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Evaluation of circular economy business models for SMEs using spherical fuzzy TOPSIS: an application from a developing countries' perspective

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Abstract
While the circular economy has recently been the subject of considerable theoretical debate, the discussion has yielded limited insight into how its implementation should look. Developing countries' inadequate regulation and policy hinder the circular economy's implementation in small- and medium-sized enterprises (SMEs) with resource, strategy, and skill constraints. Therefore, circular economy business models (CEBMs) support SMEs in overcoming the risks of implementation. However, SMEs often struggle to decide which CEBM to use. This study aims to enable developing countries' SMEs to choose the most appropriate CEBM using the spherical fuzzy TOPSIS method, which is an extremely new method for solving decision-making problems. The four main CEBMs most frequently encountered in the literature and practice have been extensively analysed. The results suggest that the resource recovery model is the most appropriate model for transitioning to a circular economy for SMEs in developing countries. Circular supply is the second suitable business model. Following these stages, after the organisation reaches a specific level of CE maturity, the product life extension and the product–service system model should be applied at the last stage. A comparative assessment and a sensitivity analysis are conducted to test the proposed methodology's robustness and reliability. The results opened up a space for discussion and for new thoughts that could improve the scope of the CEBMs theory. Using all CEBMs together, we concluded that the transition to CE will not be successful for SMEs. The order in which CEBMs should be applied in the transition to CE has been determined. Their scope, risks, and resources needed were correlated with these data from the field. This practical implementation guide, which we recommend based on theoretical foundations, offers administrators and future researchers original insights.

Keywords Circular economy business models · Small and medium enterprises · Developing countries · Spherical fuzzy TOPSIS

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1 Introduction

The circular economy (CE) has unquestionably become a crucial topic in public debate regarding more sustainable industrial paradigms and strategies (Urbinati et al., 2017). In recent years, interest in CE as a means of promoting sustainability has developed consistently in government, business, society, and academia (Ferasso et al., 2020; Chen et al., 2020; Bressanelli et al., 2018). Increasing global population, production, and consumption levels are rapidly exhausting our planet's scarce resources. Increased consumption (Mahroof et al., 2021), fast production processes, and the emergence of products with short life cycles have intensified the demand for natural resources (Garza-Reyes et al., 2019). In 2017, 89 gigatons of primary material were used in production, and this volume is expected to exceed 167 gigatons by 2060 (OECD, 2019a, b). Therefore, the demand for food, water, and energy is rising exponentially (Bag & Pretorius, 2020). The considerable quantities of metal, silicon, and plastic required to produce a single laptop computer are at odds with that end product's size and weight. Eight million tons of plastic are dumped into the world's oceans daily. Greenhouse gas levels are steadily increasing. Cement production alone produces 1.5 billion tons of CO_2 annually, equivalent to the emissions of 325 million automobiles (Geng et al., 2019). Concordantly, the United Nations' sustainable development goals set expectations for small- and medium-sized enterprises (SMEs)—representing 95–98% of private enterprises in developing countries—to minimise waste generation through prevention, reduction, and recycling, promotion of sustainable management practices, and optimisation of natural resources and usage behaviours by 2030 (United Nations, 2020). Similarly, the European Commission (2015) asserted the necessity of rethinking current production and consumption models for reducing anthropogenic environmental degradation. The application of CE principles could increase Europe's Gross Domestic Product (GDP) by up to 11% by 2030, with a net benefit of approximately €1.8 trillion and material cost savings of up to $1 trillion (Bressanelli et al., 2018).

To alleviate concerns about the planet's overexploitation, the traditional linear economic logic based on the take–make–use–dispose pattern must be radically transformed. The CE emerged as a critical approach in response to this systemic and radical logic transformation (Bocken et al., 2016; Jabbour et al., 2019; Vence & Pereira, 2019). This new logic envisions providing and preserving the highest value materials and products for as long as possible while consuming as few resources as possible (Pieroni et al., 2020). CE enhances resource and waste management efficiency by optimising business inputs and assets, especially natural resources, and following a cyclical output flow (Chhimwal et al., 2021; Santibanez Gonzalez et al., 2019; Sehnem et al., 2019). According to MacArthur (2013), a CE is an industrial economy whose purpose is restorative; it aims to rely on renewable energy; monitor, minimise, and eliminate the use of toxic chemicals; and eradicate waste through rational design. The CE aims to substitute "take-make-waste expressed as cradle to grave" patterns with "cradle to cradle, meaning closed loop of flow" (Kumar et al., 2021; Lacy & Rutqvist, 2015; Masi et al., 2017). Cradle-to-cradle product or material cycles are facilitated by multiple functions, such as maintenance, recovery, rethink and repair, reuse, refurbishment, remanufacturing, and recycling (Goyal et al., 2018; Jaeger and Upadhyay, 2020; Lacy et al., 2020). Hence, CE includes the recapture value of post-consumer products, resources, and packaging by replacing linear material and energy flows with circular flows through closed-loop production and consumption systems (Jabbour et al., 2019). Thus, it can transform linear

economic difficulties into new circular business opportunities, differentiate energy and resource consumption from economic growth, and achieve sustainable development (Chen et al., 2020).

To reverse the prevalent unsustainable economic structure, the CE approach is currently supported by the European Union, by various national governments, including China, Japan, the UK, France, Canada, the Netherlands, Sweden, Finland, and multiple businesses worldwide (Jabbour et al., 2019; Korhonen et al., 2018). CE-focused practices are concentrated in developed countries. Although national governments promote CE by introducing new laws and regulations, differences in priorities mean that these changes occur at different paces in different countries. The transition to CE is emerging alongside a series of changes in national institutional frameworks and companies' business models (Levänen et al., 2018). In developing countries, SMEs, which have experienced significant pressure regarding order fulfilment and cost problems in recent years, have put the CE on their macro agendas in response to suppliers' demands (Khan & Haleem, 2021; Luthra & Mangla, 2018), market interest, and increased governmental awareness (Elia et al., 2017; Rajput & Singh, 2019). However, micro-level CE studies are still lacking (Elia et al., 2017; Sousa-Zomer et al., 2018), despite the anticipated importance of CE success in developing countries to global efforts to achieve sustainable growth. Although developing countries are already global production centres and are ready to be international consumption drivers (Preston et al., 2019), no clear insight into this approach in developing countries has yet emerged, and policies and strategies for transition remain inadequate. This theoretical gap highlights the need for more research focusing on developing and emerging economies (Agyemang et al., 2019) to accelerate the development and spread of the CE worldwide.

The adverse effects of current prevailing production models based on the procurement, production, and disposal of resources and goods threaten natural ecosystems and affect human health and well-being (Lüdeke-Freund et al., 2019). Therefore, companies require new business models to create value (Geng et al., 2019). Similarly, CE aims to create value to benefit society. Therefore, it points to business model changes, emphasising shared use and leasing based on independent or single-use preference (Preston et al., 2019). Circular economy business models (CEBMs) have recently attracted attention in industry, government, and academia as creating profitable and beneficial business opportunities (Chen et al., 2020; De Mattos & De Albuquerque, 2018). Studies have explored the development of new CEBMs with case studies pertaining to various industries (Bocken et al., 2016; Bianchini et al., 2019; Centobelli et al., 2020; Real et al., 2020). However, the number of studies evaluating CEBMs is almost negligible (Manninen et al., 2018). Studies investigating SMEs' relationship with the CE are also scarce (Rizos et al., 2016; Ünal et al., 2019). Maximum efficiency is generally the fundamental principle of CEBMs (Whalen & Whalen, 2020), but the lack of appropriate business models impedes efforts to fully realise business-oriented solutions for increased recycling and simultaneously advance the CE (Levänen et al., 2018). Therefore, studies that simultaneously consider CE, the developing country context, SMEs, and business models are needed.

Several approaches to the ambiguity and uncertainty of real-life systems have been investigated, including fuzzy set (FS) theory (Ashraf & Abdullah, 2020). The spherical fuzzy set (SFS) proposed by Kutlu Gündoğdu and Kahraman (2019a) is a three-dimensional FS developed as an extension of the intuitionistic fuzzy set (IFS) and the Pythagorean and the neutrosophic fuzzy sets (PFS and NFS), in particular, to manage ambiguity when quantifying expert judgements (Mathew et al., 2020). SFSs' value is that they synthesise the positive aspects of other FS extensions in a single approach (Kutlu Gündoğdu & Kahraman, 2019b). Barukab et al. (2019) stated that since the SFS is better than other

FSs at overcoming uncertainties in multi-criteria decision-making problems, it is a strategic tool that makes decision-makers' confidence. SFSs are thus used to achieve superior results (Karthick et al., 2021; Mahmood et al., 2019; Yuan et al., 2021). This paper focuses on developing countries and SMEs with the primary goal of attaining a clear insight into which business model would be more advantageous for developing countries' SMEs transitioning to a CE using the SFS Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) method. CEBMs identified in this paper can promote valuable CE practice through efficient decision-making methods. SMEs with scarce resources also use priority business models determined by unbiased CE criteria, which support their success by reducing decision error risk. After summarising the key features of developing countries' SMEs, a review and typology of CEBMs is presented in response to the following questions: What CEBM patterns and design options are available? Which of these is best suited to developing countries' SMEs? How can the selection be quickly and effectively accomplished?

The remainder of the paper is structured as follows: First, CE is comprehensively defined and the concept's relationship to developing country SMEs is detailed. Second, basic CEBMs applicable to the transition to CE are specified. Third, the research methodology—spherical fuzzy TOPSIS—is explained. Fourth, 12 CE criteria were determined based on an extensive review of up-to-date literature. In line with the data obtained from professionals, the CE criteria for each CEBM for SMEs were determined. Finally, based on the findings, a suitable model and strategy for SMEs of developing countries transitioning to CE are proposed and the study's theoretical and managerial implications are discussed.

2 Literature review

The CE approach—the end-of-life concept in production/distribution and consumption processes employing reduction, reuse, recycling, and recovery models at the micro (products, companies, consumers), meso (eco-industrial parks), and macro (city, regional, national, and international) levels—defines an economic system founded on social justice-based business models that work to benefit current and future generations in achieving sustainable development that ensures environmental quality, economic prosperity, and well-being (Bressanelli et al., 2018; Kirchherr et al., 2017). This new restructuring paradigm promotes a durable and waste-free ecosystem by adopting the reduction, reuse, and recycling paradigms (Toker et al., 2020; Goyal et al., 2018). CE aims to increase resource efficiency and environmental performance at different levels (e.g. individual enterprises, industrial areas, city, and regional) (Heyes et al., 2018; Susanty et al., 2020). Morseletto (2020) notes that CE approaches support sustainable development while protecting economic growth from the negative consequences of resource consumption and environmental degradation.

The conventional economic system is traditionally perceived as open-ended: Production enterprises produce consumer goods, and capital goods are used for future manufacturing. Consumption aims to create social benefit or prosperity. Natural resource consumption may also be evaluated within this linear perspective (Andersen, 2007; Urbinati, 2017): In a linear economic system, raw materials are extracted, produced, used, and discarded. The end-of-life process causes environmental degradation through the continuous exploitation of limited resources (Chen, 2020). In overcoming the constraints of the linear production, take–make–use–dispose economy, CE is considered among the best sustainable development solutions (Aloini et al., 2020; Ngan et al., 2019). The circular approach contradicts

the conventional linear business model's buy–make–use–dispose system and the profits from open-ended material flow and industrial systems that rely heavily on fossil fuels (Bocken et al., 2016; Bressanelli et al., 2018; Hopkinson et al., 2018). This logical contradiction occurs at every stage of the economic process, from supply to production and from distribution to marketing.

CE also promotes the circular flow of resources in the production–consumption system. The system is designed to be reparative and regenerative and can be scaled differentially to the micro, meso, and macro levels (Liu et al., 2018; Ngan et al., 2019). Thus, it aims to reduce costs and derive the maximum possible value from resources (Jabbour et al., 2020). Shorter cycles are more profitable and use resources more efficiently. This structure implies a circular hierarchy of goods in the order reuse, repair, regeneration, and recycling. Rather than creating added value, the CE approach aims to maintain the value, quality, and performance of goods over time through adequate stock management. Enhanced stock management efficiency will decelerate resource flow (Vence & Pereira, 2019). Consequently, production flow will reach a level that nature can tolerate with economic cycles that respect natural reproduction rates (Škrinjarić, 2020). Thus, resource consumption will follow nature's production rate, allowing the planet to regenerate itself.

