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Analyzing the business models for circular economy implementation: A fuzzy TOPSIS approach

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Analyzing the business models for circular economy implementation: A fuzzy TOPSIS approach

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Abstract

The concept of the circular economy has acquired importance in the academic world. The corporate firms and governments believe that the pressure on the environment can be reduced by implementing the circular economic system. The switching of a linear economy to a circular economy requires to build new business models that overcome the limitations of the linear model of the economy.

This paper aims to rank the business models for the successful adoption of the circular economy through the criteria by employing an appropriate multi-criteria decision making (MCDM) method. Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (Fuzzy TOPSIS) has been used in this study. Eleven Business Models have been identified through literature review and analyzed based on nine criteria for the business model to be successful. The ranking of results indicates that the product and process design is the most important business models for the implementation of the circular economy. The findings of this research enhance the understanding about the relative importance of the several business models based on which the management can formulate an effective strategy to systematically adopt an appropriate business model for successful implementation of an economic system.

Keywords: Circular Economy; Business Models; Fuzzy TOPSIS; Supply Chain Management

1. Introduction.

A circular economy as described by Kirchherr *et al.* (2017) is “an economic system that is based on business models which replace the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level(eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations”. The concept of circular economy has acquired importance in the academic world, companies and government. It is believed that adopting circular economy the pressure on the environment can be minimized (Bakker et al., 2014; Webster, 2015) vis-à-vis the linear economy by reusing the materials in the novel products (Singh, and Ordoñez, 2016). The concerns related to poverty, gender equality, education, environmental sustainability, and related issues are included in the sustainable development goals to be acquired by 2030, proposed by the United Nations (Lowe-Martin, 2015). The circular economy has gained momentum and is vehemently seen as the solution to these problems (Geissdoerfer et al., 2016).

The adoption of the circular economy is not easy at a practical level, as the policies, arrangements, working methods, setups, and supply chains of most of the companies rely on the linear approach to growth. The switching of a linear economy to a circular economy is an extremely challenging task; therefore, organizations require to build up new business models that surmount the limitations of the linear model of the economy (Lieder et al., 2017).

The circular business models have been defined as "a business model in which the conceptual logic for value creation is based on utilizing the economic value retained in products after use in the production of new offerings” (Linder & Williander, 2015). The Circular Business Models (the business models based on the circular economy) will help the organizations in increasing differentiation, decreasing cost to serve and own, generating new revenues, reducing risks and reducing their impact on the rules of resource supply and demand. Therefore, the identification and evaluation of the business models become necessary for the adoption of the circular economy.

In this study, the Business Models have been identified through a literature review which are then analyzed on the basis of some criteria for the business model to be successful. For analyzing the Business Models, an appropriate Multi-criteria decision-making method can be applied to get the relative importance or priority of the business models towards the implementation of the circular economy. For this purpose, 'Technique for Order of Preference by Similarity to Ideal Solution' (TOPSIS) has been used in combination with the Fuzzy set theory (Zadeh, 1965), collectively known as Fuzzy TOPSIS (Chen, 2000; Junior et al., 2014). The details of the subsequent sections of this paper are as follows: Section 2 presents a literature review on the various business models. Section 3 presents the identified business models. Section 4 presents the criteria for business models to be successful. Section 5 describes the research methodology adopted to conduct the present study. Section 6 presents the results, and Section 7 presents discussion, implications, and directions for future research.

2. Literature Review

This section is based on two important concepts which are explained in this study, circular economy and business models of a circular economy.

2.1 Circular Economy

In contrast to the linear economy, China first adopted the circular economy (Geng, Y., & Doberstein, 2008). The circular economy aims at maximizing the utility and value of the materials and products by maintaining, repairing, reusing, remanufacturing, and recycling processes and decreasing waste (Webster, 2015; Merli et al., 2018; Huysveld et al., 2019). A circular economy can be taken “as a regenerative system that minimizes input waste, emission and energy use by closed loops of material and energy” (Geissdoerfer et al., 2017). The benefits of the circular economy can be further enhanced by the application of open-loop recycling of mixed and contaminated waste (Huysveld et al., 2019). The first review on the circular economy and the comparing of the practices adopted by China with Europe, Japan, and the world were conducted by Ghisellini et al. (2016). Govindan and Hasanagic (2018) conducted a review of the drivers, barriers, and practices that influence the adoption of the circular economy through the supply chain perspective. Nasir et al. (2017) presented a study from the construction industry to compare the linear supply chain and circular supply chains. Steinmann et al. (2019) argue the bases of defining the quality of materials in a circular economy manufacturing and service organizations. The impact on financial resources of adoption of circular economy systems in manufacturing organizations and their long term benefits are analyzed by Aranda-Usón et al. (2019). Niero and Kalbar (2019) present the coupling of material circularity indicators and life cycle based indicators to conclude that the circular economy approach enhances life cycle based indicators at the product level. The study presented by Sposato et al. (2017) concludes circular economy and sharing economy boost collaborative consumption innovation. Making a case for resource recovery Velenturf & Jopson (2019) suggest that action is urgently required to resource economy within planet earth’s boundaries to safeguard the human well-being by realizing an increasingly closed-loop system that maintains values of material and products within a sustainable circular economy. Tunn et al., (2019) concludes that a diverse range of business model based on the circular economy can potentially enable different consumer segments to consume sustainably. Lopez et al. (2019) analyze 143 business models on the implementation of various interlined and integrative resource efficiency measures and report inconclusive results on business model changes due to behavioral and market barriers.

The concern for ‘closed-loop” supply chains has been addressed by Kalverkamp & Young (2019) and has outlined the benefits of the ‘open-loop’ supply chain in remanufacturing of automotive components. Ünal, & Shao (2019) present a road map for managers to reach a higher degree of circularity and suggest that a maturity degree of competitive capability may determine the implementation strategy of a business model.

