,0.0336,0.0564)	(0.0548,0.1010,0.2006)	(0.1100,0.1882,0.3009)	(0.1842,0.2224,0.3244)	(0.0757,0.0960,0.1419)	(0.0329,0.0468,0.0756)
A_3	(0.0212,0.0315,0.0527)	(0.0608,0.1123,0.2237)	(0.1066,0.1814,0.2887)	(0.1847,0.2248,0.3302)	(0.0833,0.1069,0.1616)	(0.0287,0.0436,0.0740)
A_4	(0.0206,0.0311,0.0527)	(0.0644,0.1200,0.2406)	(0.1250,0.2169,0.3504)	(0.2148,0.2608,0.3824)	(0.0874,0.1115,0.1650)	(0.0423,0.0599,0.0962)
A_5	(0.0146,0.0220,0.0373)	(0.0607,0.1115,0.2208)	(0.0800,0.1331,0.2078)	(0.1303,0.1519,0.2150)	(0.0530,0.0684,0.1040)	(0.0281,0.0415,0.0687)
A_6	(0.0131,0.0199,0.0337)	(0.0413,0.1206,0.2396)	(0.0786,0.1324,0.2088)	(0.1366,0.1559,0.2163)	(0.0495,0.0654,0.1015)	(0.0261,0.0394,0.0663)

	C_{46}	C_{51}	C_{52}	C_{53}	C_{54}	C_{55}
A_1	(0.0469,0.0698,0.1040)	(0.0257,0.0428,0.0647)	(0.0488,0.0766,0.1392)	(0.0084,0.0107,0.0153)	(0.0208,0.0384,0.0673)	(0.0309,0.0485,0.0800)
A_2	(0.0441,0.0682,0.1028)	(0.0254,0.0420,0.0632)	(0.0431,0.0686,0.1260)	(0.0109,0.0136,0.0188)	(0.0204,0.0388,0.0690)	(0.0310,0.0491,0.0815)
A_3	(0.0463,0.0713,0.1092)	(0.0238,0.0394,0.0592)	(0.0296,0.0420,0.0841)	(0.0153,0.0191,0.0254)	(0.0246,0.0471,0.0842)	(0.0306,0.0483,0.0774)
A_4	(0.0334,0.0514,0.0787)	(0.0343,0.0561,0.0814)	(0.0318,0.0535,0.1026)	(0.0154,0.0191,0.0250)	(0.0240,0.0460,0.0824)	(0.0367,0.0579,0.0924)
A_5	(0.0353,0.0538,0.0817)	(0.0343,0.0560,0.0772)	(0.0322,0.0474,0.0925)	(0.0094,0.0118,0.0167)	(0.0290,0.0523,0.0898)	(0.0224,0.0361,0.0616)
A_6	(0.0294,0.0470,0.0740)	(0.0208,0.0266,0.0540)	(0.0434,0.0691,0.1270)	(0.0148,0.0185,0.0251)	(0.0293,0.0529,0.0908)	(0.0203,0.0333,0.0580)

Table B8
Distance of $AP_{ZE(j)}$ from each sustainable strategy for the circular supply chain.

	C_{11}	C_{12}	C_{13}	C_{14}	C_{21}	C_{22}
A_1	(-0.0195,-0.0039,0.0093)	(-0.0562,-0.0072,0.0454)	(-0.0399,-0.0020,0.0350)	(-0.0900,-0.0030,0.0838)	(-0.0205,0.0037,0.0291)	(-0.0198,-0.0031,0.0132)
A_2	(-0.0151,0.0027,0.02150)	(-0.0513,0.0016,0.0627)	(-0.0357,0.0054,0.0481)	(-0.0879,-0.0015,0.0838)	(-0.0210,0.0032,0.0274)	(-0.0181,-0.0019,0.0138)
A_3	(-0.0154,0.0021,0.0215)	(-0.0587,-0.0094,0.0427)	(-0.0341,0.0085,0.0542)	(-0.0804,0.0117,0.1106)	(-0.0237,-0.0004,0.0231)	(-0.0162,0.0004,0.0169)
A_4	(-0.0174,-0.0015,0.0143)	(-0.0538,-0.0018,0.0571)	(-0.0404,-0.0025,0.0346)	(-0.0907,-0.0040,0.0821)	(-0.0188,0.0065,0.0331)	(-0.0193,-0.0028,0.0132)
A_5	(-0.0173,-0.0006,0.0160)	(-0.0457,0.0102,0.0785)	(-0.0427,-0.0067,0.0269)	(-0.0866,-0.0035,0.0734)	(-0.0267,-0.0048,0.0160)	(-0.0165,0.0000,0.0164)