Compared with advances in some aspects of CE, such as recycling, concepts such as energy efficiency, operational and regeneration capacity, and slow consumption in various sectors and countries have lagged behind (Lüdeke-Freund et al., 2019). SMEs are increasingly aware of the benefits of resource efficiency. However, these benefits are rarely linked effectively to the CE concept (Rizos et al., 2016). Problems persist in many developing countries, including insufficient legal regulation, poor public support, and managerial inadequacies. According to Antikainen and Valkokari (2016), this process challenges business' to reconsider how the value of products and materials might be maximised, thus mitigating the exploitation of natural resources and exerting a positive social and environmental impact. Therefore, CE may not be an ultimate goal but part of an ongoing process to achieve greater resource productivity and efficiency (Lüdeke-Freund et al., 2019). For such a change to occur, develop, and thrive, SMEs—the essential components of economies—should play greater practical roles in the transition to CE. When the developing country context and SME insufficiencies are evaluated, practical models that will accelerate this shift can be developed.

2.1 CE in developing economies and SMEs

The use of industrialisation to accumulate technological and social talent is particularly critical for developing economies that prioritise economic growth. Traditional approaches to economic development bear the burden of waste-generating and environmentally exploitative legacies. Meanwhile, environmental threats are intensifying owing to increased demand for resources that feed economic growth, especially in developing countries (Wu et al., 2021). According to Diaz (2017), among the most critical issues in developing countries are the lack of political will to address environmental problems, the absence of national policies on solid waste management, inadequate rules and regulations, and the lack of training programmes. Most critically, no policies regarding the support or creation of CE approaches have been developed. Particularly considering the weight of SMEs in the economic structures of developing countries, the economic, social, and environmental impacts of these enterprises are crucial. Therefore, examining the issue in the context of SMEs is necessary to develop a comprehensive understanding of CE practices.

SME definitions differ from country to country. The European Commission adopted Recommendation 2003/361/EC, which defines an SME according to three criteria among the existing definitions (European Commission, 2021). These criteria are the number of personnel, annual turnover, and annual balance sheet. Specifically, an SME is defined as a business with less than 250 employees. From a financial point of view, the SME has two criteria: an annual turnover not exceeding 50 million euros and an annual balance sheet total not exceeding 43 million euros. Also, an SME must be an independent business. An independent entity is a firm that has no governance link between the firm itself and other companies. There is no ownership interest in other businesses, and no other business has a relevant stake in it (Corazza, 2019). On the other hand, SMEs are defined as economic units or enterprises with less than 250 employees and whose annual net sales or financial balance sheet does not exceed 40 million Turkish Liras in Turkey (Official Gazette, 2018). Despite the critical importance of developing economies' SMEs, many obstacles may hinder SMEs' implementation of CE applications. Rizos et al. (2015) stated that various factors, such as culture and policymaking, suppliers' behaviours, the market chain in which the SME operates, technical skills, and lack of finance, have forced SMEs' transition to CE.

While developing economies could benefit from CE through proper policy formulation and enforcement, they also offer various means of managing products such as smartphones, plastics, food, and steel: end-of-life products, such as electronics and clothing, from developed countries enter these economies for renewal and consumption (Agyemang et al., 2019). Significantly, SMEs can minimise waste and the exploitation of natural resources and contribute to the country's prosperity by reconsidering these products based on CE policies. In this context, the dominant approach to waste issues has been to try to change socio-economic structures and cultural norms by targeting individual behaviour through education, incentives, and deterrents. These efforts are often led by non-profit organisations (NPOs) or government agencies that focus on educational programmes and rely on community participation (Wu et al., 2021). However, SMEs—rather than NGOs and governments—are critical to positive results, as they represent the largest market share. However, SMEs are often heterogeneous organisations that have not reached the same environmental management stage (Ormazabal et al., 2018). In this respect, Liu et al. (2018) stated that the CE process is applied differently owing to various cultural, social, and political systems.

All of these applications do not give the same effective results and create a waste of resources and time. Therefore, SMEs with scarce resources should manage their transition to CE with one-time, appropriate business models and effective strategies.

2.2 Circular economy business models

Increased ecological issues associated with the expanding global population have prompted organisations worldwide to follow sustainable business models (D'Agostin, 2020). CE radically changes business models for new value propositions and competitive advantage (Centobelli et al., 2020; Ungerman & Dědková, 2020). The business model concept was first developed in strategic and innovation management literature rooted in the conceptual logic of how firms create appropriate economic values (Richardson, 2005). A business model represents a set of strategic decisions that define how companies develop, transfer, and capture value based on their internal operations and relationships with stakeholders, including suppliers and customers (Lahti et al., 2018; Urbinati, 2017; Antikainen & Valkokari, 2016). According to Antikainen and Valkokari (2016), radical innovations and disruptive business models are needed to overcome current challenges.

CE transition entails overall system change through technological and non-ecological innovations across the entire organisation. Such innovations range from product design and industrial manufacturing to the need to understand new business models, including how value is created, captured, and delivered to customers (Centobelli et al., 2020; Heyes, 2018). These new business models are required to increase resource utilisation value (Jabbour et al., 2019). In this sense, the CEBM has repeatedly been defined as business logic or as a business ecosystem to create, provide, and capture value by slowing, closing, or narrowing resource flows (i.e. energy or materials) (Centobelli et al., 2020; Heyes et al., 2018; Pieroni et al., 2021). Accordingly, the CEBM is to move from profit-making through the sale of products or services to profit-making through the flow of resources, materials, and outcomes over time, including the reuse and recycling of resources. This logic implies that companies can reduce their negative impact on the environment by offering and capturing value with this alternative value proposition (Lahti et al., 2018). Appropriate business models and practices support SMEs in achieving sustainable development goals and CE practices (Ünal et al., 2019; United Nations, 2020). When upstream and downstream business activities are cyclical, a business model can be considered purely cyclical (Urbinati et al., 2017). Lahti et al. (2018) stated that CEBMs are needed to create, present, and achieve value by applying circular economy principles. Business logic is reconstructed among actors/stakeholders to meet environmental, social, and economic benefits.

Organisations must clarify how they create, deliver, and capture value within closed material loops (Chen, 2020). For this reason, businesses use different business models that aim to reduce resource consumption, increase efficiency, and reduce waste while transitioning from a linear economy to CE (Gusmerotti et al., 2019; Jonker et al., 2017). However, owing to the limited application of new CEBMs, the history of successful paradigms to improve practical knowledge is not yet sufficiently comprehensive, creating uncertainty around the introduction of circular applications (Rizos et al., 2016). According to Lewandowski (2016), extensive learning is needed to design CEBMs that encourage and support CE application at the micro-level. Existing knowledge provides a detailed and validated framework of design models and tools for building business models.

In this study, four CEBM typologies proposed by the Organisation for Economic Cooperation and Development (OECD) were taken as a basis, and circular activities were categorised from a business-oriented perspective. This perspective emphasises each model's business assumption; this is important because widespread adoption will remain largely theoretical unless the private sector perceives a significant value (OECD, 2019a, 2019b). In this way, businesses can use effective business models more practically.

2.2.1 Circular supply (CS) business model

Preventing resource waste and excessive raw material extraction is central to the CE concept because processes require energy, often causing pollution and increased competition over scarce resources (Tunn et al., 2019). To close the material cycle in CE, products must be repurchased or collected in reverse logistics systems (Mentink, 2014). In typical developed supply chain activities—planning, purchasing raw materials, manufacturing, marketing, and distribution—firms must add and manage their reverse supply chain activities. That is, the reverse logistics process should include review and evaluation of products' current states, redistribution/reuse, reproduction, and recycling (De Mattos & De Albuquerque, 2018; Urbinati, 2017). Thus, value creation is based on up-and-down circularity. First, used materials are converted into lower-value materials (for example, filling the garment).

Second, higher-quality materials and improved functionality are provided (for example, polyethylene terephthalate bottles or, more recently, ocean plastics are transformed into clothes and carpets) (Lüdeke-Freund et al., 2019). Such industrial linkages are essential in CEs, where existing material input–output streams are complemented by more production and consumption cycles where unwanted outputs are used as valuable inputs. Such circular resource flow is provided by logistics and supply chain operations that facilitate recovery, reuse, and recycling as preferred alternatives to disposal (Batista et al., 2018). Thus, solid wastes are recovered and reused to minimise material leakage and maximise economic value (Goyal et al., 2018). Companies that adopt this model gradually cease exploiting scarce resources, reduce waste, and eliminate inefficiency (Svensson & Funck, 2019). De Mattos and De Albuquerque (2018) noted the importance of establishing large-scale circular systems instead of structures such as practical cooperation between chains and sectors.

2.2.2 Resource recovery (RR) business model

This business model includes the production of secondary raw materials from waste streams (OECD, 2019a, b). These include activities related to the development and use of renewable inputs, recycling of materials, and recovery of resources, all of which are recognised as having commercial and environmental benefits (Whalen & Whalen, 2020). Goyal et al. (2016) stated that this business model focuses on recycling and reusing waste use solid, electronic, etc., to create new products and minimise material leakage and maximise economic value. Since the entropy law suggests that the system should be fed with new sources when some energy goes unrecovered, the CE minimises energy consumption and reduces leakages from the closed-loop system (Ünal et al., 2019). Chen (2020) stated that the resource recovery model reworks discarded products and transforms them into new products or energy. Such a model converts waste into value, often through recycling or recycling services. Resource recovery is achieved through industrial closed-loop recycling, whereby waste materials are converted into new resources and product life is extended through remanufacturing and reuse (Lahti et al., 2018). Hence, production and consumption processes generate less waste and simultaneously promote an effective economy (Toker et al., 2020). According to Lahti et al. (2018), minerals, metals, and energy resources are replaced with renewable alternatives in the long term.

2.2.3 Product life extension (PLE) business model

Product life extension applies different approaches to prolong a product's useful life in terms of design (functional life) and maintenance and long-term use (actions performed by other actors) (Ertz et al., 2019). The design elicits user commitment and trust ensuring that products will be loved, admired, or trusted for longer (Bocken et al., 2016). This approach seeks to extend the product's useful life optimally so that unused or discarded material is channelled into something that meets fundamental needs and provides economic value to another segment of society (Goyal et al., 2018). Product can be designed for long-term use through strategies such as design for durability, design for repair and maintenance, and design for connectivity and trust. Products and services can also be designed for reuse after redistribution, remanufacture, or refurbishment (Selvefors et al., 2019). In the product life extension model, companies reduce production costs through repair, upgrade, or remanufacturing (Chen, 2020). The

process may be described as circular within the technical cycle. These practices are necessary in supporting product end-of-life and circularity (Centobelli et al., 2020).

2.2.4 Product–service system (PSS) business model

This model combines a physical product with a service component with greater emphasis on the physical product than on the service aspect (OECD, 2019a, b). According to Chen (2020), the product–service model offers leasing or rental services. If enhanced maintenance or take-back agreements are signed, other CE value factors (i.e. extending the product's life and closing the cycle) can also be monitored through such CEBM (Bressanelli et al., 2018). The implementation of these applications means that manufacturers become their users and pay for their use while retaining both the products and their components (Centobelli et al., 2020). Organisations that adopt this model allow one or more customers to rent while maintaining the product's ownership (Svensson & Funck, 2019). Products distributed under this model should be designed with ease of disassembly and service in mind. The traditional ownership model is replaced with pay-for-performance and the customer's access to the product (Laubscher & Marinelli, 2014). Long-lasting products (value proposition) can create a long-term customer relationship (value creation and delivery) and create new revenue streams at the product use phase through service packages or special contracts. This strategy reduces the need to produce new products (Geissdoerfer et al., 2020). According to Bressanelli et al. (2018), this model entails improved product design, attracting target customers, monitoring product activity, technical support, preventive and predictive maintenance, optimising product use, upgrading, renovation, and improving end-of-life performance.

While the distinction between each business model is evident in theory, it may be less evident in practice. In some cases, firms adopt business model combinations rather than single models. For example, assuming the product–service system model and maintaining the product ownership that comes with it can encourage parallel adoption of the product-to-life extension model (OECD, 2019a, b). According to Batista et al. (2018), such circular models include business networks that generate economic value through continuous resource exchange facilitated by innovative logistics and supply chain ecosystems. Moreover, they assist financially inadequate communities and nations by boosting prosperity while reducing demands on the planet's resources.