2.1.1 CE and Product Design:

Papanek and Lazarus (2005) argued that the products and service designers must be philosophically educated and skilled in learning new processes. Product and service designers should also be concerned about satisfying all the stakeholders with a basic aim to practice circular economy through ecological design. The authors concluded that industrial design must be socially and ecologically responsible and revolutionary and radical in approach.

Avital et al., (2014) suggest that the economy of "sharing" creates into market efficiencies that opens up new horizons for redesigning of established services that have positive ecological impact and may give substantial financial benefits. The authors have explored the monetary, social, and technical ramifications of the community-oriented economy, how computerized innovations empower it, and how the huge socio-technical frameworks exemplified in these new peer platforms.

Bocken et al., (2016) have tried to address the product design and the business model plans for the implementation in the circular economy. Their study proposes a framework for product design strategies and business model innovations for the transformation of linear to a circular economy and opens up the door for future research in the area of the circular economy.

Moreno et al. (2016) focuses on the product design aspect of the CE and suggest that the products should be designed for the closed loops for the successful implementation of the circular economy. They propose a conceptual framework of business strategies and provided recommendations for the designers for designs within the circular economy.

2.1.2 CE and Supply Chain:

Zhu et al. (2010) argued that the quickly developing industrial exercises in fast-growing economies have been causing asset consumption and contamination issues. The idea of the circular economy fills the need for a coordinated way to deal with the challenge of industrial advancement and ecological security. The authors have investigated the existence of diverse kinds of manufacturing endeavors on environmental-oriented supply chain cooperation (ESCC). The authors have identified four different kinds of Chinese producers differing in environmental-oriented supply chain cooperation (ESCC), featuring the significance to step up the collaboration with upstream and downstream supply chain partners to succeed in a CE environment.

Zhu et al. (2011) examined the role of Environmental Supply Chain Cooperation (ESCC) practices in the implementation of CE practices by analyzing the data collected from Chinese manufactures and concluded that ESCC practices are useful for the implementation of CE in China and but outlined need for improved coordination in supply chain operations.

Jain et al., (2018) identified the problems related to sustainability, which produced the challenges for environmentalists, ecologists, and governments. In that study, they used the grounded theory approach in order to build up the strategic framework for the circular supply chain management. Further, this research presents an integrative framework for studying, designing, and evaluating a circular supply chain management performance matrix.

Brown and Bajada (2018) argue that the present strategies for representing material streams at the firm, system, and economy levels are inadequate for the development of enlightening indicators of Circular Supply Network (CSN) productivity and performance. The authors have developed a model to clarify economic material stream in supply systems and features the significance of circular streams of reused material in terms of cycle velocity and terms of virgin material equality.

Mangla et al. (2018) identified that the developing nations lack the facilities enabling the adoption Circular supply chain, which includes regulatory policies, technological know-how, and modern infrastructure. In this study, they identified sixteen barriers for the implementation of the circular supply chain in India using a literature survey and feedback from experts. These barriers are examined using the combination of ISM and MICMAC approach to develop a contextual relationship.

Batista et al., (2018) claim that the expanded multifaceted nature and extended extent of circular supply chain (CSC) activities and their role empowering influences of business responses to sustainability, which demands more comprehension and discussion. Further, they concluded that there should be research on the resource scarceness through the circular supply chain and environmental policies which affect the adoption of circular economy.

2.1.3 CE and Life Cycle:

Niero and Kalbar (2019) observed that most fit measurements for the circular economy (CE) are open, no consensus has been developed on what CE indicators at the product level and have proposed quantification, which could help make an objective methodological system for surveying CE methodologies. The authors have examined the likelihood of coupling distinctive kinds of indicators tending to CE methodologies at the product level using the Multi-Criteria Decision Analysis (MCDA) method.

Niero and Olsen (2016) investigated the effects of including the actual alloy composition (Mn, Fe, Si, Cu) in the life cycle assessment of aluminum can (used for packaging) production and recycling using the Mass balance. According to the authors, Mn is the limiting alloying element for closed-loop products. Further, they suggest that closed product loop recycling has the lowest impact on the environment.

Niero et al. (2016) conducted scenario analysis based on a Life Cycle Assessment of the possible Cradle to Cradle certification combinations of material re-utilization and renewable energy for a '33cl aluminum can'. The authors have concluded that firstly, increasing recycled content provides more improvements to environmental impacts than increasing Renewable Energy usage. Secondly, receiving a gold certification is not necessarily preferable looking from an environmental angle than bronze or silver, since higher certification level does not necessarily mean reduction in environmental burden while assessing the product life cycle.

Bakker, (2014) specified that the product life expectancies of electrical and electronic products are decreasing, with harmful environmental consequences. The authors examined the natural effects of fridges and PCs against their expanding vitality proficiency after some time and found that product life extension is one of the favored procedures.

2.1.4 CE and Sharing Platforms:

Advancing the standards of circular economy and the new business models pushed by the circular economy can be an alternative to an increasingly prosperous society with less dependence on energy resources and having cleaner and pleasant climate. (Barbu, C. M et al. 2018). The investigation utilizes information gathered through a questionnaire, applied to a sample of 320 clients of Uber. The finding of this study demonstrates that transforming into an access-based consumption model can give us better results.

Wen et al. (2018) reviewed the Iindustrial park recycling transformation (IPRT) content, policies, and practices in Chain, and provide and suggestions for further development. This study provides two suggestions. First, investment should be diverted from traditional industries to new industries, and the second government-led model should be transformed into a government and market co-led model.

Sposato et al. (2017) presented an overview of the sharing economy, including drivers and boundaries, which can influence its effective development. Based on the literature review, the authors investigated the circularity approach and recognizes the job of sharing economy in products and services from a life cycle thinking (LCT) approach explicitly. This study considered the two aspects a) the length of the product's use phase (lifetime) and b) the intensity of use.

2.1.5 Product as a Service:

Asif et al., (2018) argued that manufacturing industries had become the key stakeholders for exploring the challenges in the adoption of circular economy and the transition from a Linear Business Model (Sales Model) to a Circular Business Model (Product as a service) is an important step. Further, it is illustrated that the Information and Communication Technologies

(ICT) framework enables information management and sharing and provided much needed real-time communication between relevant stakeholders.

