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A circular business cluster model for sustainable operations management

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ABSTRACT

Ecological pollution, scarcity of resources, climate change and population growth have forced organisations to transform from a linear to a circular economy. Hence, the need arises to redesign value chains and traditional business models. Thus, the aim of this study is to develop a new conceptual eco-cluster model called 'Circular Business Cluster Model' to combine the advantages of both clustering and a circular economy. This paper seeks to establish a framework and provide guidelines for policy-makers such as governments, local authorities and organised industrial zone administrators. The contribution of this paper is to highlight and emphasise the crucial role of circular economy principles to transform a classical business model into an eco-business model. Circular Business Cluster Model includes the conceptual framework, network structure, interactions between cluster components and 6R activities. A case study was conducted to check the applicability of the proposed Circular Business Cluster Model. Eleven centres in this model were evaluated. Fuzzy Best-Worst Method (BWM) was used to find the relative weights. Based on the Circular Business Cluster Model, theoretical and managerial implications have been presented.

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Business cluster; circular economy; circular business cluster model; sustainable management

1. Introduction

The COVID-19 pandemic identified a major socio-economic shock. The planet is in trouble; pressures on the environment are increasing and the effects of COVID-19 have resulted in widespread unemployment (Bhammar et al. 2021). Global manufacturing operations have suffered a great recession. Although efforts to produce and distribute a vaccine for the COVID-19 pandemic continue, markets are experiencing the worst downturn in a century while still being pressured to comply with global climate change agreements (Gusheva and de Gooyert 2021). Therefore, countries are now looking for new ways to boost their economies (A'Adamo, Gastaldi, and Morone 2020).

Politicians and economists are promoting green agreements, climate-neutral and environmentally sustainable governance proposals as an orchestrated legislative solution to recover from the COVID-19 pandemic (Lahcen et al. 2020). The economic decline is often seen as an incentive to accelerate the transition to sustainable development, or, to put it another way, to accomplish a green recovery. The concept of green recovery is based on the premise that economic depression can be used to restore and recover the economy and dissociate it from its environmental effect (Gusheva and de Gooyert 2021).

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The UK government has declared that £350 million will be made available to reduce pollution in heavy industry, manufacturing, space and transportation to help the economic recovery from the COVID-19 pandemic while still achieving the government's target of leading the world's most successful environmental policy (UK Government 2020). Similar attempts for an environmentally conscious stimulus have been made by the International Monetary Fund in order to ensure a long-term recovery (IMF 2020). The European Commission has proposed an ambitious programme for COVID-affected European economies, with the aim of making Europe more prosperous, resilient and more equitable for future generations. The European Green Deal, a strategy initiated prior to the pandemic but then taken forward to better deal with the COVID economic crisis, is an important cornerstone of the rescue plan, aiming to build a resource-efficient and sustainable economy for European Union (EU) countries by 2050 (Bogojevic 2020).

The concept of the circular economy might be an appropriate option to provide green recovery. Circular economy aims to reduce emissions, increase resource productivity, minimise energy consumption, reduce waste (Ghisellini, Cialani, and Ulgiati 2016; Li et al. 2016; Gupta et al. 2019), protect climate change (Stewart and Niero 2018), provide sustainable development in the supply chain (Li and Ma 2015; Jabbour et al. 2020), contribute to eco-design by various R activities (Geissdoerfer et al. 2017), maximise renewable energy efficiency and make decomposing waste into sustainable and reusable resources (Van Buren et al. 2016).

In terms of resource efficiency, business clusters have some benefits (Steinfield, Scupola, and López-Nicolás 2010; Keller, Markmann, and von der Gracht 2015). Starting from the industrial revolution, the business world has appreciated different business models with pros and cons.

One of the structural business models is business cluster, involving a network structure where producers, suppliers and related businesses share the same geographical location. The cluster model is considered to be an important contributor to the competitiveness of companies within the cluster by increasing their productivity and efficiency (Porter 1998).

The geographical proximity of locations of organisations engaged in economic activities facilitates a higher degree of efficiency, innovation and productivity. Suppliers, research labs, producers, service providers, distributors and other institutions located in the same area are the drivers of this economic field, i.e. clusters (Porter 1998).