(*continued on next page*)

Table B8 (*continued*)

	C11	C12	C13	C14	C21	C22
A6	(-0.0150,0.0026,0.0206)	(-0.0447,0.0112,0.0353)	(-0.0388,-0.0001,0.0386)	(-0.0873,0.0018,0.0936)	(-0.0275,-0.0057,0.0149)	(-0.0091,0.0091,0.0293)

	C23	*C24*	*C31*	*C32*	*C33*	*C34*
A1	(-0.0207,0.0005,0.0224)	(-0.0127,0.0019,0.0170)	(-0.1681,0.0119,0.1914)	(-0.0839,0.0256,0.1425)	(-0.0610,0.0115,0.0917)	(-0.0273 -0.0032 0.0198)
A2	(-0.0197,0.0016,0.0239)	(-0.0140,0.0002,0.0143)	(-0.1708,0.0068,0.1853)	(-0.0960,0.0054,0.1097)	(-0.0689,-0.0020,0.0641)	(-0.0217 0,0055,0.0334)
A3	(-0.014,0.0083,0.0321)	(-0.0123,0.0023,0.0175)	(-0.1820,-0.0206,0.1396)	(-0.0927,0.0190,0.1187)	(-0.0659,0.0038,0.0771)	(-0.0216 0,0057,0.0347)
A4	(-0.0213,0.0000,0.0209)	(-0.0129,0.0016,0.0167)	(-0.1819,-0.0206,0.1393)	(-0.1107,-0.0169,0.0761)	(-0.0647,0.0054,0.0795)	(-0.0222,0.0050,0.0337)
A5	(-0.0243,-0.0036,0.0158)	(-0.0165,-0.0039,0.0076)	(-0.1751,-0.0070,0.1567)	(-0.1095,-0.0155,0.0777)	(-0.0739,-0.0104,0.0474)	(-0.0281,-0.0038,0.0197)
A6	(-0.0250,-0.0048,0.0148)	(-0.0147,-0.0009,0.0124)	(-0.1584,0.0401,0.2462)	(-0.1061,-0.0087,0.0905)	(-0.0709,-0.0047,0.0551)	(-0.0297,-0.0062,0.0158)

	C35	*C41*	*C42*	*C43*	*C44*	*C45*
A1	(-0.0247,0.0049,0.0374)	(-0.1583,0.0170,0.2054)	(-0.1712,-0.0066,0.1586)	(-0.1192,0.0084,0.1406)	(-0.0639,-0.0016,0.0603)	(-0.0449,-0.0012,0.0421)
A2	(-0.0247,0.0057,0.0378)	(-0.1759,-0.0150,0.1424)	(-0.1540,0.0224,0.2035)	(-0.1052,0.0222,0.1568)	(-0.0556,0.0089,0.0741)	(-0.0422,0.0013,0.0446)
A3	(-0.0260,0.0036,0.0340)	(-0.1699,-0.0036,0.1655)	(-0.1574,0.0156,0.1913)	(-0.1047,0.0246,0.1627)	(-0.0480,0.0197,0.0938)	(-0.0464,-0.0018,0.0430)
A4	(-0.0266,0.0032,0.0341)	(-0.1662,0.0040,0.1824)	(-0.1389,0.0511,0.2530)	(-0.0746,0.0606,0.2148)	(-0.0439,0.0244,0.0972)	(-0.0327,0.0145,0.0652)
A5	(-0.0326,-0.0059,0.0186)	(-0.1700,-0.0045,0.1626)	(-0.1840,-0.0327,0.1104)	(-0.1591,-0.0483,0.0475)	(-0.0783,-0.0188,0.0362)	(-0.0470,-0.0040,0.0377)
A6	(-0.0341,-0.0081,0.0150)	(-0.1893,0.0046,0.1814)	(-0.1853,-0.0334,0.1114)	(-0.1528,-0.0444,0.0488)	(-0.0818,-0.0217, 0.0336)	(-0.0490,-0.0061,0.0353)