2.1.6 CE and Recovery and Recycling:

Stewart and Niero (2018) present a systematic review of 46 commercial sustainability reports in the "Fast- Moving Consumer Goods sector" to conclude that the integration of Circular Economy into the Sustainability agenda of companies has started making an impact on recovery and recycling strategies of business firms.

The authors suggest expanding life expectancy of steel products presents a significant opportunity to reduce global demand for steel and thus helps decrease the CO_2 emissions from steel production. Another study based on literature review by Cooper et al. (2014) states that the design of components for long effective life is focused on methods to repair and upgrade using three related strategies: standardization, modularity and functional segregation.

Grosso et al. (2017) suggested that Material Recycling should be encouraged to achieve the targets set by European circular economy package for the implementation of circular economy. Further, they conclude that aluminum (except for its use in explosive applications), steel in all different uses, glass (for bottles), copper and manganese are in full compliance with the Concept of Permanent Materials (CPeM). The same does not apply to paper and plastics since they fail to comply with the definition mainly because of the technical limitations of their recycling, affecting the actual possibility of repeated recycling.

2.1.7 CE and Incentivized Return and Reuse:

Cong et al., (2019) address issue of low economic return of end-of-use (EOU) value recovery and proposed a design method to facilitate EOU product value recovery. The authors used the EOU scenario, Analytic Hierarchy Process (AHP), Pareto Analysis in the case study of hard disk drives to present the drawbacks, developmental opportunities and design proposals, and measures the recyclability of the modules and evaluate design suggestions for material selection.

2.1.8 CE and Asset Management:

Ali (2014) raises the issues concerning restoration and reuse of the polluted sites in Rear Earth (RE) mineral processing and the perception of social sustainability and need for technical ability to rehabilitate contaminated sites to tackle the issue related to health risks. Further, they discovered that the Social view of risk at the site level requires to be balanced with the national trajectory in deciding the social sustainability of the RE division. This study concluded that recycling and service sector opportunities for this sector have much potential for the development of technologies to improve the micro-retrieval of the metals. The author concludes that reducing social backlash as a circular economy for RE is offering better results than green economic endeavors.

Wen et al. (2018) state that the industrial parks recycling transformation (IPRT) approaches and policies have geared up the rapid economic development in China, its linear industrial growth model is characterized by high resource consumption and heavy pollution, which had made the further development unsustainable. This study reviewed China's IPRT policies, and suggestions were put forward to further develop IPRT practices in the future. Further, they concluded that the investments should be in emerging industries rather than in traditional companies and the government should establish more effective incentives and restraint mechanisms to attract participation from enterprises and social capital.

2.1.9 CE and Dematerialized Services:

Durable policy implementation is an essential dynamic effective governmental facilitation of Sustainable Industrial Parks (SIPs). For an understanding of such dynamics, Jiao et al. (2018) have concentrated on the co-evolution of the Chinese incitement approaches of Eco-Industrial Parks (EIPs) and Circular Economy Industrial Parks (CEIPs) and focused on how they have strengthened the sturdy advancement of one another, and how that shared impact has influenced the general dispersion of SIPs. This study utilized the methodologies of Event Sequence Analysis and the Social Network Analysis of strategy collections, featuring the way that the individual arrangement forms are portions of a more extensive "web" of procedures. Finally, this study concluded that the intercession in the Circular Economy approach brought the two strategies into a co-transformative connection of beneficial interaction which appeared to have turned out to be less concentrated after some time.

Fonseca et al. (2018) present quantitative research based on an online survey among 99 Portuguese organizations, comprising of various sectors and sizes. The authors concluded that

CE is regarded as a strategic and relevant issue for profitability and value creation, and the successful implementation of the Circular Economy, new business models, should be adopted in addition to the classical "reduce, reuse and recycle" approach.

2.1.10 CE and Hire & Leasing:

van Loon et al., (2018) compared and evaluated the company's expected profit and the consumer's total cost of ownership (TCO) in Linear and circular supply chains by enlisting the cost components of renting the same product multiple times. The authors acquired the methodology of literature review and found that it is challenging for the original equipment manufacturer (OEM) to compete with an already established efficient second-hand market. This second-hand market allows consumers to resell their products after use, reducing their TCO in the sales system. This study showed that the circular economy is attractive from a macroeconomic perspective; on the individual firm level, there are serious barriers to overcome, making the transition to the circular economy far from obvious.

2.1.11 CE and Collaborative Consumption:

Sposato, et al. (2017) considered that sharing economy business encounters are quickly rising worldwide and profoundly changing structures and models of clients purchasing attitudes and needs and necessities. Goods and service access encouraged by sharing plans of action are rising in the spot of a more established model dependent on private appropriateness and a consumerist perspective on society. This research presented an overview of the sharing economy, including drivers and boundaries, which can influence its effective development. Based on the literature review the authors investigated the circularity approach and recognizes explicitly the job of sharing economy in products and services from a life cycle thinking (LCT) approach considering the two aspects a) the length of the product's use phase (lifetime) and b) the intensity of use.

2.1.12 Growing attention to the CE concepts

A great deal of research that has resulted in academic studies has been accompanied by increases in practice of circular economy concepts. For increasing the maturity of CE concepts and applications, a number of challenges have been recently formulated that require responses and development work. Morsietto (2020) points out the dearth of rigorous work on developing and applying systematic and rigorous CE performance targets. As such targets are a key part of management, Morsietto calls for and proposes a comprehensive set of such targets, yet has not defined adequately the ‘unit of analysis’ of such targets, which could be for a whole or part economy, or a single supply network that is partially or substantially circular. Referring to our eleven-fold set of CE business models in this study, their implementation would necessarily involve the development and application of measurable targets.