Multi-criteria decision-making (MCDM) means evaluating various alternatives in the light of independent or conflicting criteria. This evaluation may consider ranking, prioritisation, or selection (Fenton & Wang, 2006). Fuzzy MCDM methods are effective and accurate in ambiguous and undefined circumstances (Yalçın and Pehlivan, 2019). The TOPSIS method (Hwang & Yoon, 1981) is the second most frequently used MCDM method after Saaty's (1980) analytic hierarchy process (AHP) (Çelikbilek & Tüysüz, 2020; Zyoud & Fuchs-Hanusch, 2017). This is because computational steps are understandable and meaningful and can be applied to decision problems in many social and industrial areas (Balcerzak, 2020; Behzadian et al., 2012; Yu & Pan, 2021). FS theory combined with TOPSIS allows decision-makers to measure more accurate, error-free outcomes (Mathew et al., 2020).

3 Methods

The usage of MCDM methods in the context of problem solving in the circular economy, sustainability, and green challenges is increasing (Bachér et al., 2018; Sassanelli et al., 2019; Stojcić et al., 2019; Khan & Haleem, 2021). In addition, in the studies carried out, the concrete benefits of MCDM methods within the scope of the mentioned subjects are emphasised Govindan et al., 2015; Chowdhury & Paul, 2020; Stević et al., 2020). It is seen that various fuzzy extensions of the TOPSIS method, which is one of the popular MCDM methods, are used in these areas (Agrawal et al., 2021; Deveci et al., 2018; Lee & Chang, 2018; Mahpour, 2018; Sagnak et al., 2021). Our methodology is based on a relatively new fuzzy multi-criteria decision-making method. The spherical fuzzy sets (SFS) are presented as an extension to IFS by Kutlu Gündoğdu and Kahraman (2019a). The concept behind SFS is to allow decision-makers to generalise other fuzzy sets by specifying a membership function on a spherical surface and independently assigning the parameters of that membership function to a broader domain (Kutlu Gündoğdu & Kahraman, 2019b, c).

In this paper, a three-stage fuzzy methodology composed of (i) structuring an MCDM problem and collecting data, (ii) determining the criteria's importance for the SME to CE transition, and (iii) evaluation of CE business models using TOPSIS under the SF set is presented. Integration of TOPSIS and SFS is recently developed approach that has swiftly attracted attention, having been applied in different fields, including hospital location selection (Kahraman et al., 2019), evaluating industrial robots and advanced manufacturing systems (Barukab et al., 2019; Mathew et al., 2020), AS/RS technology selection (Boltürk, 2019), emergency decision support modelling (Ashrafd and Abdullah, 2020), assessment of learning analytics projects (Onar et al., 2020), optimal site selection (Kutlu Gündoğdu & Kahraman, 2021), and improving the FMEA method (Gul & Ak, 2021). This unique method, which can cope with uncertainties in decision-making, has not been encountered in circular economy issues or in evaluating CEBMs.

The methodological flow chart is illustrated in Fig. 1. We propose an approach that can be applied to real-life problems by combining TOPSIS, an accepted method, and the SFS to facilitate the decision-making problem's structuring and solution.

3.1 Spherical fuzzy sets: preliminaries

The most recent expansion of ordinary fuzzy sets is the SFS (Otay et al., 2020). Spherical numbers are the generalised form of neutrosophic and Pythagorean fuzzy numbers. In SFSs, while the squared sum of membership, non-membership, and hesitancy parameters can be between 0 and 1, each can be defined between 0 and 1 independently to ensure a squared sum that equals 1 at most (Kutlu Gündoğdu & Kahraman, 2020a, b). In the decision-making system, membership, non-membership, and hesitancy are this approach's significant benefits. This condition contributes positively to the efficacy of the analysis (Yuan et al., 2021). The differences between IFS, PFS, NS, and SFS are illustrated in Fig. 2.

In the following, the preliminaries of SFS are presented (Kutlu Gündoğdu & Kahraman, 2019a, 2021):

Definition 2.1 Single-valued Spherical Fuzzy Sets (SFS) $\tilde{A}_S$ of the universe of discourse U is given by.

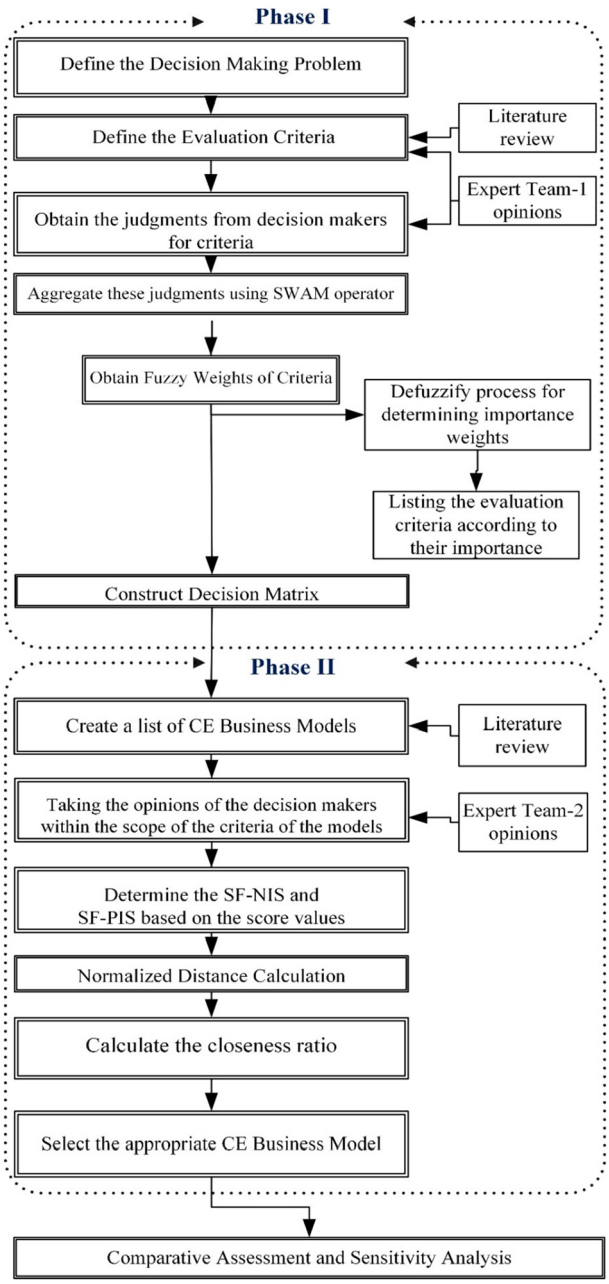


Fig. 1 Proposed evaluation model flow chart

$$\tilde{A}_S = \left\{ \langle u, \left(\mu_{\tilde{A}_S}(u), v_{\tilde{A}_S}(u), \pi_{\tilde{A}_S}(u) \right) \middle| u \in U \right\} \tag{1}$$

where

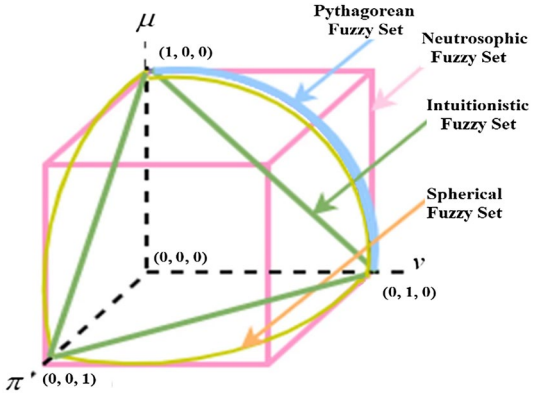


Fig. 2 Geometric representations of fuzzy sets (Kutlu Gündoğdu & Kahraman, 2020a, 2020b)

$$\mu_{\tilde{A}_S}(u) : U \to [0,1], v_{\tilde{A}_S}(u) : U \to [0,1], \pi_{\tilde{A}_S}(u) : U \to [0,1]$$

and

$$0 \leq \mu^2_{\tilde{A}_S}(u) + v^2_{\tilde{A}_S}(u) + \pi^2_{\tilde{A}_S}(u) \leq 1 \forall u \in U \tag{2}$$

For each u, the numbers $\mu_{\tilde{A}_S}(u), v_{\tilde{A}_S}(u)$ and$\pi_{\tilde{A}_S}(u)$ are the degree of membership, non-membership, and hesitancy of u to $\tilde{A}_S$, respectively. $\chi_{\tilde{A}_s}(u) = \sqrt{1 - \mu^2_{\tilde{A}_s}(u) - v^2_{\tilde{A}_s}(u) - \pi^2_{\tilde{A}_s}(u)}$ is called a refusal degree.

Definition 2.2 Basic operators of single-valued SFS.

$$\text{(i)} \quad \tilde{A}_S \oplus \tilde{B}_S = \left\{ \begin{array}{c} \left(\mu^2_{\tilde{A}_S} + \mu^2_{\tilde{B}_S} - \mu^2_{\tilde{A}_S}\mu^2_{\tilde{B}_S}\right)^{1/2}, v_{\tilde{A}_S} v_{\tilde{B}_S}, \\ \left(\left(1 - \mu^2_{\tilde{B}_S}\right)\pi^2_{\tilde{A}_S} + \left(1 - \mu^2_{\tilde{A}_S}\right)\pi^2_{\tilde{B}_S} - \pi^2_{\tilde{A}_S}\pi^2_{\tilde{B}_S}\right)^{1/2} \end{array} \right\} \tag{3}$$

$$\text{(ii)} \quad \tilde{A}_S \otimes \tilde{B}_S = \left\{ \begin{array}{c} \mu_{\tilde{A}_S}\mu_{\tilde{B}_S}, \left(v^2_{\tilde{A}_S} + v^2_{\tilde{B}_S} - v^2_{\tilde{A}_S} v^2_{\tilde{B}_S}\right)^{1/2}, \\ \left(\left(1 - v^2_{\tilde{B}_S}\right)\pi^2_{\tilde{A}_S} + \left(1 - v^2_{\tilde{A}_S}\right)\pi^2_{\tilde{B}_S} - \pi^2_{\tilde{A}_S}\pi^2_{\tilde{B}_S}\right)^{1/2} \end{array} \right\} \tag{4}$$

$$\text{(iii)} \quad \lambda \cdot \tilde{A}_S = \left\{ \begin{array}{c} \left(1 - \left(1 - \mu^2_{\tilde{A}_S}\right)^{\lambda}\right)^{1/2}, v^{\lambda}_{\tilde{A}_S}, \\ \left(\left(1 - \mu^2_{\tilde{A}_S}\right)^{\lambda} - \left(1 - \mu^2_{\tilde{A}_S} - \pi^2_{\tilde{A}_S}\right)^{\lambda}\right)^{1/2} \end{array} \right\} \text{for } \lambda \geq \tag{5}$$

$$\text{(iv)} \qquad \tilde{A}_S^{\lambda} = \left\{ \begin{array}{c} \mu_{\tilde{A}_S}^{\lambda}, \left(1 - \left(1 - v_{\tilde{A}_S}^2\right)^{\lambda}\right)^{1/2} \\ \left(\left(1 - v_{\tilde{A}_S}^2\right)^{\lambda} - \left(1 - v_{\tilde{A}_S}^2 - \pi_{\tilde{A}_S}^2\right)^{\lambda}\right)^{1/2} \end{array} \right\} \text{for } \lambda \geq 0 \tag{6}$$

Definition 2.3 For these SFS $\tilde{A}_S$=$(\mu_{\tilde{A}_S}, v_{\tilde{A}_S}, \pi_{\tilde{A}_S})$ and $\tilde{B}_S$=$(\mu_{\tilde{B}_S}, v_{\tilde{B}_S}, \pi_{\tilde{B}_S})$ the followings are valid under the conditions λ, λ_1, $\lambda_2 \geq 0$.