	C46	*C51*	*C52*	*C53*	*C54*	*C55*
A1	(-0.0438,0.0104,0.0654)	(-0.0402,0.0003,0.0377)	(-0.0613,0.0184,0.1017)	(-0.0122,-0.0044,0.0033)	(-0.0592,-0.0071,0.0429)	(-0.0433,0.0038,0.0519)
A2	(-0.0466,0.0088,0.0642)	(-0.0405,-0.0005,0.0363)	(-0.0670,0.0104,0.0886)	(-0.0097,-0.0014,0.0068)	(-0.0596,-0.0068,0.0446)	(-0.0432 0.0044,0.0535)
A3	(-0.0444,0.0119,0.0706)	(-0.0421,-0.0031,0.0323)	(-0.0805,-0.0162,0.0467)	(-0.0053,0.0040,0.0134)	(-0.0554,0.0016,0.0597)	(-0.0436,0.0036,0.0494)
A4	(-0.0572,-0.0080,0.0401)	(-0.0316,0.0136,0.0545)	(-0.0783,-0.0047,0.0652)	(-0.0052,0.0041,0.0130)	(-0.0561,0.0005,0.0579)	(-0.0375,0.0131,0.0643)
A5	(-0.0554,-0.0056,0.0431)	(-0.0316 0.0135,0.0502)	(-0.0779,-0.0107,0.0550)	(-0.0112,-0.0032,0.0047)	(-0.0511,0.0067,0.0653)	(-0.0517,-0.0086,0.0335)
A6	(-0.0613,-0.0125,0.0353)	(-0.0451,-0.0160,0.0271)	(-0.0667,0.0110,0.0896)	(-0.0058,0.0035,0.0131)	(-0.0508,0.0073,0.0664)	(-0.0539,-0.0114,0.0300)

References

Aboutorab, H., Saberi, M., Asadabadi, M.R., Hussain, O., Chang, E., 2018. ZBWM: the Z-number extension of Best Worst Method and its application for supplier development. Expert Syst. Appl. 107, 115–125.

Agyemang, M., Kusi-Sarpong, S., Khan, S.A., Mani, V., Rehman, S.T., Kusi-Sarpong, H., 2019. Drivers and barriers to circular economy implementation: an explorative study in Pakistan's automobile industry. Manag. Decis.

Alamelu, R., Jayanthi, M., Dinesh, S., Nalini, R., Shobhana, N., Amudha, R., 2023. Sustainable supply chain and circular economy ingenuities in small manufacturing firms-a stimulus for sustainable development. Mater. Today: Proc.

Ayough, A., Shargh, S.B., Khorshidvand, B., 2023. A new integrated approach based on base-criterion and utility additive methods and its application to supplier selection problem. Expert Syst. Appl. 221, 119740.

Bisht, K., Kumar, A., 2022. Stock portfolio selection hybridizing fuzzy base-criterion method and evidence theory in triangular fuzzy environment. In: Operations Research Forum, vol. 3. Springer International Publishing, pp. 1–32, 4.

Bisht, G., Pal, A.K., 2023. Functional dependency-based group decision-making with incomplete information under social media influence: an application to automobile. J. Intell. Fuzzy Syst. 1–23. Preprint.

Büyüközkan, G., Mukul, E., Kongar, E., 2021. Health tourism strategy selection via SWOT analysis and integrated hesitant fuzzy linguistic AHP-MABAC approach. Soc. Econ. Plann. Sci. 74, 100929.