Shortfalls in policy development required to encourage and incentivize business organisations and supply chain managers to move further into circular concepts and business models have been recognised as an ongoing challenge by Hartley et al (2020). The different business models identified and evaluated in this study can contribute to such policy considerations, since policy formation should consider relevant domains and their outcomes being governed. At the micro level, innovative new measures of performance are needed for CE as distinguished from linear supply chain performance parameters, as for example developed by Kristensen and Mosgaard (2020), but as yet to be tested and validated. In terms of policy, measures and business models that might be adopted, we cannot assume that the forces acting to create CE operations and supply networks will be the same in developed and developing economies, as Patwa (2021) showed in their 2021 study of emerging economies, in which they showed how in such circumstances, a variety of influences impact on CE adoption.

With the new digitalisation technologies coming to the fore, it is reasonable to consider that forward thinking companies who wish to explore and engage in CE applications will also be considering such Industry 4.0 capabilities such as Blockchain (Kouhizadeh et al, 2020), that have potential to improve CE outcomes.

At the macro level, meaning country and global level, CE has the potential to deliver many benefits, as modeled by Aguilar-Hernandez et al (2021), in their 30 year forward scenario meta-analysis, considering a triple bottom line (economic, environmental and societal) of outcomes, finding variously their scenarios that incremental or larger amounts of simultaneous progress are in prospect.

Scholars have pointed out the organisational levels of the challenges of transitioning to CE business models, such as the requirement for significant innovation capabilities (Pieroni et al, 2021), culture (Gue, 2020) and particularly the learning culture and its requisite knowledge management (Atiku, 2020). The benefits side of what CE delivers is broadly conceived in practice and in this study, being beyond those traditional benefits to the businesses financial bottom line, but to social responsibility metrics also (Parast, 2021) and ‘green’ environmental outcomes (Huo et al, 2021).

These recent studies aggregate to the picture that CE is currently in an immature state in practice as an organisational form and set of arrangements, however in practice it is clearly ‘in play’ where economic forces incentivize it, and where environmental benefits can arise. Many studies have noted the different and specific conditions related to CE potentials in different industries and indeed across industries. There is no single ‘silver bullet’ of organisational form or business model that is or will become a dominant model of CE deployment. However, practitioners will benefit from guiding frameworks that set out the relationships between generic business model types and beneficial outcome parameters, which is the primary aim of this study.

2.2 Business Models Based on Circular Economy

The idea of the business models of the circular economy is to merge the commercial value created with the implementation of circular policies that help extend the product life (Pieroni et al., 2019).

Business Models can be described by the system that illustrates how the parts of the business fit together. A Business model in the circular economy is characterized by the three main elements: value proposition, value creation/ delivery, and value capture (Ranta et al., 2017; Bocken, 2016).

Value proposition deals with products and services to create economic returns in a circular business (Baldassarre et al., 2019). Lieder et al., (2018) suggest the focus has shifted from selling a product to providing access to functionality through business innovation and thereby offering value propositions. Manninen et al., (2018) examine the environmental value propositions offered by circular economy throughout the value chain.

Value creation captures values by taking hold of new business opportunities, new marketplaces, and new revenue flows and simultaneously using reduce, reuse, and recycle principles (Ratna et al., 2017). Jensen et al. (2019) present three industry-based cases to demonstrate that if remanufacturing is to occupy a central role in circular economy based businesses, then to create value sustainably, one needs to consider and remodel complementary and synchronous business activities. Nußholz (2019) presents a visualization tool to map circular business and its performance in value creation.

Value capture deals with the ways of generating revenues from the products and services (Cong et al., 2019). The circular business models aim to help companies in the adoption of circular practices (Bakker et al., 2014; Bocken et al., 2016). Roos (2014) has identified key questions that can help figure out the value captured from circular economy business models.

To the best of our information and knowledge, no one has reported a study outlining the methodology for ranking of circular economy based business models using fuzzy TOPSIS. This article is aiming to close this gap in the literature.

3. Major Business Models for successful adoption of the circular economy

A business model depicts how a company does business, survives, and grows (Osterwalder et al.,2005). The business models are the possible enabling measures for the adoption of the circular economy. Table 1 depicts models identified for the successful adoption of the circular economy with their brief description and references.

Table 1: Business Models for the successful adoption of the circular economy.

Business model	Description	Literature sources
B1. Product and Process Design	These models provide planning and design for elements, systems, products to enhance service life. It provides solutions for improvement, how a product should be designed, manufactured, maintained, repaired, remanufactured, and refurbished.	Lieder *et al.*, (2017); Bocken et al., (2016); EMF (2016); Accenture (2014); Moreno et al., (2016); Papanek and Lazarus (2005)
B2. Circular Supplies	Circular supplies focus on the improvement of new materials to increase renewable energy, bio-based, less resource-intensive, or fully recyclable materials. This model suits those companies that deal with scarce commodities.	Brown and Bajeda (2018); Mangla et al., (2018); De Angelis et al, (2018); Batista et al., (2018);

		Jain et al., (2018); Van Renswoude et al., (2015); Zhu et al., (2011); Zhu et al., (2010).
B3. Product Life Extension	This model aims at increasing the life of product elements and systems through engineering processes, which include ease in easy disassembling and reassembling, repairing, maintaining, and upgrading.	Steinmann et al., (2019); WRAP, 2018; Ali (2014); Bakker et al, (2014); Cooper et al., (2014); Niero et al.,(2016); Niero and Olsen(2016); Niero and Kalbar (2019); Stewart and Niero (2018).
B4. Sharing Platforms	In this business model, a platform is provided for the shared use of products to enhance the utility of products or systems. Simultaneously it increases off-site design and the use of shared production services.	Accenture (2014); Wen et al., (2014); Sposato et al., (2017); Sarti et al., (2017); Barbu et al., (2018).
B5. Product as a Service	In this model, performance is delivered without delivering the product, and the ownership of the product is kept by the service provider. The primary revenue flow comes from payment for performance delivered. This model is generally fitted manufacturing plant, lighting, and filled-out, but it possesses the potential to be applied to whole building and infrastructure.	WRAP (2012); Accenture (2014);Gnoni et al., (2017); Asif et al., (2018).
B6. Recovery and Recycling	In this business model, a system of production and consumption is created in which the material considered to be waste is used and rejuvenated. The end of life concept is replaced here.	Damen (2012); Lacy *et al.* (2013); Planing (2015); Niero and Kalbar (2019); Grosso et al., (2017).