$$\text{(i)} \qquad \tilde{A}_S \oplus \tilde{B}_S = \tilde{B}_S \oplus \tilde{A}_S \tag{7}$$

$$\text{(ii)} \qquad \tilde{A}_S \otimes \tilde{B}_S = \tilde{B}_S \otimes \tilde{A}_S \tag{8}$$

$$\text{(iii)} \qquad \lambda\left(\tilde{A}_S \oplus \tilde{B}_S\right) = \lambda\tilde{A}_S \oplus \lambda\tilde{B}_S \tag{9}$$

$$\text{(iv)} \qquad \lambda_1\tilde{A}_S \oplus \lambda_2\tilde{A}_S = \left(\lambda_1 + \lambda_2\right)\tilde{A}_S \tag{10}$$

$$\text{(v)} \qquad \left(\tilde{A}_S \otimes \tilde{B}_S\right)^{\lambda} = \tilde{A}_S^{\lambda} \otimes \tilde{B}_S^{\lambda} \tag{11}$$

$$\text{(vi)} \qquad \tilde{A}_S^{\lambda_1} \otimes \tilde{A}_S^{\lambda_2} = \tilde{A}_S^{\lambda_1+\lambda_2} \tag{12}$$

Definition 2.4 Single-valued Spherical Weighted Arithmetic Mean (SWAM) withrespect to, $w = \left(w_1, w_2 \ldots, w_n\right); w_i \in [0,1]; \sum_{i=1}^{n} w_i = 1$, SWAM is defined as.

$$\begin{aligned} &\text{SWAM}_w\left(\tilde{A}_{S1}, \ldots, \tilde{A}_{Sn}\right) = w_1\tilde{A}_{S1} + w_2\tilde{A}_{S2} + \cdots + w_n\tilde{A}_{Sn} \\ &= \left\{ \begin{array}{l} \left[1 - \prod_{i=1}^{n}\left(1 - \mu_{\tilde{A}_{Si}}^2\right)^{w_i}\right]^{1/2}, \\ \prod_{i=1}^{n} v_{\tilde{A}_{Si}}^{w_i}, \left[\prod_{i=1}^{n}\left(1 - \mu_{\tilde{A}_{Si}}^2\right)^{w_i} - \prod_{i=1}^{n}\left(1 - \mu_{\tilde{A}_{Si}}^2 - \pi_{\tilde{A}_{Si}}^2\right)^{w_i}\right]^{1/2} \end{array} \right\} \end{aligned} \tag{13}$$

Definition 2.5 Single-valued Spherical Weighted Geometric Mean (SWGM) with respect to, $w = \left(w_1, w_2 \ldots, w_n\right); w_i \in [0,1]; \sum_{i=1}^{n} w_i = 1$, SWGM is defined as.

$$\begin{aligned} &SWAM_w\left(\tilde{A}_1, \ldots, \tilde{A}_n\right) = \tilde{A}_{S1}^{w_1} + \tilde{A}_{S2}^{w_2} + \cdots + \tilde{A}_{Sn}^{w_n} \\ &= \left\{ \begin{array}{l} \prod_{i=1}^{n} \mu_{\tilde{A}_{Si}}^{w_i}\left[1 - \prod_{i=1}^{n}\left(1 - v_{\tilde{A}_{Si}}^2\right)^{w_i}\right]^{1/2}, \\ \left[\prod_{i=1}^{n}\left(1 - v_{\tilde{A}_{Si}}^2\right)^{w_i} - \prod_{i=1}^{n}\left(1 - v_{\tilde{A}_{Si}}^2 - \pi_{\tilde{A}_{Si}}^2\right)^{w_i}\right]^{\frac{1}{2}} \end{array} \right\} \end{aligned} \tag{14}$$

Definition 2.6 Score functions and accuracy functions of sorting SFS are defined by.

$$\text{Score}\left(\tilde{A}_S\right) = \left(2\mu_{\tilde{A}_S} - \frac{\pi_{\tilde{A}_S}}{2}\right)^2 - \left(v_{\tilde{A}_S} - \frac{\pi_{\tilde{A}_S}}{2}\right)^2 \tag{15}$$

$$\text{Accuracy}\left(\tilde{A}_S\right) = \mu_{\tilde{A}_S}^2 + v_{\tilde{A}_S}^2 + \pi_{\tilde{A}_S}^2 \tag{16}$$

Note that: $\tilde{A}_S < \tilde{B}_S$ if and only if.

(i) $Score(\tilde{A}_S) < Score(\tilde{B}_S)$ and
(ii) $Score(\tilde{A}_S) = Score(\tilde{B}_S)$ and $Accuracy\ (\tilde{A}_S) < Accuracy\ (\tilde{B}_S)$.

3.2 Spherical fuzzy TOPSIS method

The relatively new single-valued SF-TOPSIS method comprises several processing steps. The methodology proposed by Kutlu Gundogdu in 2019 is summarised below.

An MCDM problem can be presented in a decision matrix that shows all alternatives' assessed values under the spherical fuzzy environment for each criterion. Let $X = \{x_1, x_2, \ldots x_m\} (m \geq 2)$ be a discrete set of m feasible alternatives and $C = \{C_1, C_2, \ldots C_n\}$ be a finite set of criteria, and $w = \{w_1, w_2, \ldots w_n\}$ be the weights vector of all criteria which satisfies $0 \leq w_j \leq 1$ and $\sum_{j=1}^{n} w_j = 1$.

Step 1 Let decision-makers (DM) complete the decision matrices using the linguistic terms given in Table 1. DMs can also evaluate the criteria to define their weights using Table 1.

Step 2 Complete each decision-maker's judgement with spherical weighted arithmetic mean (SWAM) using Eq. (17). Each DM may have a different weight depending on its experiences, $w_j, j = 1, 2, \ldots, n$.

Table 1 Linguistic terms and corresponding spherical fuzzy numbers (Kahraman et al., 2019)

Linguistic terms	(μ, v, π)
Absolutely more importance (AMI)	(0.9, 0.1, 0.1)
Very high importance (VHI)	(0.8, 0.2, 0.2)
High importance (HI)	(0.7, 0.3, 0.3)
Slightly more importance (SMI)	(0.6, 0.4, 0.4)
Equally importance (EI)	(0.5, 0.5, 0.5)
Slightly low importance (SLI)	(0.4, 0.6, 0.4)
Low importance (LI)	(0.3, 0.7, 0.3)
Very low importance (VLI)	(0.2, 0.8, 0.2)
Absolutely low importance (ALI)	(0.1, 0.9, 0.1)

$$\mathrm{SWAM}_w\left(\tilde{A}_{S1},\ldots,\tilde{A}_{Sn}\right)=w_1\tilde{A}_{S1}+w_2\tilde{A}_{S2}+\cdots+w_n\tilde{A}_{Sn}$$

$$=\left\{\begin{array}{l}\left[1-\prod_{i=1}^{n}\left(1-\mu_{\tilde{A}_{Si}}^{2}\right)^{w_i}\right]^{1/2},\\ \prod_{i=1}^{n}v_{\tilde{A}_{Si}}^{w_i},\left[\prod_{i=1}^{n}\left(1-\mu_{\tilde{A}_{Si}}^{2}\right)^{w_i}-\prod_{i=1}^{n}\left(1-\mu_{\tilde{A}_{Si}}^{2}-\pi_{\tilde{A}_{Si}}^{2}\right)^{w_i}\right]^{1/2}\end{array}\right\} \tag{17}$$

At this step, if defuzzification is necessary to interpret the criteria's importance (especially in criterion weighting problems), the following equation can be used:

$$w_j^s=\left(\mu_j-\pi_j\right)^2-\left(v_j-\pi_j\right)^2 \tag{18}$$

Step 3 Aggregate the criteria weights.

Step 4 Construct the aggregated spherical fuzzy decision matrix (SFDM) based on the individual decision matrices.

Denote the evaluation values of alternative $X_i(i=1,2\ldots m)$ with respect to criterion $C_j(\mathrm{j}=1,2\ldots n)$ by $C_j\left(\underline{X_i}\right)=(\mu_{ij},\ v_{ij},\ \pi_{ij})$. $D=(\mathrm{C}_j(X_i))_{mxn}$ is a SFDM. For an MCDM problem with SFSs, the aggregated decision matrix $D=(\mathrm{C}_j(X_i))_{mxn}$ should be constructed as in Eq. (18). Decision-makers assess the alternatives as if all were benefit criteria such that if the cost criterion is chosen, they would give a lower linguistic term.

$$D=\left(C_j\left(X_i\right)\right)_{mxn}=\left(\begin{array}{ccc}\left(\mu_{11},v_{11},\pi_{11}\right) & \left(\mu_{12},v_{12},\pi_{12}\right) & \ldots\left(\mu_{1n},v_{1n},\pi_{1n}\right)\\ \left(\mu_{21},v_{21},\pi_{21}\right) & \left(\mu_{22},v_{22},\pi_{22}\right) & \ldots\left(\mu_{2n},v_{2n},\pi_{2n}\right)\\ & \vdots\ \vdots\ \vdots & \\ \left(\mu_{m1},v_{m1},\pi_{m1}\right) & \left(\mu_{m2},v_{m2},\pi_{m2}\right) & \ldots\left(\mu_{mn},v_{mn},\pi_{mn}\right)\end{array}\right) \tag{19}$$

Step 5 Construct the aggregated weighted SFDM as given in Eq. (20). After the aggregated weights of the criteria and the aggregated rating of the alternatives are determined, the aggregated weighted SFDM is formed using Eq. (4), and the aggregated weighted SFDM can be defined as follows:

$$D=\left(C_j\left(X_{iw}\right)\right)_{mxn}=\left(\begin{array}{ccc}\left(\mu_{11w},v_{11w},\pi_{11w}\right) & \left(\mu_{12w},v_{12w},\pi_{12w}\right) & \ldots\left(\mu_{1nw},v_{1nw},\pi_{1nw}\right)\\ \left(\mu_{21w},v_{21w},\pi_{21w}\right) & \left(\mu_{22w},v_{22w},\pi_{22w}\right) & \ldots\left(\mu_{2nw},v_{2nw},\pi_{2nw}\right)\\ & \vdots\ \vdots\ \vdots & \\ \left(\mu_{m1w},v_{m1w},\pi_{m1w}\right) & \left(\mu_{m2w},v_{m2w},\pi_{m2w}\right) & \ldots\left(\mu_{mnw},v_{mnw},\pi_{mnw}\right)\end{array}\right) \tag{20}$$

Step 6 Defuzzify the aggregated weighted decision matrix using the proposed score function.

$$\mathrm{Score}\left(C_j\left(X_{iw}\right)\right)=\left(2\mu_{ijw}-\frac{\pi_{ijw}}{2}\right)^2-\left(v_{ijw}-\frac{\pi_{ijw}}{2}\right)^2 \tag{21}$$

Step 7 Determine the spherical fuzzy negative ideal solution (SF-NIS) and spherical fuzzy positive ideal solution (SF-PIS), based on the values obtained in Step 6.

For the SF-NIS,

$$X^{-} = \left\{ C_j, \min_i < \text{Score}\left(C_j\left(X_{iw}\right)\right) > | \, j = 1, 2 \ldots n \right\} \tag{22}$$

$$X^{-} = \left\{ \langle C_1, \left(\mu_1^{-}, v_1^{-}, \pi_1^{-}\right)\rangle, \langle C_2, \left(\mu_2^{-}, v_2^{-}, \pi_2^{-}\right)\rangle \ldots \langle C_n, \left(\mu_n^{-}, v_n^{-}, \pi_n^{-}\right)\rangle \right\} \tag{23}$$

For the SF-PIS,

$$X^{*} = \left\{ C_j, \max_i < \text{Score}\left(C_j\left(X_{iw}\right)\right) > | \, j = 1, 2 \ldots n \right\} \tag{24}$$

$$X^{*} = \left\{ \langle C_1, \left(\mu_1^{*}, v_1^{*}, \pi_1^{*}\right)\rangle, \langle C_2, \left(\mu_2^{*}, v_2^{*}, \pi_2^{*}\right)\rangle \ldots \langle C_n, \left(\mu_n^{*}, v_n^{*}, \pi_n^{*}\right)\rangle \right\} \tag{25}$$

Step 8 Calculate the distances between alternative X_i and the SF-NIS as well as SF-NIS, respectively. Normalised Euclidean distance will be used for this step (Szmidt & Kacprzyk, 2000; Gündoğdu and Kahraman, 2020). Normalised Zhang and Xu's distance equations can also be used (Ejegwa, 2020; Zhang & Xu, 2014).