The roots of the cluster definition of Porter (1990) is based on Porter's diamond model, composed of four factors; (1) firm strategy, structure and rivalry; (2) demand conditions; (3) factor conditions; and (4) related and supporting industries.

According to Porter (1998), clustering is the geographical proximity of inter-related business enterprises; this includes specialised suppliers, specialised infrastructure providers, machinery, services, institutions such as universities, agencies, consultants engaged in education, research, training, information and technical support activities. Clusters enlarge vertically to include customers and supply channels; they also enlarge horizontally to include producers who manufacture complementary products, businesses related to their abilities in technology or the use of common inputs. The cluster can be a city, state, country or even neighbouring countries.

The clustering approach is related to industrial symbiosis. According to Ayres (1989), Geissdoerfer et al. (2017), Lewandowski (2016) and Scott (2013), industrial symbiosis is a combination of different industries where each industry strives for optimal access to materials and resources. Homrich et al. (2018) stated that the theoretical background of industrial ecology and symbiosis stands on the following concepts; transaction costs (Su et al. 2013; Hsu 2013), symbiosis (Chertow 2000; Li, Dong, and Ren 2015), externalities (Dahlman 1979) and partnership and alliance (Barber, Beach, and Zolkiewski 2012).

In transaction cost theory, an organisation tries to decrease the internal costs related to the exchange of resources (Choi and Krause 2006). Chertow (2000) asserted that industrial symbiosis is composed of exchanges of 'water, energy, materials, and by-products' among different entities. The externalities concept proposed by Dahlman (1979) is the outcome and resulting consequence of an economic initiative, production or consumption with an impact on a third party which may not even be related to that resource. Vachon and Klassen (2006) stated that partnership and alliance are defined as interactions among different parties or companies cooperating to decrease the use of energy and waste, i.e. in pollution preventive processes.

Homrich et al. (2018) indicated that the use of resources and energy in an economic system presents certain similarities to that of biological ecosystems and organisms. It is also mentioned that the cyclical patterns of resource-use are observed in biological ecosystems; these are taken as a model to design industrial ecosystems whose productivity depends on waste emission and resource extraction (Graedel and Allenby 1995; Geissdoerfer et al. 2017; Lewandowski 2016; Ellen MacArthur Foundation 2015; Scott 2013).

Hence, circular economy and industrial symbiosis concepts can be integrated around new business models to enhance waste minimisation, promote circular activities and provide green recovery. Therefore, the cluster concept as an example of industrial ecosystems emerges as an important research area to propose a unique business model that will harmonise the circular economy and cluster concept with industrial symbiosis to provide sustainable environmental management. From this perspective, the aim of this paper is to develop a novel conceptual eco-cluster model adapted to the circular economy concept. Briefly, the 'Circular Business Cluster Model' will be designed to combine the advantages of both clustering and circular economy. In addition, this paper aims to establish a framework and guidelines for policy-makers such as government bodies, local authorities, municipalities and organised industrial zone administrators within a circular economy context. As a result, in-depth interviews were conducted with experts from the Ministry of Environment and Urban Planning of Turkey, Ministry of Industry and Technology of Turkey, Ministry of Trade of Turkey, The Union of Chambers and Commodity Exchanges of Turkey, organised industrial zones and academia to verify the need for integration of a circular economy into business clusters. A case study was conducted to check the applicability of the Circular Business Cluster Model. The proposed model includes eleven centres, namely Joint Collection and Classification Centre (JCCC), Joint Circular Operations Centre (JCOC), Joint Circular Energy Centre (JCEC), Resource Efficiency Centre (REC), Waste and Emission Reduction Centre (WERC), Circular Education Centre (CEC), Circular Design Centre (CDC), Joint Quality Control Centre (JQCC), Joint Maintenance and Reliability Centre (JMRC), Joint Tool Centre (JTC) and Joint Circular Material Warehouse (JCMW). These eleven centres were used as evaluation criteria. Fuzzy Best-Worst Method (BWM) was used to find the relative criteria weights. Within this perspective, the research questions of this study can be specified as:

> RQ1: How is a Circular Business Cluster Model developed to harmonise the circular economy and cluster concept with industrial symbiosis to provide green recovery?