B7. Incentivised return and reuse	In this business model, the used products are returned by customers at a decided value. These collected products are maintained or refurbished and sold again for reuse.	Mentink (2007); Damen (2012); WRAP (2012); Lacy et al. (2013); Huysveld et al (2019).
B8. Asset Management	This model takes a sustainable approach to the management of assets. it ensures the gainful internal collection, reuse of the products, refurbishment and reselling of materials	Damen (2012); Bakker *et al.* (2014); Planing (2015); Korse et al., (2016)
B9. Dematerialized Services	In this model, the physical product may not exist at all. It provides services containing product benefits. This model seems to change the consumption pattern to have possible material saving by not manufacturing products.	WRAP (2012)
B10. Hire and Leasing	This model encourages the long-term hiring and leasing of the products approaching towards increased product durability and extended life.	WRAP (2012); Van Loop et al., (2018).
B11. Collaborative Consumption	This model encourages the rental of products between the familiar people or people in the business. It includes the generation of money for owners and ease of access to the user.	Lacy et al. (2013), Sposato et al, (2017); Avital et al., (2014)

4. Criteria for Business Models to be successful

The criteria for the success of business models have been identified through literature review and are given in Table 2. From these criteria, eleven business models evaluated and ranked. The linking of business model types with their multidimensional aspects of success criteria will have both theoretical contributions and practical (decision guiding) benefits. The choices facing professionals who make business model choices or are indeed considering whether to invest in CE practices at all will be enhanced with this guidance. By connecting the business models to the benefit criteria, choices can be better informed.

Table 2: Significant criteria for Business Models to be successful

Criteria	Description	Reference

C1. Partnership	For the business model to be successful, there must be a collaborative partnership between the government and the various stakeholders. The Government, through its agencies, is the most vital player exclusively responsible for the formation of policies. (Horvath et al., 2018). The goal of these policies should be to encourage employment and investment.	Linder, & Cantrell, (2000). Weill and Vitale (2001) Stähler (2002). Afuah and Tucci 2003 Osterwalder et al., 2005 Lewandowski, M. (2016). Horvath *et al.*, 2018
C2. Activities	It includes activities like Reuse, Recycle, Remanufacturing, etc. which must be fulfilled for the success of the business model. There should be the use of proper technology to mechanize the processes. (Horvath et al., 2018).	Linder, & Cantrell, (2000). Stähler (2002). Afuah and Tucci, 2003 Osterwalder et al. 2005 Lewandowski, M. (2016). Horvath et al., 2018
C3. Resources	Emphasis should be laid on the production of long-lasting and recycled products for the minimum use of energy and material utilization. (Horvath et al., 2018)	Weill and Vitale,2001 Afuah and Tucci, 2003 Osterwalder et al. 2005 Lewandowski, M. (2016). Horvath et al., 2018
C4. Value Proposition	With the use of recycled products, there is a reduction in the reliance on virgin materials. The benefit of this is the minimization of the outpouring of financial resources and a clean environment. (Horvath et al., 2018)	Weill and Vitale,2001 Stähler (2002). Afuah, and Tucci, 2003 Osterwalder et al. 2005 Lewandowski, M. (2016). Horvath et al., 2018
C5.Customer Relationships	The productive relationship among the various players like Government, institutions, manufacturers, and customers should be sustained for the accomplishment of the business model. (Horvath et al., 2018)	Linder & Cantrell, (2000). Osterwalder et al. 2005

	Proper awareness camps should be organized among the consumers, as the model can be successful only if the public is well educated and are willing in the participation of the process	Lewandowski (2016). Horvath et al., 2018
C6. Distribution Channels	Distribution channels act as a medium for the manufactures' product distribution to the consumers. Current distribution channels include the supplier's relationship with the wholesale and retail outlets that push their products to consumers. Sharing platforms are a new and cheaper channel where goods and services are shared among consumers. (Horvath et al., 2018)	Linder, J., & Cantrell, S.(2000). Weill and Vitale(2001) Osterwalder *et al.*, 2005 Lewandowski (2016). Horvath *et al.*, 2018
C7. Client Segments	It includes the pricing at which the consumers get the products, health concerns, quality and safety issues	Weill and Vitale,2001 Afuah and Tucci, 2003 Osterwalder et al. 2005 Lewandowski, M. (2016). Horvath et al., 2018
C8. Cost Structure	Some of the business models need high initial capital investment, and costs include (Research and Development, technological selection, human resources, channel costs, etc. The government should take a positive role by giving incentives, technical support, favorable legislation, etc.	Afuah, and Tucci, 2003 Osterwalder et al. 2005 Lewandowski, M. (2016). Horvath et al., 2018
C9. Revenue Flows	Revenue Flows act as cost-saving measures for the industries which heavily rely on the import of virgin materials. with the utilization of recycled products and government support, there will be a reduction in costs related to the shipment, insurance, delivery delays, negotiation fees, and taxes	Linder & Cantrell (2000). Weill andVitale,2001 Stähler (2002). Afuah, and Tucci, (2003) Osterwalder et al. 2005 Van Ostaeyen et al., 2013 Lewandowski, M. (2016). Horvath et al., 2018

5. Research methodology

The objective of this paper is to Rank the Business Models for the successful adoption of the circular economy through the criteria shown in Table 2 by employing an appropriate multi-criteria decision making (MCDM) method. In order to determine the relative importance or priority of these business models various MCDM methods are available in the literature, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) has been extensively used for prioritizing the decision criteria involved in a particular system (Kirubakaran, and Ilangkumaran 2015; İç, and Yurdakul, 2015). As there is uncertainty in data of the real-world systems, the TOPSIS method in combination with the Fuzzy set theory, is quite effective (Seyedhosseini and Taleghani, 2015; Khoshnevisan, 2012). The method used will also the degree of importance with which they affect the implementation process. For using Fuzzy TOPSIS, it is required to collect data by gathering feedback from experts / decision-makers (DMs) about the importance of the various business models and criteria for business models of a circular economy. For this purpose, a group of two experts were selected. Each DM was requested to give his preference of importance for each business model on a scale of 1 to 5 where 1: represents Very Poor (VP), 2: represents Poor (P), 3: represents Fair(F), 4: represents Good (G) and 5: Very Good (VG). Table 3 shows the linguistic response of the DMs for the various business models.