Centobelli, P., Cerchione, R., Del Vecchio, P., Oropallo, E., Secundo, G., 2021. Blockchain technology for bridging trust, traceability and transparency in circular supply chain. Inf. Manag., 103508

Cezarino, L.O., Liboni, L.B., Hunter, T., Pacheco, L.M., Martins, F.P., 2022. Corporate social responsibility in emerging markets: opportunities and challenges for sustainability integration. J. Clean. Prod., 132224

Chen, X., Chen, L., Jiang, M., Yan, J., 2021. Does R&D intensity promote the adoption of circular supply chain management? Evidence from China. Ind. Market. Manag. 99, 153–166.

Chen, Z.H., Luo, W., 2023. An integrated interval type-2 fuzzy rough technique for emergency decision making. Appl. Soft Comput. 137, 110150.

Chen, L., Su, S., 2022. Optimization of the trust propagation on supply chain network based on blockchain plus. J. Intell. Manag. Decis. 1 (1), 17–27.

Cheraghalipour, A., Paydar, M.M., Hajiaghaei-Keshteli, M., 2018. Applying a hybrid BWM-VIKOR approach to supplier selection: a case study in the Iranian agricultural implements industry. Int. J. Appl. Decis. Sci. 11 (3), 274–301.

Cheraghalipour, A., Paydar, M.M., Hajiaghaei-Keshteli, M., 2017. An integrated approach for collection center selection in reverse logistics. Int. J. Eng. 30 (7), 1005–1016.

Dallasega, P., Rauch, E., Linder, C., 2018. Industry 4.0 as an enabler of proximity for construction supply chains: a systematic literature review. Comput. Ind. 99, 205–225.

Daú, G., Scavarda, A., Scavarda, L.F., Portugal, V.J.T., 2019. The healthcare sustainable supply chain 4.0: the circular economy transition conceptual framework with the corporate social responsibility mirror. Sustainability 11 (12), 3259.

De Angelis, R., Howard, M., Miemczyk, J., 2018. Supply chain management and the circular economy: towards the circular supply chain. Prod. Plann. Control 29 (6), 425–437.

Deveci, M., Erdogan, N., Cali, U., Stekli, J., Zhong, S., 2021. Type-2 neutrosophic number based multi-attributive border approximation area comparison (MABAC) approach for offshore wind farm site selection in USA. Eng. Appl. Artif. Intell. 103, 104311.

Dey, S.K., Giri, B.C., 2023. Corporate social responsibility in a closed-loop supply chain with dual-channel waste recycling. Int. J. Syst. Sci.: Oper. Logist. 10 (1), 2005844.

Ecer, F., Haseli, G., Krishankumar, R., Hajiaghaei-Keshteli, M., 2024. Evaluation of sustainable cold chain suppliers using a combined multi-criteria group decision-making framework under fuzzy ZE-numbers. Expert Syst. Appl. 245, 123063.

Ecer, F., Pamucar, D., 2022. A novel LOPCOW-DOBI multi-criteria sustainability performance assessment methodology: an application in developing country banking sector. Omega 112, 102690.

Farooque, M., Zhang, A., Liu, Y., 2019a. Barriers to circular food supply chains in China. Supply Chain Manag.: Int. J.