> RQ2: Which solution methods can be used to guide managers and policymakers in applicability of a Circular Business Cluster Model to green recovery?

This business model may arise as an important opportunity to achieve long-term sustainability based on the circular economy. A Circular Business Cluster Model includes a conceptual framework, network structure, interactions between the cluster components and 6R activities. The model development study includes a conceptual model, network structure, interactions between the cluster components and sustainability of the model, model outcomes and implications. The contribution of this paper is to highlight and emphasise the crucial role of circular economy principles to transform a classical business model into an eco-business model. Therefore, the proposed innovative circular economy business model for logistics and supply chain management post-pandemic will enhance the collaborative relationships towards the circular economy.

Following the introduction, Section 2 introduces the theoretical background, including clustering and circular economy 6R framework. Section 3 explains the proposed circular cluster business model. Section 4 summarises the case study. Section 5 highlights the implications. Section 6 includes the discussions and finally, Section 7 summarises the concluding remarks.

2. Theoretical background

In this section, the clustering approach and the circular economy 6R framework are explained in detail. The theoretical background has been structured based on clustering and circular economy with a circular 6R framework.

2.1. Clustering and CE

One of the structural business models is a business cluster that has a network structure where producers, suppliers and related businesses share the same geographical location. Porter (1998) set out the properties of business clusters as follows:

(1) The boundaries of a cluster are determined in the context of the ties within the cluster and the complementarity of institutions that are crucial to the competition. Although clusters are often in line with political boundaries, they can even cross national borders.
(2) Clusters rarely adapt to a standard industrial classification system that is inadequate to see many important actors and relationships in competition. Important clusters may therefore be hidden or undefined.
(3) Clusters increase both collaboration and competition. Enterprises compete extensively to gain and retain customers. Without intense competition, clusters fail. Clusters also have collaboration, most of which is vertical. Competition and cooperation can happen together because they are of different sizes and between different players.
(4) Clusters are a new form of regional organisation between a structure appropriate to market conditions and hierarchical or vertical integration. Thus, clusters are another way of organising the value chain. From the point of view of transactions between scattered and randomly located buyers and sellers, proximity and repetitive exchanges between businesses and institutions nurture cooperation and trust.
(5) The cluster of businesses and institutions linked by independent and informal ties appears to be a solid organisational shape that outperforms efficiency, productivity and flexibility.

Enright (2000) also contributed to the clustering approach by defining the dimensions of clusters. Clusters vary according to a number of factors. These factors are geographical extent, width, depth, basis of activity, growth potential, innovation capacity, competition position, administration structure, ownership structure and the type of clusters (Enright 2000).

Porter (2000) described the advantages of clustering as (1) access to specialised input and staff, (2) joint marketing, (3) innovation, (4) reputation of geographical area, (5) access to experienced labour, (6) access to institutions and public goods, (7) access to information on new markets, (8) access to information on technological advances, (9) complements and (10) incentives and performance measurement. Also, Berkshire (2006) summarised the advantages of clustering as (1) faster growth of firms than usual, (2) allowing a large of new firms to enter the sector, (3) becoming more innovative within the cluster, (4) enabling the formation and development of new firms, (5) opportunities to attract qualified outside the workforce and (6) providing proximity to specialised suppliers and customers.

The clustering approach is related to industrial symbiosis. The industrial symbiosis concept can be integrated with a circular economy to develop new business models in order to enhance waste minimisation and to promote circular activities. The circular economy concept that is observed in biological ecosystems can be adapted into industrial ecosystems. Thus, initially, it is necessary to scrutinise the industrial ecology concept.

According to Homrich et al. (2018), there are four main pillars of industrial ecology and symbiosis; these are externalities, transaction cost, partnership and industrial symbiosis.

Dahlman (1979) stated that business activities provide benefits to stakeholders as a contribution defined as externalities.

Choi and Krause (2006) asserted that in most business activities, the management aims to minimise the transaction costs incurred as a result of exchanging resources.

Partnerships and alliances established by companies give an opportunity for the joint use of energy and other resources in order to reduce pollution and waste (Vachon and Klassen 2006).