Table 3: Decision maker's opinion for the various Business Models

	DM1											DM2										
	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
C1	G	F	F	G	G	F	G	G	G	F	G	F	G	F	VG	G	F	G	G	P	F	G
C2	VG	G	F	F	P	VG	F	F	F	F	VP	G	G	F	F	P	G	G	G	F	G	P
C3	F	G	F	P	P	G	G	G	VG	F	P	G	F	G	P	G	G	VG	P	G	G	F
C4	G	G	G	F	G	G	G	F	P	P	F	G	G	G	G	G	G	G	P	F	F	F
C5	G	P	G	F	F	P	F	G	F	G	P	G	P	G	F	G	F	F	P	G	P	G
C6	F	G	P	VG	G	F	F	P	P	G	VP	F	VG	G	P	G	F	G	P	P	G	F

C7	G	G	F	F	P	F	G	F	P	G	F	G	G	G	F	G	F	G	VP	F	P	G
C8	VG	G	F	G	F	G	F	G	F	F	F	G	VG	G	G	P	G	F	F	F	F	F
C9	F	G	F	G	F	G	G	G	VG	G	F	VG	F	G	F	G	G	F	F	G	G	F

Decision Makers response for the importance of criteria for business models on a scale 1 to 5 where 1: represents Very Low (VL), 2: represents Low (L), 3: represents Medium (M), 4: represents High (H) and 5: Very High (VH). The linguistic response of the DMs for the various criteria for business models to be successful is shown in Table 4

Table 4: criteria weightage by Decision Makers

Criteria	DM1	DM2
C1	VH	VH
C2	VH	H
C3	H	H
C4	H	M
C5	M	L
C6	M	M
C7	M	L
C8	H	H
C9	M	M

The linguistic variables shown in Table 3 and Table 4 were converted to the equivalent fuzzy triangular numbers using the Fuzzy set theory proposed by Zadeh (1965), which is explained below:

The Fuzzy Set Theory

The fuzzy set theory is used to get the required results from uncertain and ambiguous data. (Zadeh, 1965). The uncertain information is represented by a fuzzy number. A triangular fuzzy number is used in the present study as it simplifies the lengthy computations (Giachetti et al., 1997)

The function μ_F represents the membership function for any fuzzy set F whereas $\mu_F(x)$ shows the degree of membership that *y*, of the universal set *Y*, belong to set *Z*, and is generally represented by a number from 0 to 1, i.e.,

$$\mu_F(z): Z \rightarrow [0,1]$$

$$\mu_F(Z) = \begin{cases} \frac{z-p}{q-p} & if\ p \leq z \leq q \\ \frac{r-z}{r-q} & if\ q \leq z \leq r \\ 0 & otherwise \end{cases}$$

Where *p* represents the lower limit, *q* is the most favourable value, and *r* is the upper limit of the fuzzy number *F* written as (p, q, r).

Let the two triangular fuzzy numbers i.e. $\tilde{F}_1 = (p_1, q_1, r_1)$ and $\tilde{F}_2 = (p_2, q_2, r_2)$, for which the following definitions hold good (Bohlender et al. , 1986)

- Addition of Fuzzy numbers:

  $\tilde{F}_1 \oplus \tilde{F}_1 = (p_1, q_1, r_1) \oplus (p_2, q_2, r_2) = (p_1+p_2, q_1+q_2, r_1+r_2)$

- Subtraction of Fuzzy numbers:

  $\tilde{F}_1 \Theta \tilde{F}_1 = (p_1, q_1, r_1) \Theta (p_2, q_2, r_2) = (p_1 - p_2, q_1 - q_2, r_1 - r_2)$

- Multiplication of Fuzzy numbers

  $F_1 \otimes F_1 = (p_1, q_1, r_1) \otimes (p_2, q_2, r_2) = (p_1 \times p_2, q_1 \times q_2, r_1 \times r_2)$

- Division of Fuzzy numbers

$$\tilde{F}_1 \oslash \tilde{F}_1 = (p_1, q_1, r_1) \oslash (p_2, q_2, r_2) = (p_1/p_2,\ q_1/q_2,\ r_1/r_2)$$

- Reciprocal of Fuzzy number

$$(\tilde{F})^{-1} = (p, q, r)^{-1} = (1/p,\ 1/q,\ 1/r) \text{ for } p, q, r > 0$$

The linguistic variables are changed into fuzzy triangular numbers by a conversion scale, shown in Table 5. The linguistic variables and their corresponding triangular Fuzzy numbers are also shown in Figure 1.

Table 5: Linguistic variables and their corresponding triangular fuzzy numbers

CRITERIA WEIGHTS	**BUSINESS MODEL ASSESSMENT**	**Corresponding triangular fuzzy number**
Very Low (VL)	Very Poor (VP)	(0.0,0.1,0.3)
Low (L)	Poor(P)	(0.1,0.3,0.5)
Medium (M)	Fair(F)	(0.3,0.5,0.7)
High (H)	Good(G)	(0.5,0.7,0.9)
Very High (VH)	Very Good (VG)	(0.7,0.9,1.0)