Normalised Euclidean distance to SF-NIS:

$$D_E\left(\tilde{X}_{ij}, \tilde{X}_j^{-}\right) = \sqrt{\frac{1}{2n}\sum_{i=1}^{n}\left(\mu_{\tilde{X}_{ij}} - \mu_{\tilde{X}_j^{-}}\right)^2 + \left(v_{\tilde{X}_{ij}} - v_{\tilde{X}_j^{-}}\right)^2 + \left(\pi_{\tilde{X}_{ij}} - \pi_{\tilde{X}_j^{-}}\right)^2} \forall i \tag{26}$$

Normalised Euclidean distance to SF-PIS:

$$D_E\left(\tilde{X}_{ij}, \tilde{X}_j^{*}\right) = \sqrt{\frac{1}{2n}\sum_{i=1}^{n}\left(\mu_{\tilde{X}_{ij}} - \mu_{\tilde{X}_j^{*}}\right)^2 + \left(v_{\tilde{X}_{ij}} - v_{\tilde{X}_j^{*}}\right)^2 + \left(\pi_{\tilde{X}_{ij}} - \pi_{\tilde{X}_j^{*}}\right)^2} \forall i \tag{27}$$

Normalised Zhang and Xu's distance to SF-NIS:

$$D_{ZX}\left(\tilde{X}_{ij}, \tilde{X}_j^{-}\right) = \frac{1}{2n}\sum_{j=1}^{n}\left(\left|\mu_{\tilde{X}_{ij}}^2 - \mu_{\tilde{X}_j^{-}}^2\right| + \left|v_{\tilde{X}_{ij}}^2 - v_{\tilde{X}_j^{-}}^2\right| + \left|\pi_{\tilde{X}_{ij}}^2 - \pi_{\tilde{X}_j^{-}}^2\right|\right) \forall i \tag{28}$$

Normalised Zhang and Xu's distance to SF-PIS:

$$D_{ZX}\left(\tilde{X}_{ij}, \tilde{X}_j^{*}\right) = \frac{1}{2n}\sum_{j=1}^{n}\left(\left|\mu_{\tilde{X}_{ij}}^2 - \mu_{\tilde{X}_j^{*}}^2\right| + \left|v_{\tilde{X}_{ij}}^2 - v_{\tilde{X}_j^{*}}^2\right| + \left|\pi_{\tilde{X}_{ij}}^2 - \pi_{\tilde{X}_j^{*}}^2\right|\right) \forall i \tag{29}$$

Step 9 Calculate the classical closeness ratio using Eq. (30). According to this equation, the best option is the alternative with the highest closeness ratio (Kahraman et al., 2019).

$$CR\left(X_i\right) = \frac{D\left(X_i, X^{-}\right)}{D\left(X_i, X^{*}\right) + D\left(X_i, X^{-}\right)} \tag{30}$$

In some cases, however, the classical relative closeness cannot ensure that the ideal solution simultaneously has the shortest distance from the PIS and the farthest distance from the NIS (Hadi-Vencheh & Mirjaberi, 2014; Zhang & Xu, 2014). They thus indicated

that the revised closeness ratio formula would be used rather than the classical relative closeness ratio. The revised closeness ratio is given in Eq. (31) (Boltürk, 2019):

$$\xi(X_i) = \frac{D(X_i, X^-)}{D_{max}(X_i, X^-)} - \frac{D(X_i, X^*)}{D_{min}(X_i, X^*)} \tag{31}$$

Equation (30) yields zero or negative results, as the second element of subtraction is at least identical to the first element. This equality has been modified, as in Eq. (32), so that zero or positive results can be obtained. The lowest value obtained is the best or most advantageous option in a ranking.

$$\xi(X_i) = \frac{D(X_i, X^*)}{D_{min}(X_i, X^*)} - \frac{D(X_i, X^-)}{D_{max}(X_i, X^-)} \tag{32}$$

4 Application

4.1 Problem

This study addresses the problem of which business model should be prioritised by SMEs in developing countries transitioning to a CE approach. Since SMEs' mobility is lower than that of large industrial enterprises, they are unable to simultaneously implement all CE business models.

4.2 Criteria

To identify the specific criteria that SMEs should consider when transitioning to a CE, we first examined the relevant literature. The criteria that we evaluated were then finalised in consultation with the expert decision-making group, and 12 criteria were included in the decision model. As Table 2 illustrates, the comprehensive literature review revealed four restore and reduce, three rethink and reconfigure, two skills and capabilities, and three fiscal durability-related assessment criteria. (Table 3).

4.2.1 Restore and reduce

CE has a clear link to reducing environmental impact because the system's objectives are to counter the depletion of natural resources gradually reduce waste and greenhouse gas emissions, (use hazardous materials, (and effect a complete transition to renewable and sustainable energy sources (Mentink, 2014). Moreover, the company is incentivised to take back products to minimise overall life cycle cost, thereby minimising operating costs (for example, increasing resource efficiency), extending product life, and allowing multiple life cycles (Bressanelli et al., 2018). CE's specific purpose is to reduce resource and energy consumption and waste through the continuous return of used resources to the economy (Vence & Pereira, 2019). Significant progress towards CE also necessitates reducing the global use of non-renewable energy sources (Whalen & Whalen, 2020). Therefore, all economic cycle resources should be managed as permanent renewable resources (Vence

Table 2 CEBMs evaluation criteria for SMEs

Criteria	Brief description	Supporting literature
Restore and Reduce		
C_1 Energy from renewable sources	To stop using fossil fuels in production processes, simultaneously using renewable energy, such as solar and wind, or generating energy from waste	Chen, (2020); Whalen & Whalen, (2020); Lahti et al., (2018); Agyemang et al., (2018); Mentink, 2014)
C_2 Green sourcing	To use abundant non-food resources, including biological waste, and the adoption of green and sustainable transformation methods to produce high-value products and ensure their post-use safety	Gusmerotti et al., (2019); Vence & Pereira, (2019); Kaur et al., (2018)
C_3 Cost optimisation	Reducing products' material costs and simultaneously eliminating the risks associated with supply restrictions and price volatility	Tura et al., (2019); Bressanelli et al., (2018); Agyemang et al., (2018)
C_4 Separated waste collection system	Waste systems separate and collect food waste, packaging waste, secondary raw materials, by-products, plastics, critical raw materials, biomass, bio-based materials, etc.	Gusmerotti et al., (2019); Goyal et al., (2016)
Rethink & Reconfigure		
C_5 Products and packaging design	Product and package redesign to enhance multiple lifecycles, to improve reuse, refurbishment, remanufacturing, and recycling	Whalen & Whalen, (2020); Bressanelli et al., (2018); Jonker et al., (2017)
C_6 Maximise durability	Extension of the period that starts when a product is put into use after production and ends when a product becomes too old to be recycled	Selvefors et al., (2019); Hart et al., (2019
C_7 Repair information and support	For a defective product to be used with its original function, it provides continuous information and support to the customer to repair and maintain the faulty parts and get the product to work again	Morseletto, (2020); De Mattos & De Albuquerque, (2018); Potting et al., (2017)
Skills & Capabilities		
C_8 Training and education	Including employees and stakeholders in the CE transition process and supporting their development via education and training programmes	Bag et al., (2021); Kumar et al., (2021); Aloini et al., (2020); Skrinjaric, (2020); Daou et al., (2020); Laubscher & Marinelli, (2014)

Table 2 (continued)

Criteria		Brief description	Supporting literature
C_9	Involvement and motivation	Ensuring employees' and stakeholders' active participation in the CE transformation process and increasing successful CE implementers' performance and motivation through rewards	Daou et al., (2020); Jabbour et al., (2020); Laubscher & Marinelli, (2014)
Fiscal Durability			
C_{10}	Separate budget allocation	Budgets should be allocated for high upfront investment costs in the context of supportive infrastructures for CE, the certification and compliance processes required for R&D, and new CE models	Aranda-Usón et al., (2019); Hart et al., (2019); Rizos et al., (2016)
C_{11}	Support of stakeholders and government	The need for fiscal support from key stakeholders, such as customers, potential partners, regional authorities, and the government for the success of the CE initiative	Jabbour et al., (2020); Ünal et al., (2019); Manninen et al., (2018); Rizos et al., (2015)
C_{12}	Revenue from products and services	Companies monetise their CE-based product and service offerings); consumers get the desired functionality and determine who is responsible for the tools that provide this functionality	Tura et al., (2019);Tunn et al., (2019); Mentink, (2014

Table 3 CE business model alternatives

CE business models	References
Circular supply	Lacy & Rutqvist, (2015); Angelis, (2018); OECD, (2019a, b); Rosa et al., (2019); Lacy et al., (2020)
Resource recovery	Lacy & Rutqvist, (2015); Singh and Ordoñez, (2016); OECD, (2019a, b); Velenturf & Jopson, (2019); Whalen & Whalen, (2020
Product life extension	Lacy & Rutqvist, (2015); Angelis, (2018); Bocken et al., (2016); OECD, (2019a), (2019b); Whalen & Whalen, (2020)
Product–service system	Reim et al., (2015); Tukker, (2015); Thompson et al., (2010); Lacy & Rutqvist, (2015); Kjaer et al., (2019)

& Pereira, 2019). When designing business models, companies should seek to conserve energy and fuel-containing resources. Renewable energies can support the CE target of closing cycles in many consumption and production areas (Centobelli et al., 2020). CE offers cost-saving opportunities by reducing waste and energy costs (Tura et al., 2019). This relationship stems from, for example, replacement, reuse, or recycling of production inputs, better use of by-products, waste conversion into products, and reduced waste disposal costs (Toker et al., 2020; Gusmerotti et al., 2019). Resource use, material and building costs, energy consumption, and material waste reduction also complement these physical factors from an environmental and cyclical perspective (İkiz Kaya et al., 2021). According to Kaur et al. (2018), CE targets can be achieved by integrating renewable and greener processes to achieve high production efficiency and productivity through efficient use of resources and reduced waste streams, thus adopting a social approach.

4.2.2 Rethink and reconfigure

CE logic minimises waste by beginning from design at the lowest potential operating costs throughout the entire physical life cycle and using (raw) materials and products for as long as possible (Jonker et al., 2017). The period that starts with the activation of a product after production and ends when a product becomes too old for recycling is extended (Selvefors et al., 2019). A sustainable product design incentive is to process reflection and residual flows as efficiently as possible to preserve residual value. Extending a product's life creates ecological value, delays new product purchases, and promotes more intensive use of raw materials (Jonker, 2017). Products must be designed to close *"cycles"* and generate revenue backed by low-cost return chains and rework structures as well as effective policies and instructions (De Mattos & De Albuquerque, 2018). However, the product–service system should be purposefully designed for resource separation; otherwise, it may create unwanted or rebound effects that could increase resource consumption (Geissdoerfer et al., 2020). According to De Mattos and De Albuquerque (2018), it is crucial to create a technological infrastructure for proximity, knowledge, and experience that stakeholders should share collaboratively.

4.2.3 Skills and capabilities

The CE requires an entirely new mindset that encourages managers and practitioners to develop competencies and skills, such as balancing linear and circular systems and

addressing complex and highly dynamic factors, including rapid technological changes and market fluctuations (Centobelli et al., 2020). Such change requires adequate cultural adaptation. Education programmes should support transformation. Companies' performance and reward schemes should be designed to change workforce mentality (Laubscher & Marinelli, 2014). This transformation refers to the company's (managers and employees) philosophy, habits, and attitudes towards implementing CE business practices (Rizos et al., 2016). Essential in achieving this is the integration of CE initiatives into the organisation's strategy, mission, vision, goals, and key performance indicators that will require employee training (Agyemang et al., 2019). Therefore, CE principles should be supported by effective commercial and promotional initiatives, such as customers' direct involvement in the same initiatives and extensive communication, and raise customers' awareness of the products' educational, ethical, and economic value (Centobelli et al., 2020). Otherwise, CE applications will fail to fully achieve their goals.

4.2.4 Fiscal durability

Organisations risk incorporating CE into their real applications mainly as a result of new investments in recycling, recovery infrastructure, and eco-technologies used to close cycles. Inadequate investment in these activities and infrastructure and insufficient funding for eco-innovation are critical issues in the transition to CE (Aranda-Usón et al., 2019). This criterion also defines how companies profit from their offerings, how consumers achieve the desired functionality, and who is responsible for the tools supporting this function (Tunn et al., 2019). Plans and legislation are explicitly adopted to increase resource efficiency and therefore waste in Europe, encouraging stricter laws or circular models with respect to production (Mentink, 2014). A linear production/business model's transition to a cyclical production/business model requires distribution planning, inventory management, production planning, reverse logistics network management, and considerable time and investment (Rizos et al., 2016). Therefore, enterprises should budget for high upfront investment costs in the context of a supportive infrastructure for CE, certification and compliance processes for R&D, and new CE models (Hurt et al., 2019). Subsidies and supportive taxation, such as recycling policies, also reduce organisations' risks of starting new businesses around CE (Aranda-Usón et al., 2019; Tura et al., 2019). Hart et al. (2019) stated that policy support could include public procurement.