Farooque, M., Zhang, A., Liu, Y., Hartley, J.L., 2022. Circular supply chain management: performance outcomes and the role of eco-industrial parks in China. Transport. Res. E Logist. Transport. Rev. 157, 102596.
Farooque, M., Zhang, A., Thürer, M., Qu, T., Huisingh, D., 2019b. Circular supply chain management: a definition and structured literature review. J. Clean. Prod. 228, 882–900.
Fatima, T., Elbanna, S., 2022. Corporate social responsibility (CSR) implementation: a review and a research agenda towards an integrative framework. J. Bus. Ethics 1–17.
García-Sánchez, I.M., Hussain, N., Khan, S.A., Martínez-Ferrero, J., 2022. Assurance of corporate social responsibility reports: examining the role of internal and external corporate governance mechanisms. Corp. Soc. Responsib. Environ. Manag. 29 (1), 89–106.
Gholian-Jouybari, F., Hajiaghaei-Keshteli, M., Bavar, A., Bavar, A., Mosallanezhad, B., 2023. A design of a circular closed-loop agri-food supply chain network—a case study of the soybean industry. J. Industr. Inform. Integr. 36, 100530.
Goudarzi, V., Shahabi-Ghahfarrokhi, I., Babaei-Ghazvini, A., 2017. Preparation of ecofriendly UV-protective food packaging material by starch/TiO2 bio-nanocomposite: characterization. Int. J. Biol. Macromol. 95, 306–313.
Govindan, K., Hasanagic, M., 2018. A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective. Int. J. Prod. Res. 56 (1–2), 278–311.
Hader, M., Tchoffa, D., El Mhamedi, A., Ghodous, P., Dolgui, A., Abouabdellah, A., 2022. Applying integrated Blockchain and Big Data technologies to improve supply chain traceability and information sharing in the textile sector. J. Industr. Inform. Integr. 28, 100345.
Hameed, K., Barika, M., Garg, S., Amin, M.B., Kang, B., 2022. A taxonomy study on securing Blockchain-based Industrial applications: an overview, application perspectives, requirements, attacks, countermeasures, and open issues. J. Industr. Inform. Integr. 26, 100312.
Hämäläinen, E., Inkinen, T., 2019. Industrial applications of big data in disruptive innovations supporting environmental reporting. J. Industr. Inform. Integr. 16, 100105.
Haseli, G., Bonab, S.R., Hajiaghaei-Keshteli, M., Ghoushchi, S.J., Deveci, M., 2024a. Fuzzy ZE-numbers framework in group decision-making using the BCM and CoCoSo to address sustainable urban transportation. Inf. Sci. 653, 119809.
Haseli, G., Deveci, M., Isik, M., Gokasar, I., Pamucar, D., Hajiaghaei-Keshteli, M., 2024b. Providing climate change resilient land-use transport projects with green finance using Z extended numbers based decision-making model. Expert Syst. Appl. 243, 122858.
Haseli, G., Jafarzadeh Ghoushchi, S., 2022. Extended base-criterion method based on the spherical fuzzy sets to evaluate waste management. Soft Comput. 1–14.
Haseli, G., Ögel, İ.Y., Ecer, F., Hajiaghaei-Keshteli, M., 2023a. Luxury in female technology (FemTech): selection of smart jewelry for women through BCM-MARCOS group decision-making framework with fuzzy ZE-numbers. Technol. Forecast. Soc. Change 196, 122870.
Haseli, G., Sheikh, R., 2022. Base criterion method (BCM). In: Multiple Criteria Decision Making. Springer, Singapore, pp. 17–38.
Haseli, G., Sheikh, R., Sana, S.S., 2020. Base-criterion on multi-criteria decision-making method and its applications. Int. J. Manag. Sci. Eng. Manag. 15 (2), 79–88.
Haseli, G., Torkayesh, A.E., Hajiaghaei-Keshteli, M., Venghaus, S., 2023b. Sustainable resilient recycling partner selection for urban waste management: consolidating perspectives of decision-makers and experts. Appl. Soft Comput. 137, 110120.
Horodytska, O., Valdés, F.J., Fullana, A., 2018. Plastic flexible films waste management–A state of art review. Waste Manag. 77, 413–425.
Huang, G., Xiao, L., Pedrycz, W., Pamucar, D., Zhang, G., Martínez, L., 2022. Design alternative assessment and selection: a novel Z-cloud rough number-based BWM-MABAC model. Inf. Sci. 603, 149–189.