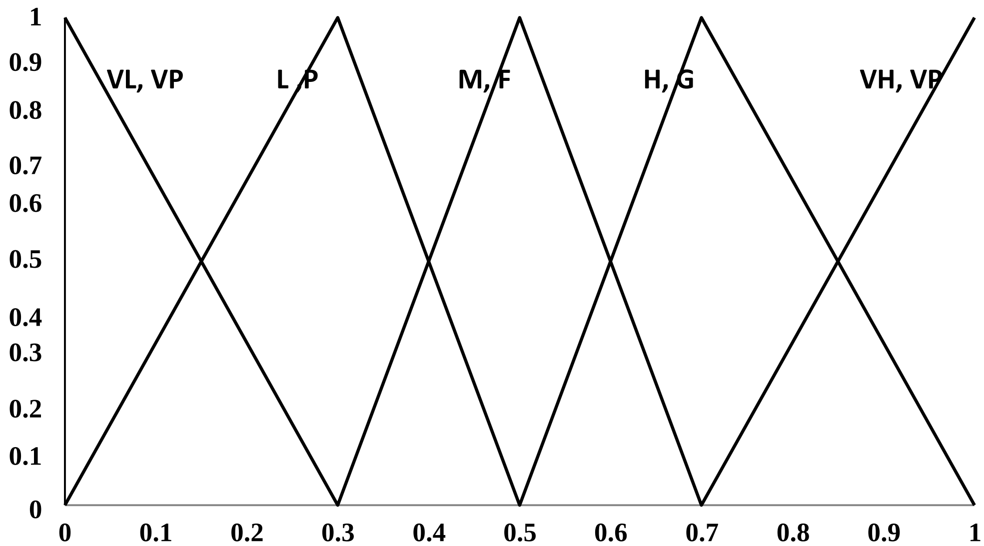

Figure 1: Linguistic variables and corresponding triangular Fuzzy numbers

Fuzzy TOPSIS is an MCDM method that helps find the significance of factors to solve decision-making problems. (Chen, 2000) Used the fuzzy set theory approach to eliminate the vagueness in the information, where linguistic variables are employed to rate the decision criteria. The linguistic variables are changed into fuzzy numbers through the conversion scale. Subsequently, the positive and negative ideal solutions are calculated using the Euclidean approach for ranking the business models. Following steps are involved in the Fuzzy TOPSIS method:

Step 1: Generation of the Fuzzy decision matrix

The fuzzy decision matrix is attained by organizing the linguistic terms of decision-makers in rows and the decision criteria in columns as given in Eq. (1).

$$D=\begin{bmatrix} x_{11} & x_{12} & \dots & x_{1j} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2j} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots & \dots & \\ x_{i1} & x_{i2} & \dots & x_{ij} & \dots & x_{in} \\ \dots & \dots & \dots & \dots & \dots & \\ x_{m1} & x_{m2} & \dots & x_{mj} & \dots & x_{mn} \end{bmatrix} \quad (1)$$

where x_{ij} corresponds to a triangular fuzzy number (a_{ij}, b_{ij}, c_{ij}) assigned to the linguistic term by *the i*th decision maker (DM) to the corresponding *j*th factor. *i*= 1, 2, …, *m* are the number of decision-makers (DMs) and *j* = 1, 2, …, *n* are the number of factors. In the present study, the feedback was taken from two decision-makers (DMs) for eleven business models and nine criteria for business models.

Step 2: Normalization of the decision matrix

The normalized decision matrix is obtained using Eq. (2) and Eq. (3).

$$R = [r_{ij}]_{m\times n} \quad (2)$$

$$r_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), \quad i = 1,2,3 \dots \dots ., m; \quad j = 1,2,3, \dots . ., n \quad (3)$$

where $c_j^* = \max_i c$

Step 3: Calculation of Weighted Normalized decision matrix

The weighted normalized decision matrix is obtained using Eq. (4) and Eq. (5).

$$V = [v_{ij}]_{m\times n} \quad (4)$$

$$v_{ij} = r_{ij} \times w_j \quad (5)$$

w_j is the criteria weightage. The criteria weightage in the present study is shown in Table 6

Table 6: Aggregated weightage of the Criteria

Criteria	Aggregated weightage
C1	0.7,0.9,1
C2	0.5,0.8,1
C3	0.5,0.7,0.9
C4	0.3,0.6,0.9
C5	0.1,0.4,0.7
C6	0.3,0.5,0.7
C7	0.1,0.4,0.7
C8	0.5,0.7,0.9
C9	0.3,0.5,0.7

Step 4: Computation of Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS) for the business models

The FPIS and FNIS are obtained using Eq. (6) and Eq. (7) respectively.

$$Z^{+} = \{ v_1^{+}, v_2^{+}, v_3^{+}, \ldots\ldots, v_n^{+}\} \quad (6)$$

$$\{ Z^{-} = \{ v_1^{-}, v_2^{-}, v_3^{-}, \ldots\ldots, v_n^{-}\} \quad (7)$$

The following are the FPIS $v_j^{+}$and FNIS (v_j^{-})in the present study.

$$v_j^{+} = (1,1,1), (1,1,1), (0.9,0.9,0.9), (0.81,0.81,0.81), (0.63,0.63,0.63), (0.7,0.7,0.7), (0.63,0.63,0.63), (0.9,0.9,0.9), (0.7,0.7,0.7) \quad (8)$$

$$v_j^- = (0.07,0.07,0.07), (0,0,0), (0.05,0.05,0.05), (0.03,0.03,0.03), (0.01,0.01,0.01), (0,0,0), (0,0,0), (0.05,0.05,0.05), (0.03,0.03,0.3) \quad (9)$$

Step 5: Calculation of the sum of distances

Sum of the distances from FPIS and FNIS are obtained using Eq. (10) and Eq. (11) respectively.

$$D_j^+ = \frac{\sum_1^n d(v_{ij} - v_j^+)}{n} \quad for\ j = 1,2, \ldots \ldots, m \tag{10}$$

$$D_j^- = \frac{\sum_1^n d(v_{ij} - v_j^-)}{n} \quad for\ j = 1,2, \ldots \ldots, m \tag{11}$$

where, $d(v_{ij} - v_j^+)$ is the distance between two fuzzy numbers and it can be calculated using the Euclidean approach according to which the distance between two points i.e. $(\tilde{Z}_1) = (a_1, b_1, c_1)$ and $(\tilde{Z}_2) = (a_2, b_2, c_2)$ in space is defined by Eq. (12)

$$d(\tilde{Z}_1, \tilde{Z}_2) = \sqrt{\frac{[(a_2 - a_1)^2 + (b_2 - b_1)^2 + (c_2 - c_1)^2]}{3}} \tag{12}$$

Step 6: Calculation of closeness coefficient

The relative closeness between the business models and the ideal solution is called closeness coefficient (CC_i) which is calculated using Eq. (13).

$$CC_i = \frac{D_i^-}{(D_i^+ + D_i^-)} \quad for\ \ i = 1,2, \ldots \ldots \ldots, m \tag{13}$$

If a business model is closer to the positive ideal solution, then CC_i will approach to 1. (Siddiquie et al., 2017). Therefore, CC_i provides the ranking order of business models.