4.3 Alternative business models

The four main CEBMs available to SMEs are our alternatives in this study. These business models are expressed as circular supply, resource recovery, product life extension, and product–service system. Although several business models are proposed in the literature, our consideration is limited to models that can be used by SMEs (Acerbi & Taisch, 2020). For example, the sharing platform business model is expressed as a consumer-to-consumer (C2C) or peer-to-peer (P2P) model rather than a business-to-business (B2B) model (Curtis, 2021; Lacy & Rutqvist, 2015). This model includes businesses that connect 3D printer owners with customers and host platform-based processes focused on software infrastructure.

4.4 Data Collection

It is not realistic to conclude that all evaluation criteria are equally relevant in assessing models for SMEs. In this study, an expert group of nine people—including three faculty members who work in SMEs, sustainability, supply chain and management—was formed to generate data within the scope of the spherical fuzzy TOPSIS method during the first stage of data collection. The other group members were businesspeople with 14 to 25 years' experience as managers in companies operating in the manufacturing sector. All decision-making group members were experts with experience and knowledge of the CE, industry, and SMEs. No exact number has been recommended for the size of the expert group in such studies (Özdemir et al., 2020; Goyal et al., 2021). Before eliciting the decision-makers views, an informative document on the subject was sent to experts, and after a short time, the authors delivered an in-person presentation and explained the purpose, criteria, and alternative models in considerable detail. The experts' evaluations were collected using a semi-structured questionnaire and arranged within the decision-making method's scope.

In the second stage of data collection, we interviewed three researchers who had profound knowledge of CE theory and its applications and more than 15 years' experience in production–operation management and developing countries. To evaluate the transition models to the CE, face-to-face evaluations were captured using a semi-structured form. The group evaluating the criteria and the team assessing the models differed for two reasons: the first group the weights they give to the criteria do not affect the model evaluations, and the second group has knowledge about SMEs' working systems in developing countries.

4.5 Determining the importance of the criteria

Linguistic terms are used in Table 1 to determine the evaluation criteria's importance. First, decision-makers' fuzzy judgements were obtained during the first phase using this scale. All judgements are presented in Table 4.

Table 4 Importance weights of the criteria

Criteria	DM1	DM2	DM3	DM4	DM5	DM6	DM7	DM8	DM9
C_1	AMI	VHI	AMI	VHI	VHI	AMI	AMI	VHI	VHI
C_2	HI	HI	HI	HI	HI	SMI	HI	VHI	HI
C_3	EI	VHI	VHI	HI	VHI	SMI	VHI	VHI	SMI
C_4	VHI	VHI	VHI	VHI	VHI	VHI	VHI	VHI	VHI
C_5	HI	AMI	AMI	HI	AMI	AMI	VHI	AMI	AMI
C_6	SMI	HI	VHI	HI	HI	VHI	HI	HI	VHI
C_7	EI	HI	HI	EI	HI	SMI	EI	HI	HI
C_8	EI	HI	HI	EI	HI	HI	EI	SMI	HI
C_9	HI	AMI	HI	HI	AMI	HI	HI	AMI	HI
C_{10}	VHI	VHI	HI	VHI	VHI	HI	VHI	VHI	HI
C_{11}	AMI	AMI	SMI	AMI	VHI	SMI	VHI	AMI	VHI
C_{12}	VHI	VHI	AMI	HI	VHI	VHI	VHI	VHI	VHI

Table 5 Aggregated, defuzzified, normalised criteria weights, and ranking

Criteria		Aggregated weights	Defuzzified Weights	Normalised weights	Rank
C_1	Energy from renewable sources	(0.85, 0.15, 0.23)	0.38	0.12	2
C_2	Green sourcing	(0.70, 0.30, 0.29)	0.17	0.05	10
C_3	Cost optimisation	(0.73, 0.27, 0.30)	0.19	0.06	9
C_4	Separated waste collection system	(0.80, 0.20, 0.20)	0.36	0.11	3
C_5	Products and packaging design	(0.86, 0.14, 0.12)	0.55	0.17	1
C_6	Maximise durability	(0.73, 0.27, 0.25)	0.23	0.07	8
C_7	Repair information and support	(0.64, 0.37, 0.39)	0.06	0.02	11
C_8	Training and education	(0.64, 0.37, 0.39)	0.06	0.02	12
C_9	Involvement and motivation	(0.80, 0.21, 0.22)	0.33	0.10	5
C_{10}	Separate budget allocation	(0.77, 0.23, 0.23)	0.29	0.09	6
C_{11}	Support of stakeholders and government	(0.83, 0.17, 0.24)	0.34	0.11	4
C_{12}	Revenue from products and services	(0.81, 0.19, 0.29)	0.26	0.08	7

Using the linguistic weights of the evaluation criteria determined by the decision-makers and the SWAM operator, the aggregated spherical fuzzy weight of each criterion was obtained. To determine which criterion emerge as salient in the evaluation, the fuzzy weights were clarified and normalised. Aggregated, defuzzified, and normalised criteria weights and overall ranking are presented in Table 5.

4.6 Ranking of the CE business models

Following the computation of criteria weights, the second phase began to determine the alternative models' suitability for SMEs. In this phase, the expert group formed to evaluate alternative business models was asked to evaluate each alternative against the criteria. All assessments are given in Table 6.

Using Eq. (19) with the fuzzy evaluations of the expert team, the aggregated decision matrix was formed and is presented in Table 7. The weighted SFDM was constructed using Eq. (20), as given in Table 8.

Based on Table 8 and Eq. (21), the score function values are calculated as in Table 9. Their use with Eqs. (22–25), the corresponding spherical fuzzy positive ideal solution (SF-PIS), and spherical fuzzy negative ideal solution (SF-NIS) are given in Table 10.

Normalised Euclidean distance (Eqs. 26–27) is used for this step (Szmidt & Kacprzyk, 2000; Kutlu Gündoğdu and Kahraman, 2020b). Finally, classical and revised closeness ratio values were calculated, and the business model alternatives were ranked as presented in Table 11.

The closeness ratios indicate that the most suitable CE business model for SMEs is resource recovery. The priority ranking of the business models within the scope of our study is RR > CS > PSS > PLE.

SMEs in developing countries should adopt the RR model as a starting point for the CE in the light of the data covered by the application's case. According to the order of

Table 6 Assessments of DM-A, DM-B, and DM-C

Decision-makers	CE business models	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
DM-A	CS	AMI	VHI	SMI	SMI	SMI	EI	EI	EI	EI	HI	VHI	HI
	RR	AMI	AMI	HI	AMI	VHI	EI	EI	SLI	EI	HI	VHI	HI
	PLE	HI	HI	VHI	EI	AMI	AMI	AMI	HI	EI	HI	HI	VHI
	PSS	SMI	EI	AMI	EI	HI	VHI	VHI	HI	HI	VHI	HI	AMI
DM-B	CS	AMI	AMI	HI	HI	SMI	EI	EI	EI	SMI	VHI	VHI	HI
	RR	AMI	AMI	VHI	AMI	HI	SMI	EI	EI	EI	HI	VHI	HI
	PLE	HI	SMI	VHI	EI	AMI	AMI	AMI	VHI	SMI	VHI	HI	VHI
	PSS	HI	EI	AMI	EI	VHI	VHI	AMI	VHI	HI	VHI	HI	AMI
DM-C	CS	AMI	AMI	VHI	VHI	SMI	EI	EI	VHI	EI	VHI	VHI	VHI
	RR	AMI	AMI	VHI	AMI	HI	EI	EI	SLI	SLI	HI	VHI	VHI
	PLE	HI	EI	VHI	EI	AMI	AMI	AMI	VHI	VHI	VHI	HI	AMI
	PSS	EI	EI	AMI	EI	HI	AMI	VHI	VHI	HI	VHI	VHI	AMI

Table 7 Decision matrix using SWAM operator

Alternatives		CS	RR	PLE	PSS
C1	μ	0.90	0.90	0.70	0.61
	v	0.10	0.10	0.30	0.39
	π	0.10	0.10	0.30	0.40
C2	μ	0.87	0.90	0.61	0.50
	v	0.13	0.10	0.39	0.50
	π	0.13	0.10	0.40	0.50
C3	μ	0.71	0.77	0.80	0.90
	v	0.29	0.23	0.20	0.10
	π	0.30	0.23	0.20	0.10
C4	μ	0.71	0.90	0.50	0.50
	v	0.29	0.10	0.50	0.50
	π	0.30	0.10	0.50	0.50
C5	μ	0.60	0.74	0.90	0.74
	v	0.40	0.26	0.10	0.26
	π	0.40	0.27	0.10	0.27
C6	μ	0.50	0.54	0.90	0.84
	v	0.50	0.46	0.10	0.16
	π	0.50	0.47	0.10	0.16
C7	μ	0.50	0.50	0.90	0.84
	v	0.50	0.50	0.10	0.16
	π	0.50	0.50	0.10	0.16
C8	μ	0.64	0.44	0.77	0.77
	v	0.37	0.56	0.23	0.23
	π	0.40	0.44	0.23	0.23
C9	μ	0.54	0.47	0.67	0.70
	v	0.46	0.53	0.34	0.30
	π	0.47	0.47	0.36	0.30
C10	μ	0.77	0.70	0.77	0.80
	v	0.23	0.30	0.23	0.20
	π	0.23	0.30	0.23	0.20
C11	μ	0.80	0.80	0.70	0.74
	v	0.20	0.20	0.30	0.26
	π	0.20	0.20	0.30	0.27
C12	μ	0.74	0.74	0.84	0.90
	v	0.26	0.26	0.16	0.10
	π	0.27	0.27	0.18	0.10

importance observed in the present study, within the framework of their opportunities, applications of other models may be incorporated into their strategic plans.

Table 8 Weighted decision matrix based on SWAM operator

Alternatives		CS	RR	PLE	PSS
C1	μ	0.77	0.77	0.60	0.52
	v	0.18	0.18	0.33	0.41
	π	0.25	0.25	0.36	0.44
C2	μ	0.62	0.63	0.43	0.35
	v	0.32	0.31	0.48	0.56
	π	0.31	0.30	0.45	0.52
C3	μ	0.52	0.57	0.59	0.66
	v	0.39	0.35	0.33	0.29
	π	0.40	0.36	0.35	0.31
C4	μ	0.57	0.72	0.40	0.40
	v	0.35	0.22	0.53	0.53
	π	0.34	0.22	0.51	0.51
C5	μ	0.52	0.64	0.78	0.64
	v	0.42	0.29	0.17	0.29
	π	0.41	0.29	0.16	0.29
C6	μ	0.37	0.39	0.66	0.62
	v	0.55	0.52	0.29	0.31
	π	0.51	0.49	0.27	0.29
C7	μ	0.32	0.32	0.57	0.54
	v	0.59	0.59	0.38	0.40
	π	0.54	0.54	0.39	0.41
C8	μ	0.41	0.28	0.49	0.49
	v	0.50	0.64	0.42	0.42
	π	0.49	0.49	0.42	0.42
C9	μ	0.43	0.37	0.53	0.56
	v	0.50	0.56	0.39	0.36
	π	0.49	0.49	0.40	0.36
C10	μ	0.60	0.54	0.60	0.62
	v	0.32	0.37	0.32	0.30
	π	0.32	0.36	0.32	0.30
C11	μ	0.67	0.67	0.58	0.61
	v	0.26	0.26	0.34	0.31
	π	0.30	0.30	0.37	0.34
C12	μ	0.60	0.60	0.68	0.73
	v	0.32	0.32	0.25	0.22
	π	0.38	0.38	0.33	0.30

Table 9 Score function values

Models	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
CS	0.27	0.09	0.02	0.05	0.01	0.02	0.05	0.01	0.00	0.08	0.13	0.04
RR	0.27	0.11	0.04	0.25	0.12	0.01	0.05	0.02	0.01	0.03	0.13	0.04
PLE	0.05	0.00	0.06	0.01	0.38	0.15	0.03	0.00	0.02	0.08	0.05	0.11
PSS	0.01	0.03	0.12	0.01	0.12	0.10	0.02	0.00	0.04	0.10	0.07	0.17