Hur, W.M., Moon, T.W., Choi, W.H., 2019. When are internal and external corporate social responsibility initiatives amplified? Employee engagement in corporate social responsibility initiatives on prosocial and proactive behaviors. Corp. Soc. Responsib. Environ. Manag. 26 (4), 849–858.
Idumah, C.I., Hassan, A., Ihuoma, D.E., 2019. Recently emerging trends in polymer nanocomposites packaging materials. Polym.-Plast. Technol. Mater. 58 (10), 1054–1109.
Jawahir, I.S., Bradley, R., 2016. Technological elements of circular economy and the principles of 6R-based closed-loop material flow in sustainable manufacturing. Procedia Cirp. 40, 103–108.
Jayasekara, S., Dissanayake, L., Jayakody, L.N., 2022. Opportunities in the microbial valorization of sugar industrial organic waste to biodegradable smart food packaging materials. Int. J. Food Microbiol. 377, 109785.
Jia, Q., Hu, J., Safwat, E., Kamel, A., 2021. Polar coordinate system to solve an uncertain linguistic Z-number and its application in multicriteria group decision-making. Eng. Appl. Artif. Intell. 105, 104437.
Khandelwal, C., Barua, M.K., 2020. Prioritizing circular supply chain management barriers using fuzzy AHP: case of the Indian plastic industry. Global Bus. Rev., 0972150920948818
Lahane, S., Kant, R., Shankar, R., 2020. Circular supply chain management: a state-of-art review and future opportunities. J. Clean. Prod. 258, 120859.
Lahane, S., Kant, R., 2022. Investigating the circular supply chain implementation challenges using Pythagorean Fuzzy AHP approach. Mater. Today: Proc.
Latapí Agudelo, M.A., Jóhannsdóttir, L., Davídsdóttir, B., 2019. A literature review of the history and evolution of corporate social responsibility. Int. J. Corp. Soc. Responsib. 4 (1), 1–23.
Li, M., Cao, G., Cui, L., Liu, X., Dai, J., 2023. Examining how government subsidies influence firms' circular supply chain management: the role of eco-innovation and top management team. Int. J. Prod. Econ., 108893
Liu, P., Wang, D., 2022. A 2-dimensional uncertain linguistic MABAC method for multiattribute group decision-making problems. Comp. Intell. Syst. 8 (1), 349–360.
Macassa, G., McGrath, C., Tomaselli, G., Buttigieg, S.C., 2021. Corporate social responsibility and internal stakeholders' health and well-being in Europe: a systematic descriptive review. Health Promot. Int. 36 (3), 866–883.
Maleki, S., Nourani, V., Najafi, H., Baghanam, A.H., Ke, C.Q., 2023. Z-numbers based novel method for assessing groundwater specific vulnerability. Eng. Appl. Artif. Intell. 122, 106104.
Mohammadalinejhad, S., Almasi, H., Moradi, M., 2020. Immobilization of Echium amoenum anthocyanins into bacterial cellulose film: a novel colorimetric pH indicator for freshness/spoilage monitoring of shrimp. Food Control 113, 107169.
Narang, M., Joshi, M.C., Bisht, K., Pal, A., 2022a. Stock portfolio selection using a new decision-making approach based on the integration of fuzzy CoCoSo with Heronian mean operator. Dec. Mak.: Appl. Manag. Eng.
Narang, M., Joshi, M.C., Pal, A.K., 2021. A hybrid fuzzy COPRAS-base-criterion method for multi-criteria decision making. Soft Comput. 25 (13), 8391–8399.
Narang, M., Joshi, M.C., Pal, A.K., 2022b. A hesitant fuzzy multiplicative Base-criterion multi-criteria group decision making method. Informatica 46 (2).
Naz, S., Shafiq, A., Butt, S.A., Ijaz, R., 2023. A new approach to sentiment analysis algorithms: extended SWARA-MABAC method with 2-tuple linguistic q-rung orthopair fuzzy information. Eng. Appl. Artif. Intell. 126, 106943.
Niyommaneerat, W., Suwanteep, K., Chavalparit, O., 2023. Sustainability indicators to achieve a circular economy: a case study of renewable energy and plastic waste recycling corporate social responsibility (CSR) projects in Thailand. J. Clean. Prod. 391, 136203.