Industrial production requires the exchange of resources such as water, materials, energy and by-products between processes, resulting in industrial symbiosis, according to Chertow (2000).

Industrial symbiosis supports firms to reach a collective approach for the exchange of materials, water, energy and by-products in which firms may benefit by decreasing the consumption of materials and reducing emissions (Geng and Cote 2002; Chertow 2007).

Dong et al. (2013) stated that industrial symbiosis can bring significant benefits to the struggle against climate change by minimising waste at source and converting waste to usable resources. The production of virgin materials is energy-intensive.

Thus, the four concepts in the theoretical background of industrial ecology and symbiosis can be correlated. This includes (i) decreasing transaction cost with the aid of the reuse and recycling activities of circular economy, (ii) exchange of resources in a more efficient symbiosis, (iii) minimising adverse externalities such as pollution and emissions and (iv) improving partnership and alliance among companies can be regarded as cooperation with circular economy principles.

2.2. Circular 6R framework

Looking beyond the existing take-make-dispose industrial model, the circular economy approach aims to describe growth by concentrating on positive benefits across society. It requires the gradual separation of economic activities from the consumption of resources and the design of waste disposal. The circular model, supported by the transition to renewable energy sources, develops economic, natural and social capital. The principles of the circular economy are to (1) prevent pollution and waste, (2) keep materials and products in use and (3) restore natural systems (Ellen MacArthur Foundation 2015).

The concept of the circular economy has evolved in order to build a more sustainable environment for humankind (Kazancoglu, Kazancoglu, and Sagnak 2018; Sehnem et al. 2019; García-Quevedo, Jové-Llopis, and Martínez-Ros 2020; Kazancoglu et al. 2020; Kazancoglu et al. 2021; Yadav, Kumar, et al. 2020). Organisations have developed sustainable operations based on CE-based production systems (Khan et al. 2021) in order to provide system sustainability by improving the circularity of materials and natural resources (Kirchherr, Reike, and Hekkert 2017; Moktadir et al. 2020; Tseng et al. 2021). This has been receiving growing attention among researchers and practitioners, as evidenced by more than 100 peer-reviewed articles published in 2016 compared to 30 in 2014 (Geissdoerfer et al. 2017). The CE concept is adapted as an alternative to the linear economy's 'take, make and dispose' model (Ness 2008; Dey et al. 2020; Rajput and Singh 2021), emphasising the usage of renewable materials and technologies. In other words, CE is a regenerative system in which waste emissions and leakage are minimised through reuse, remanufacturing/refurbishing or recycling activities (Geissdoerfer et al. 2017; Dossa et al. 2020). CE aims to preserve our natural resources for the future of humankind (Zucchella and Previtali 2019).

Closed-loop operations, recovery and reverse logistics activities are the main linkages between circularity and sustainability. The CE's major pillar is reverse logistics, which includes operations such as recycling, reverse distribution, reusing, remanufacturing, repairing and refurbishing (Kazancoglu et al. 2021). Furthermore, CE assists organisations in improving their economic and environmental sustainability by integrating forward, using reverse logistics as well as developing waste management. The ability of businesses to adapt to CE has a direct relationship with their sustainability performance. Moreover, CE not only provides resource efficiency and life cycle extension but also creates a supply chain-wide sustainable production system; hence, sustainable operations must be aligned with CE practices (Sagnak et al. 2021).

Several circular economy frameworks have been used by scholars and practitioners. Blomsma and Brennan (2017) applied 3R, and eventually 4R frameworks because they were the most prominent for them. Beyond 4R, scholars have used various R frameworks such as 6Rs (Sihvonen and Ritola 2015) and 9Rs (Van Buren et al. 2016).