Table 10 SF-PIS and SF-NIS

	C_1	C_2	C_3	C_4	C_5	C_6
X^*	(0.77, 0.18, 0.25)	(0.63, 0.31, 0.30)	(0.66, 0.29, 0.31)	(0.72, 0.22, 0.22)	(0.78, 0.17, 0.16)	(0.66, 0.29, 0.27)
X^-	(0.52, 0.41, 0.44)	(0.43, 0.48, 0.45)	(0.52, 0.39, 0.40)	(0.40, 0.53, 0.51)	(0.52, 0.42, 0,41)	(0.39, 0.52, 0.49)
	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
X^*	(0.32, 0.59, 0.54)	(0.28, 0.64, 0.49)	(0.56, 0.36, 0.36)	(0.62, 0.30, 0.30)	(0.67, 0.26, 0.30)	(0.73, 0.22, 0.30)
X^-	(0.54, 0.40, 0.41)	(0.49, 0.42, 0.42)	(0.43, 0.50, 0.49)	(0.54, 0.37, 0.36)	(0.58, 0.34, 0.37)	(0.60, 0.32, 0.38)

Table 11 Distances to positive, negative ideal solutions and closeness ratio of each model

CE business model	$D(X_i,X^*)$	$D(X_i,X^-)$	Revised closeness ratio	Classical closeness ratio	Rank
CS	0.161	0.140	0.510	0.465	2
RR	0.126	0.182	0.000	0.592	1
PLE	0.171	0.136	0.610	0.444	3
PSS	0.192	0.118	0.877	0.381	4

5 Conclusions

Our findings have given several outcomes that provide theoretical and practical contributions to researchers and practitioners. In this context, practical contributions will first be explained in detail, and then theoretical contributions will be discussed.

5.1 Practical Contributions

The transition from a linear to a circular paradigm is complex for any administrator. Our findings offer significant insights and practical contributions for SME administrators by recommending a business model for transition to CE. Basic CEBMs were analysed using the spherical fuzzy TOPSIS method to produce this recommendation. While the differences between each form of business model are evident in principle, they might be less so in implementation. In some situations, companies adopt business model combinations rather than isolated models (OECD, 2019a, 2019b). Thompson et al. (2010) stated that the PSS and PLE models could complement one another. Our findings, however, form a basis for inspiring critical actions among SME administrators by addressing the difficulty in selecting CE business models using a systematic framework.

According to the findings, the optimum CE transition business model for developing economy SMEs is RR. This CEBM requires fewer resources and skills to implement than other business models, as it involves the production of secondary raw materials from waste streams (OECD, 2019a, 2019b). This model focuses on recycling and reusing waste to minimise material leaks and maximise economic value (Goyal et al., 2018). Cantú et al. (2021) found that SMEs generally lack capital (i.e. human, finance, time),

technology, or technical knowledge in the transition to CE in their case study on SMEs operating in Mexico. Similarly, our findings show that beginning CE practices with the RR business model are advantageous for SMEs in emerging economies due to a lack of capital. Hsu et al. (2019) found that 10 out of 22 SMEs implemented the RR business model in their research on the CEBMs of SMEs in Taiwan. When evaluated together with our findings, these results show that developing country SMEs have similar CEBM orientations in comparative contexts.

The RR business model prevents waste by reorganising existing businesses rather than making new investments and provides the mindset required to begin CE. As Richardson (2008) noted, this business model highlights the conceptual logic change needed to create economic value. For the mental transformation that this business model needs, administrators should examine the CE best practice examples in the ecosystem. They should then first engage with this model by undergoing training on this topic. In line with their leadership, they should be role models for employees in waste reduction and resource recovery activities. The employees should be trained in CE and the RR model, and skill development opportunities should be provided. In the implementation phase, administrators' active mentorship motivates employees and increases their participation in change. Similarly, Svensson and Funck (2019) found that managers should establish a strong CE culture to reflect a higher level of detail and a longer time horizon in the decision-making process. The RR business model is an ideal CE transition model for emerging economy SMEs, being relatively low in risk and requiring fewer resources.

Another managerial implication emerging from this study is that the second notable CEBM for SMEs is the CS business model. Development of CS chains requires an expansion of the business from a view of internal variables to suppliers. This business model cannot be implemented as quickly and effectively as the RR business model, as it requires close cooperation and common CE strategies with suppliers. Similar to our findings, Shpak et al. (2020) propose that for Ukraine to transition to CE, it must first increase waste and resource efficiency, reduce global pressure on resources and supply insecurity, and create a recycling society. Likewise, Scheel et al. (2020) emphasised the importance of business models evaluating waste and old products in Latin American countries' transition to the CE. Therefore, in this model, managing stakeholders proactively includes a long-term perspective and the need to close, decelerate, concentrate, narrow, and dematerialise resource cycles (Geissdoerfer et al., 2018). For this purpose, the entire supply chain must be configured end-to-end, based on CE principles, to use unwanted outputs as valuable inputs. According to Batista et al. (2018), such a circular flow of resources in the supply chain requires industrial connections. In particular, to establish recycling systems and ensure their sustainability throughout the supply chain, managers require integration and coordination skills. Therefore, this model's associated risks and responsibilities are relatively high. If SME administrators switch to the CS before completing the RR, they may struggle to develop these connections. Most CE implementation failures are due to the business' outward opening without having completed its internal CE processes. It is crucial to understand the relationships and sequences among CEBMs. Otherwise, SMEs' administrators are faced with processes that exceed their resources, capabilities, and capacities. In this context, Mishra et al. (2019) stated that a multi-stakeholder approach is required to ensure circularity in developing countries, as the participation of single SMEs will not be sufficient in their study in a North African country. In particular, government involvement and support are vital to building a broader stakeholder ecosystem in developing countries for implementing CE. Also, Hanuláková et al. (2021) stated that for companies considering the

circular economy in Slovakia, providing state support by applying different motivation and economic tools can help them reduce their cost concerns.

The third CEBM that SME administrators should consider is the PLE business model. PLE, which is said to benefit society by reducing the need for product disposal and producing new products to replace old products, covers many areas (Whalen & Whalen, 2020). In this model, it is necessary to redesign products within the framework of CE principles. According to Sevensson and Funck (2019), when CE is adopted and implemented, it is crucial to implement changes in product design, supply, and production stages. Long-lasting products inspire consumers' confidence and create economic value for the customer. Business models that slow down resource cycles maintain the highest product value for as long as possible (Lüdeke−Freund et al., 2019). According to Chen (2020), the renewal of waste and by-products and their transformation into new and practical products are also crucial. Comprehensive service offerings should also be developed to reduce consumerism, support recycling mechanisms, and extend product life. High-value products provide stability and increase business income. In this model, the customer and the business both win simultaneously. However, the investment and financial and human resources required by this model are greater owing to the different design principles for long-term use products, such as design for durability, repair, maintenance, connectivity, and trust. Products and services can also be designed for reuse after they have been deployed, manufactured, or renovated (Selvefors et al., 2019). Therefore, SMEs' transition to the PLE business model requires a developed organisational infrastructure, effective planning and strategy, an unbroken human resource structure, and financial potentialities. RR and CS business models create a fit infrastructure for this business model. After administrators create internal and external closed loops, the PLE business model allows these circles to be extended. CE success requires administrators to develop clear insights and understand these links among CEBMs, such that Oncioiu et al. (2018) found that carrying out CE activities such as innovative and environmentally friendly product design and energy labelling and establishing advanced production facilities achieve clean production in Romanian SMEs. This finding is an important finding supporting our results that developing countries that overcome their fundamental infrastructure problems implement more advanced CE business models.

Liu and Bai (2014) determined that contextual problems can facilitate or hinder developing a circular economy because they affect the values and priorities of the people in their research in China. A firm's environmental behaviour is influenced by the contextual environment, such as government regulations, markets, and community residents. Geissdoerfer et al. (2018) also stated that the success of CEBMs depends on changes in supplier and customer behaviour. Accordingly, the last CEBM that SMEs can use is the PSS business model. In this model, the customers and the business agree based on the related CE understanding and sensitivity. The product–service model provides leasing services whereby customers pay to use the product rather than purchasing the product outright (Chen, 2020). Therefore, customer support is essential to these models' success. In other words, the customer actively participates in an essential part of the business process. Suppose advanced maintenance or take-back agreements are signed with customers: in this case, administrators can also monitor other CE value factors through this type of CEBM (Bressanelli et al., 2018). Thus, it is risky to set to this model without applying other CE models, and it also seems unlikely. Besides, the customer's level of awareness and readiness to adapt to a CE determines the effectiveness of the model. At first, SME managers may be tempted to share some of the implementation burdens with the customer. However, the lack of state and community sensitivity to CE in developing countries is a significant barrier. Therefore, SMEs must first make their processes controlled within the organisation sensitive to CE

and then gradually get contracts with customers for PSS. Data from SME experts and CE researchers confirm this tactical suggestion.

Such models can be a long-term initiative as they involve changes in the CE supply chain, stakeholder networks, and product–service offerings. Improvement in CE business models based on systems thinking will guide policymakers to address their goals and tasks (Chen, 2020). Straightforward managerial tools are required for this guide. Indeed, out-of-context theoretical discussions are not meaningful or useful for practitioners, as CEBMs are complicated to be used together. Our findings emphasise that these business models should be implemented systematically and determine the guide for this application. Thus, we minimised the risks that administrators will be exposed to while choosing and applying CEBM and developed a result-oriented, realistic CEBM application system.

Within the scope of the data we have obtained, the most important evaluation criteria according to our model are products and packaging design, energy from renewable sources, and separated waste collection system, respectively. The most significant reason that the proposed method returns robust results is that SFS can qualify uncertain information sufficiently and more precisely and can explain the decision-makers' judgements and priorities are expressed clearly and in a more precise form (Sharaf & Khalil, 2021). In this context, sensitivity analysis was carried out to determine the results' behaviour against changes in the criterion weights.

5.2 Sensitivity analysis

A sensitivity analysis (SA) tests the reliability and applicability of the proposed methodology (Ayyildiz & Gumus, 2020). The present study's SA aims to assess the impact of the criteria weights on the evaluation of CE business models. For this purpose, eight scenarios in which different criteria weights are represented were created. The first scenario implied the reduction in the six most important criteria (C_5, C_1, C_4, C_{11}, C_9, C_{10}) by 10%. In the second scenario, while the importance weights of the weakest six criteria (C_{12}, C_6, C_3, C_2, C_7, C_8) in the original situation were increased by 10%, in the third scenario, the situations in the first two scenarios were applied simultaneously. The fourth, fifth, and sixth scenarios were constructed similarly to the first three scenarios, but the value used was changed to 20%. In the seventh scenario, decision-making was based only on the six strongest criteria

Table 12 Defuzzified criteria weights for different scenarios

Criteria	S0	S1	S2	S3	S4	S5	S6	S7	S8
C_1	0.38	0.34	0.38	0.34	0.30	0.38	0.30	0.38	–
C_2	0.17	0.17	0.19	0.19	0.17	0.20	0.20	–	0.17
C_3	0.19	0.19	0.21	0.21	0.19	0.23	0.23	–	0.19
C_4	0.36	0.32	0.36	0.32	0.29	0.36	0.29	0.36	–
C_5	0.55	0.49	0.55	0.49	0.44	0.55	0.44	0.55	–
C_6	0.23	0.23	0.25	0.25	0.23	0.28	0.28	–	0.23
C_7	0.06	0.06	0.07	0.07	0.06	0.07	0.07	–	0.06
C_8	0.06	0.06	0.07	0.07	0.06	0.07	0.07	–	0.06
C_9	0.33	0.30	0.33	0.30	0.26	0.33	0.26	0.33	–
C_{10}	0.29	0.26	0.29	0.26	0.23	0.29	0.23	0.29	–
C_{11}	0.34	0.31	0.34	0.31	0.27	0.34	0.27	0.34	–
C_{12}	0.26	0.26	0.29	0.29	0.26	0.31	0.31	–	0.26

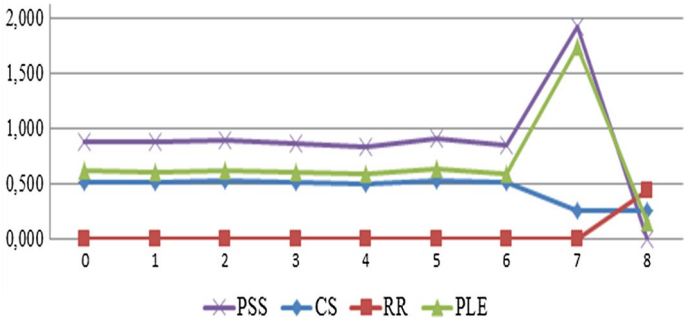


Fig. 3 Sensitivity analysis of CE business models through eight scenarios

in the original state; in the eighth scenario, it represented the elimination of the six least significant criteria. The original case is represented by "S0", and the criteria weights for the scenarios considered are given in Table 12.