Okafor, A., Adeleye, B.N., Adusei, M., 2021. Corporate social responsibility and financial performance: evidence from US tech firms. J. Clean. Prod. 292, 126078.
Orji, I.J., U-Dominic, C.M., Okwara, U.K., 2022. Exploring the determinants in circular supply chain implementation in the Nigerian manufacturing industry. Sustain. Prod. Consum. 29, 761–776.
Pamučar, D., Ćirović, G., 2015. The selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation area Comparison (MABAC). Expert Syst. Appl. 42 (6), 3016–3028.
Pamučar, D., Stević, Ž., Zavadskas, E.K., 2018. Integration of interval rough AHP and interval rough MABAC methods for evaluating university web pages. Appl. Soft Comput. 67, 141–163.
Puška, A., Stojanović, I., 2022. Fuzzy multi-criteria analyses on green supplier selection in an agri-food company. J. Intell. Manag. Decis. 1 (1), 2–16.
Powell, W., Foth, M., Cao, S., Natanelov, V., 2022. Garbage in garbage out: the precarious link between IoT and blockchain in food supply chains. J. Industr. Inform. Integr. 25, 100261.
Rezaei, J., 2015. Best-worst multi-criteria decision-making method. Omega 53, 49–57.
Rhim, J.W., Park, H.M., Ha, C.S., 2013. Bio-nanocomposites for food packaging applications. Prog. Polym. Sci. 38 (10–11), 1629–1652.
Saaty, T.L., 1980. The analytic hierarchy process (AHP). J. Operation. Res. Soc. 41 (11), 1073–1076.
Saraji, M.K., Streimikiene, D., 2022. Evaluating the circular supply chain adoption in manufacturing sectors: a picture fuzzy approach. Technol. Soc. 70, 102050.
Sarkar, S., Pramanik, A., Maiti, J., 2023. An integrated approach using rough set theory, ANFIS, and Z-number in occupational risk prediction. Eng. Appl. Artif. Intell. 117, 105515.
Schroeder, P., Dewick, P., Kusi-Sarpong, S., Hofstetter, J.S., 2018. Circular economy and power relations in global value chains: tensions and trade-offs for lower income countries. Resour. Conserv. Recycl. 136, 77–78.
Schultz, F.C., Everding, S., Pies, I., 2021. Circular supply chain governance: a qualitative-empirical study of the European polyurethane industry to facilitate functional circular supply chain management. J. Clean. Prod. 317, 128445.
Simic, V., Gokasar, I., Deveci, M., Karakurt, A., 2022. An integrated CRITIC and MABAC based type-2 neutrosophic model for public transportation pricing system selection. Soc. Econ. Plann. Sci. 80, 101157.
Singhal, D., Jena, S.K., Tripathy, S., 2019. Factors influencing the purchase intention of consumers towards remanufactured products: a systematic review and meta-analysis. Int. J. Prod. Res. 57 (23), 7289–7299.
Smol, M., Kulczycka, J., Henclik, A., Gorazda, K., Wzorek, Z., 2015. The possible use of sewage sludge ash (SSA) in the construction industry as a way towards a circular economy. J. Clean. Prod. 95, 45–54.
Song, C.J., Xu, B.J., Xu, L., 2023. Dual-channel supply chain pricing decisions for low-carbon consumers: a review. J. Intell. Manag. Decis. 2 (2), 57–65.
Sotoudeh-Anvari, A., 2020. A critical review on theoretical drawbacks and mathematical incorrect assumptions in fuzzy OR methods: review from 2010 to 2020. Appl. Soft Comput. 93, 106354.
Sotoudeh-Anvari, A., 2022. The applications of MCDM methods in COVID-19 pandemic: a state of the art review. Appl. Soft Comput., 109238
Sotoudeh-Anvari, A., 2023. Root Assessment Method (RAM): a novel multi-criteria decision making method and its applications in sustainability challenges. J. Clean. Prod. 423, 138695.
Sotoudeh-Anvari, A., 2024. A state-of-the-art review on D number (2012-2022): a scientometric analysis. Eng. Appl. Artif. Intell. 127, 107309.
Tan, J., Liu, Y., Senapati, T., Garg, H., Rong, Y., 2022. An extended MABAC method based on prospect theory with unknown weight information under Fermatean fuzzy environment for risk investment assessment in B&R. J. Ambient Intell. Hum. Comput. 1–30.
Tharanathan, R.N., 2003. Biodegradable films and composite coatings: past, present and future. Trends Food Sci. Technol. 14 (3), 71–78.