Step 7: Ranking of the Business Models

Ranking of the business models is done in the decreasing order of their closeness coefficients (CC_i).

6. Results

This paper evaluates the business models for the successful adoption of the circular economy. After critically reviewing past research works, eleven business models and nine criteria were identified and compiled in Table 1 and Table 2, respectively. After identifying the business models and criteria for the success of business models the decision-makers were asked to give their responses about the various business models and the criteria, as shown in Table 3 and Table 4. These linguistic responses were then converted into fuzzy triangular numbers using the scale shown in Table 5. Consequently, the positive and negative ideal solutions are calculated using the Euclidean approach for ranking the business models. The business models were then ranked by following the Fuzzy TOPSIS method, subsequently, as discussed above in section 3. From the results shown in Table 7, the decreasing order of importance of models are as follows.

Product and Process Design > Circular Supplies > Incentivized return and reuse > Incentivized return and reuse > Product Life Extension > Sharing Platforms > Product as a Service > Asset Management > Dematerialized Services > Hire and Leasing > Collaborative Consumption.

The adoption of a circular economy depends on various business models. However, all the business models are not equally important; instead, some business models are highly important, and some are the least important.

Table 7: Ranking of Business Models

Table 7: BUSINESS MODEL	D^+	D^-	CC_i	Ranking
B1. Product and Process Design	4.379	4.033	0.520	1
B2. Circular Supplies	4.212	4.125	0.505	2
B3. Product Life Extension	4.05	4.375	0.480	5
B4. Sharing Platforms	3.933	4.388	0.472	6
B5. Product as a Service	3.934	4.498	0.466	7
B6. Recovery and Recycling	3.995	4.117	0.492	4
B7. Incentivized return and reuse	4.151	4.107	0.502	3
B8. Asset Management	3.876	4.511	0.462	8
B9. Dematerialized Services	3.658	4.610	0.442	9
B10. Hire and Leasing	3.639	4.589	0.441	10
B11. Collaborative Consumption	3.392	4.762	0.415	11

7. Discussion, Implications, and Direction for Future Research

In this research work, the identified business models have been ranked using Fuzzy TOPSIS method with an aspiration to give fruitful information about the severity of the business models with respect to the adoption of the circular economy. The order of importance of various business models based on CC_i values is given in Table 8. The ranking results shown in Table 7 indicate that the product and process design is the most influential business model. The objective of this model is to improve the service life of the components. The product and process design model provide the specific solutions for the maintenance, repairing, upgrading, and refurbishment of the component. The second most crucial business model is Circular Supplies, which focuses on the development of materials that are bio-based, fully recyclable to increase renewable energy.

Table 8: Order of importance of business models

Business Model	Ranking
B1. Product and Process Design	1
B2. Circular Supplies	2
B7. Incentivized return and reuse	3
B6. Recovery and Recycling	4
B3. Product Life Extension	5
B4. Sharing Platforms	6
B5. Product as a Service	7
B8. Asset Management	8
B9. Dematerialized Services	9
B10. Hire and Leasing	10
B11. Collaborative Consumption	11

While our results have produced rankings of business model types, it must be acknowledge that these are necessarily a function of the preferences and strategies of participants and evaluators. Such findings are quite generic and are in that sense general indications of the power and expected outcomes of such business models, however if in any situation, there are specific and focussed reasons motivating the CE adoption such as corporate social responsibility (Parast, 2021) or 'green' environmental priorities (Huo et al 2021), then a specifically different ranking would likely occur. For example, Yan et al (2019) examined fresh food supply chain challenges in their study published in this journal: the perishability context of such would impact on the relative desirability and indeed the feasibility of circular economy business models in that context. Yet the inherent method is robust in providing the means for such specific evaluations across a variety of such specific situations.

Managerial Implications

The results of this study may help organizations on issues related to the adoption of the circular economy, in understanding the degree of importance of the business models, based on which the management can formulate an effective strategy to systematically adopt the business models as per their importance to successfully implement the circular economy. This study may prove to be instructive for the managers for making the business models practicable for the adoption of the circular economy. The findings of this research could benefit the managers interested in developing and maintain organizations based on environmental sustainability and circular economy principles. The prioritization of the business models will help management to focus only on the highest priority business models for the successful adoption of the circular economy.

Theoretical Implications

The eleven business models and nine criteria for the adoption of the circular economy given in this study provide theoretical insinuation for the scholarly discussion on the circular economy. The findings of this research will also help academics and business decision-makers in order to develop a deeper understanding of the problem situation and the importance of the business models of the circular economy. This study provides opportunities for advanced research in the emerging field of the circular economy.

Conclusion and Directions for Future Research

The business models for the successful implementation of the circular economy are identified through the literature review. After finalizing the business models, they were analyzed on the basis of some criteria for the business model to be successful using Fuzzy TOPSIS approach. These business models were ranked, and the result is discussed with the expert, and useful insight is provided in the discussion section. This study provides a review of the various business models which can affect the adoption of the circular economy.

The limitation of this study is that it is based on the opinion of only a few experts. In the future, the business models stated above may be evaluated by any other MCDM Techniques to establish the priority and relation among them. Moreover, many more business models may be found through focussed studies and similar methodology may be applied for a better understanding of results.

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