In the 6R methodology of circular economy, six activities – Reduce, Reuse, Recycle, Recover, Redesign and Remanufacture are highlighted. Reduce focuses primarily on the first three phases of the product life cycle, meaning a reduction in the use of pre-production resources, a reduction in the use of energy, materials and other resources during production, plus a reduction of emissions and waste generated during the use phase. Reuse means reusing components from products, or a product as a whole, in order to produce new components or products by reducing the need for brand-new components. Recycling refers to the process of transforming components, which would formerly have been regarded as waste, into new components or products. Recover involves the collection of products at the end of use phase, disassembling, sorting and cleaning for use in subsequent life cycles. Redesign includes the process of planning new products using components of a previously-formed product. Remanufacture refers to reproducing used products to re-establish their original situation, or a new form, by reusing as many components as possible without losing functionality (Jawahir and Bradley 2016). Figure 1 represents the natural sequence of the 6R methodology.

2.3. Research gaps

Liu, Tian, and Chen (2014) stated that waste is one of the greatest problems of eco-industrial parks and therefore suggested that it is crucial to minimise waste at source and increase material efficiency. In the same study, it is suggested that there is a need to improve the recycling rate of solid waste handled by third parties outside of the industrial parks. In a similar manner, the transportation of wastes was noted as another critical source of emissions.

Further, Dong et al. (2013) proposed that applications such as joint collection mechanisms for various materials, symbiotic use of scrap and packaging materials, reuse and remanufacturing among firms should be promoted and supported.

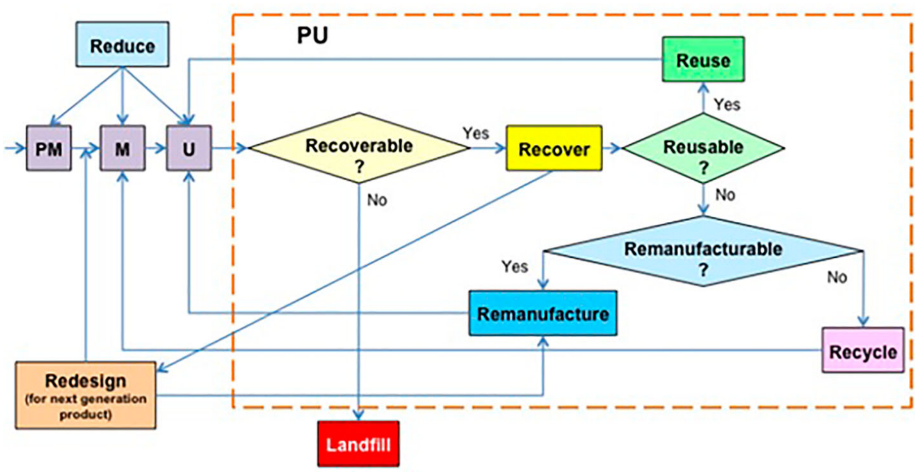

Figure 1. Natural sequence of 6R methodology (Zhang et al. 2013).

Thus, as mentioned by Liu, Tian, and Chen (2014), necessary policies should be prepared to encourage industrial symbiosis while supporting reuse and recycling.

Dong et al. (2017) indicated that it is important to improve and sustain the linkage between the circular economy concept and industry through technology; this should be further extended to new business models.

The combination of the advantages of clustering and circularity creates symbiosis and synergy in an integrated system, including suppliers, producers, distributors, service providers, recycled material businesses, energy suppliers, intermediaries and consumers. The cluster model is a good basis for further development to be fortified with environmental sensitivity, sustainability, circular economy and green production concepts.

3. Proposed conceptual model

The European Environment Agency report 'Circular economy in Europe - developing the knowledge base' identified the circular economy concept and its characteristics. According to the report, there is a need for fundamental changes from design and manufacturing activities to consumption standards and new business models in order to create circularity (European Environment Agency 2016). The term 'business model' indicates how business enterprises create economic value (Linder and Williander 2017). Thunman et al. (2019) stated that there is the possibility to include the properties of circularity in the transformation process of a cluster involving the benefits of a feasible infrastructure. Also, the industrial ecology perspective renders good insight about how industrial symbiosis comes into existence but is less clear about changes in the economic role; the circular economy concept provides good insight about the economic role but does not consider the systematic behaviour of industrial ecology. Therefore there is a need for integration of the two approaches (Bocken et al. 2017; Baldassarre et al. 2019). Homrich et al. (2018) stated that eco-parks demonstrate how externalities, transaction costs and symbiosis can promote a circular economy for policymakers by giving new insights while transiting into the circular economy. Therefore, the need to redesign value chains and traditional business models arises in order to achieve the transition from a linear economy to a circular economy. Thus, the following model has been developed to close this gap and to contribute to existing related literature. Furthermore, the proposed model will serve as a guideline for business managers and practitioners.