Tian, Y., Mi, X., Ji, Y., Kang, B., 2021. ZE-numbers: a new extended Z-numbers and its application on multiple attribute group decision making. Eng. Appl. Artif. Intell. 101, 104225.

Trivellas, P., Rafailidis, A., Polychroniou, P., Dekoulou, P., 2018. Corporate social responsibility (CSR) and its internal consequences on job performance: the influence of corporate ethical values. Int. J. Qual. Serv. Sci.

Tundys, B., 2021. Corporate social responsibility and sustainable value creation. In: Sustainability in Bank and Corporate Business Models. Palgrave Macmillan, Cham, pp. 67–110.

Tura, N., Hanski, J., Ahola, T., Ståhle, M., Piiparinen, S., Valkokari, P., 2019. Unlocking circular business: a framework of barriers and drivers. J. Clean. Prod. 212, 90–98.

Vegter, D., Hillegersberg, J.V., Olthaar, M., 2021. Performance measurement systems for circular supply chain management: current state of development. Sustainability 13 (21), 12082.

Vegter, D., van Hillegersberg, J., Olthaar, M., 2023. Performance Measurement System for Circular Supply Chain Management. Sustainable Production and Consumption.

Walker, A.M., Vermeulen, W.J., Simboli, A., Raggi, A., 2021. Sustainability assessment in circular inter-firm networks: an integrated framework of industrial ecology and circular supply chain management approaches. J. Clean. Prod. 286, 125457.

Wandosell, G., Parra-Meroño, M.C., Alcayde, A., Baños, R., 2021. Green packaging from consumer and business perspectives. Sustainability 13 (3), 1356.

Wang, C., Zhang, Q., Zhang, W., 2020. Corporate social responsibility, green supply chain management and firm performance: the moderating role of big-data analytics capability. Res. Transp. Busi. Manag. 37, 100557.

Wang, T., Wu, X., Garg, H., Liu, Q., Chen, G., 2023. A prospect theory-based MABAC algorithm with novel similarity measures and interactional operations for picture fuzzy sets and its applications. Eng. Appl. Artif. Intell. 126, 106787.

Weng, Y.H., Qian, K., Fu, F., Fang, Q., 2020. Numerical investigation on load redistribution capacity of flat slab substructures to resist progressive collapse. J. Build. Eng. 29, 101109.

Yao, X., Hu, H., Qin, Y., Liu, J., 2020. Development of antioxidant, antimicrobial and ammonia-sensitive films based on quaternary ammonium chitosan, polyvinyl alcohol and betalains-rich cactus pears (Opuntia ficus-indica) extract. Food Hydrocolloids 106, 105896.

Zadeh, L.A., 1965. Information and control. Fuzzy sets 8 (3), 338–353.

Zadeh, L.A., 2011. A note on Z-numbers. Inf. Sci. 181 (14), 2923–2932.

Zafaranlouei, N., Ghoushchi, S.J., Haseli, G., 2023. Assessment of sustainable waste management alternatives using the extensions of the base criterion method and combined compromise solution based on the fuzzy Z-numbers. Environ. Sci. Pollut. Control Ser. 1–16.

Zaman, R., Jain, T., Samara, G., Jamali, D., 2022. Corporate governance meets corporate social responsibility: mapping the interface. Bus. Soc. 61 (3), 690–752.

Zhang, K., Huang, T.S., Yan, H., Hu, X., Ren, T., 2020. Novel pH-sensitive films based on starch/polyvinyl alcohol and food anthocyanins as a visual indicator of shrimp deterioration. Int. J. Biol. Macromol. 145, 768–776.

Zhang, S., Wei, G., Alsaadi, F.E., Hayat, T., Wei, C., Zhang, Z., 2020. MABAC method for multiple attribute group decision making under picture 2-tuple linguistic environment. Soft Comput. 24 (8), 5819–5829.

Zhao, Q., Ju, Y., Dong, P., Gonzalez, E.D.S., 2022. A hybrid decision making aided framework for multi-criteria decision making with R-numbers and preference models. Eng. Appl. Artif. Intell. 111, 104777.

Zhu, X., Ran, Y., Zhang, G., Chen, J., Heli, L., 2023. Identification of maintenance significant items for machine tools by integrating DEMATEL and MABAC with spherical fuzzy sets. Eng. Appl. Artif. Intell. 126, 107155.