The results of the SA are represented in Fig. 3. The revised closeness ratio values in Fig. 3 indicate that RR is the best CE business model for SMEs in seven out of eight different sets of weights, proving that the proposed methodology gives a robust result. As in the eighth scenario, if we do not take into account the criteria created based on the literature, which have the highest weight as a result of the analysis, the PSS business model comes first. The eighth scenario, which expresses a rather extreme situation, was added to see what might happen as a result of a lack of research, failure to reach enough criteria or failure to work with the right criteria. In other words, when we use the least important half of the criteria set, we may be unable to reach the option that actually offers the solution to our problem. This inference demonstrates that due to the possible changes in the weights of the criteria, our model is affected to a small degree and that working with the appropriate set of criteria will affect the results.

5.3 Comparison analysis

This section illustrates the comparative analysis performed to validate the suggested methodology. To assess the robustness of the SF-TOPSIS results, alternative strategies evaluated via different extensions of the TOPSIS method for the decision-making were applied in the fuzzy (Chu & Lin, 2003; Yıldızbaşı et al., 2021), type-2 fuzzy environments (Chen & Lee, 2010; Görener et al., 2017), and intuitionistic fuzzy (Boran et al., 2009; Rouyendegh et al., 2020). In addition, the classical TOPSIS method (Hwang & Yoon, 1981) applied under crisp conditions was also used for comparison.

Table 13 and Fig. 4 present the final results of CE business models with different approaches. Clearly, resource recovery is the most appropriate business model among all methods. This demonstrates that the approach presented in this study is effective. The results of the evaluation showed that the classically applied method of crisp has difficulty sorting some options. The closeness ratio values of the CS and PLE business models are very close to each other. In the Crisp TOPSIS method, it can be said that some alternatives are not completely differentiated from each other, although there is a small change in the ranking compared to fuzzy methods. Calculations may take less time in Crisp methods, but

Table 13 Comparison of the spherical fuzzy extension with other TOPSIS methods

CEModels	TOPSIS Methods									
	Crisp		Type 1-Fuzzy		Type 2-Fuzzy		Intuitionistic Fuzzy		Spherical Fuzzy	
	CR_i	Rank	CR_i	Rank	CR_i	Rank	CR_i	Rank	CR_i	Rank
CS	0.494	3	0.214	2	0.488	2	0.719	2	0.465	2
RR	0.597	1	0.285	1	0.601	1	0.759	1	0.592	1
PLE	0.501	2	0.195	3	0.451	3	0.682	3	0.444	3
PSS	0.385	4	0.184	4	0.364	4	0.593	4	0.381	4

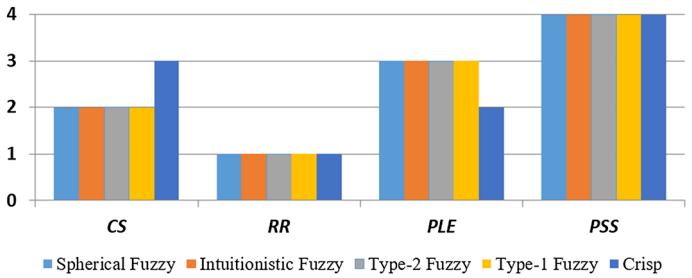


Fig. 4 CE business models' ranks of different methods

reliable rankings of the analysis result may not be reached, since precise numerical values cannot capture uncertainty (Mathew et al., 2020).

The ranking obtained by the IF-TOPSIS, type-2, and type-1 fuzzy TOPSIS is RR > CS > PLE > PSS the same as the SF-TOPSIS ranking. This indicates that the proposed SF-TOPSIS is reliable. We can observe that the best option in type-2 fuzzy TOPSIS and SF-TOPSIS methods is more clearly distinguished from the others. In terms of closeness ratio values, it is said that the first choice differs substantially from the second alternative. Within the scope of our research, this is very important for SMEs to identify the starting points for the transition to the circular economy. Another comparison method, the intuitionistic fuzzy TOPSIS, demonstrates that the problem of the inseparability of some choices, particularly in the Crisp environment, may be handled. As a consequence, the intuitionistic fuzzy TOPSIS can properly rank the possibilities, but that the discrimination power is not high, which is similar to other studies (Karasan et al., 2019). SF-TOPSIS seems to be sufficient for situations where action should be taken, especially by deciding on a specific option. SFSs include more information than standard fuzzy sets since they account for the hesitancy of experts throughout the computation process (Haktanir & Kahraman, 2020).

5.4 Theoretical contributions

CEBMs offer profitability and business growth by pursuing increased production efficiency, risk reduction, and new revenue opportunities (Whalen & Whalen, 2020). These business models promise cleaner production, eco-efficiency, and performance economy

and include various actors, including suppliers, manufacturers, customers, and even the government (Chen, 2020). Theoretical discussions on the CE continue among governments and businesses as well as in the academy. While developed countries determine some policy, strategy, and regulation outputs from these discussions, such mechanisms aimed at encouraging businesses in developing countries to transition to a CE approach remain inadequate (Diaz, 2017; Kumar et al., 2019). This gap shows that cultural and contextual factors can effectively cause businesses to transition to a CE approach (Ünal et al., 2019). Moreover, SMEs form the basis of developing economies. Hence, SMEs in the context of developing countries were examined in this research. This paper also aimed to determine when SMEs should use CEBMs in the transition to CE.

It is crucial to provide CEBMs in developing countries' SMEs. CEBMs can help break the vicious circle that causes poverty to prioritise people's urgent needs over long-term considerations. It can cause environmental degradation, leading to reduced income opportunities, increased poverty, and vulnerability among local populations (Lüdeke - Freund et al., 2019). By transitioning to CE, SMEs can reduce waste generation, use fewer natural resources, and contribute to the country's welfare by re-evaluating these products (Wu et al., 2021). However, although these SMEs are required in transitioning to CE, they are insufficient in terms of the transition process they should design. Even if SMEs wish to take advantage of CEBMs in an efficient transition to CE, no consensus yet exists regarding which CEBM should be used in what context. Since the redundancy and diversity in CE criteria and CEBM make it difficult for administrators to plot effective CE roadmaps, four main CE criteria and twelve sub-criteria were determined using the expert group insights in this study. We then determined which of these criteria met the four CEBMs set by the United Nations (2020) via the master researchers group.

Our findings demonstrated that SME managers seeking to understand and apply CE results could comfortably succeed using appropriate business models. A crucial methodological implication is recognising that to present a rigorous analysis of CEBMs, an approach that simultaneously addresses the details of business model activities, organisational characteristics, and their interaction is required (Levänen et al., 2018). In this direction, in the analysis using spherical fuzzy TOPSIS, the most appropriate CEBM ranking was made for the specific conditions of SMEs. It was found that the scope of business models has expanded from inside to outside. This striking result emphasises that managers should focus on and develop internal processes during the transition to CE. The findings also ranked the business models from least to most risky. The ability to control intra-organisational cycle processes increases managers' success in implementing the RR model. As the PSS business model, which ranks fourth, is shaped under the influence of consumer attitudes and behaviours, the enterprise's control power over this model is weak, and accordingly, the risk is high. Simultaneously, the results ranked the business models from that which required the most minor financial and human investment to the most required model. It is crucial that SMEs in developing countries with limited resources and financing opportunities do not waste their resources in transitioning to CE. The systematic approach suggested by our findings has theoretical and practical implications that prevent the waste of these resources.

Technical differences between the early and later stages of the transition to CE require different business models. The findings reveal how the CEBM is transformed into concrete action plans to achieve CE objectives. Misunderstanding and implementing CEBM alternatives can have dramatic consequences for SMEs. However, this research eliminated the overlapping features of different CEBMs as much as possible and clarified the distinctions among models. SMEs require resource efficiency above all else. Many SMEs see it as a

bridge to achieve resource efficiency with the transition to CE. Therefore, beginning with the RR business model will be motivating for managers. Seeing the contribution of waste prevention to the business's financial condition and operational outcomes will encourage managers to progress to the following business models. This topic has been narrowly explored in previous studies or discussed only on a conceptual level (Pieroni et al., 2021). Examination of this issue from an application perspective provides administrators with useful managerial tools.

CS business models are the first step in which the closed loop expands from inside the business to the outside. In such models, the company influences the actors in the supply chain of which it is a part to apply CE principles. This process requires more industrial collaboration. Resource waste is eliminated from one end of the chain to the other, and recycling practices are adopted simultaneously. The challenge of implementing CEBMs starts here. Businesses that do not implement the RR model in the supply chain will fail to switch to the CS business model, and the stakeholders in the chain will negatively affect the CE performance. This situation highlights the difficulty in independently evaluating the issue of macro effects. SME managers often overlook this holistic perspective.

We argue that a more rational CE managerial policy would be to switch businesses that succeed in the SC business model to the PLE business model. In the latter, while product ownership is transferred to the customer, the company can sell a combination of single standard products and industrial services, such as maintenance and repair (Bressanelli et al., 2018). Thus, while the customer uses the product for a longer period, the company prevents a decrease in maintenance and repair activities and income flow. Then, to transform the PLE business model into a stable CE application tool, economic and environmental value creation methods are sought in the design and production of the product. Similarly, Whalen and Whalen (2020) proposed an approach that reduces the material requirements of production, produces less harmful effects, and improves quality. Additionally, incorporating artistic thinking into the company culture can promote behavioural change and environmental and social awareness at the management level and even extend the product life cycle (Chen, 2020). The PLE business model requires advanced insights to achieve CE and more tangible and intangible resources and capabilities.

Finally, the business model that SME managers should target is PSS. The main challenge associated with this business model is that it is difficult to achieve by simply improving the CE capabilities and skills of the business. PSS also expects consumers to match the CE insight and engagement that they expect from employees. Clearly, the understanding of CE begins with the manager and subsequently extends to the suppliers. The product is redesigned according to this understanding, and finally, the customer is included in this common understanding. Unable to comprehend this CEBM pattern, the SME manager gets lost in the jungle of CE criteria, model, and theory. The company alone cannot change the customer's consumption habits and sensitivities. To achieve this change in the client, all stakeholders, particularly the public and NGOs, are needed. Therefore, the PSS needs the broadest public consensus. In this model, the customer gives up ownership of the product, and the same product is used by many customers. Therefore, a radical transformation in conventional consumption habits is required to successfully implement this model. Since the expert group worked in this field, they witnessed this challenge; it was determined that starting CE from this model would not be practical. This implication is one of the remarkable results of this research that seeks to attract the attention of administrators.

Trigkas et al. (2020) stated that while business managers and leaders seem to appreciate the importance of CE in Greece, there is still significant confusion about the exact meaning of CE, value cycles, and the strategic application of CE principles to value chain

management. Our results opened up a space for discussion and for new thoughts that could improve the scope of the CEBM model theory. First, we concluded that transition to CE using all CEBMs simultaneously would not be successful for SMEs. Then, the order in which the CEBMs should be applied in the transition to CE was determined. Their scope, risks, and the resources that they need were associated with these data results from the field. This practical application guide, which we propose based on theoretical foundations, is open to the development and contribution of managers and future researchers.

Since CE theory has been constantly developing and intensifying, no optimal business model can be said to exist for all world economies. For this reason, we recommend that the research design be repeated in different developing and developed countries. Models that address where the boundary of each business model begins and ends are not yet explicit. For this reason, studies that include the parameters that determine the capability of the chosen business model and the transition time to the next business model will contribute to the clarification of the road map that we recommend here. Finally, a criticism of the transition from business-based CE business models to supply chain-scale and cluster-scale CE business models will facilitate discussion of the issue from a macro perspective.

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