Figure 2 represents the proposed Circular Business Cluster (CBC) model.

The model is developed based on the Circular 6R framework and has three inclusive layers; the inner layer (I) encompasses business cluster, the second layer (II) covers both cluster and circular units, namely Circular Business Cluster and the third layer (III) covers circular business cluster and environmental bodies, namely ecosystem.

In the content of the inner layer, there is a traditional business cluster. It is represented by a simple input-transformation-output model. The mainstream starts with the procurement of resources from supply markets and after transformation to outputs, they are presented to customers, companies and other clusters.

While this process is going on, circular units in the second layer start to progress and cover the cluster with the blanket of the circular economy to reach the goals and objectives of sustainability. The model will be active in an ecosystem including stakeholders and other environmental bodies.

There are various organisations, units and functions in the circular business cluster model shown in Figure 2. The structure of the model and the functions of proposed units and their contributions from the circular economy point of view will now be explained as a brief proposed business model.

The proposed units to improve circularity within a business cluster are:

- Joint collection and classification centre (JCCC): JCCC is one of the most important units as a starting point to collect and circulate recyclable materials. The joint collection function will be performed from the related units of the cluster which dispose of those materials. It will

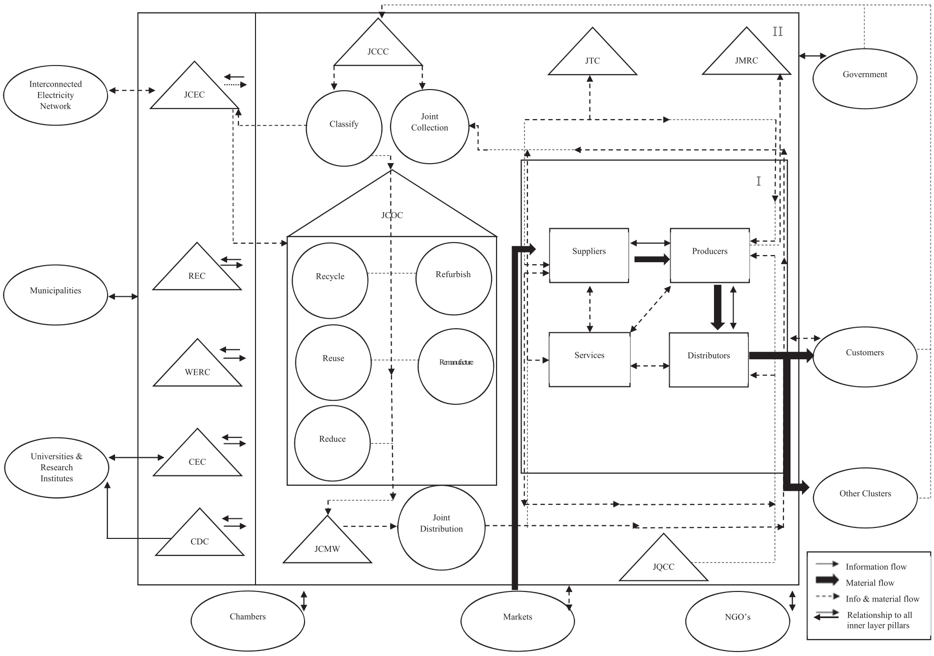

Figure 2. Circular Business Cluster model.

contribute both to extending the lifespan of the product and its parts and will also have a useful application of materials. The units following JCCC are suggested to directly serve 6R activities. The suggested classification function performs a crucial activity; the first output will be the materials that would be used by Joint Circular Energy Centre (JCEC) to generate energy for the business cluster. In this way, the recovery of materials would be realised. Other materials will be directed to other circular operations such as recycle, refurbish, reuse, repair and reduce.

- Joint Circular Operations Centre (JCOC): JCOC is a crucial part of the model where materials coming from JCCC will be processed by circular operations. This unit can perform circular operations such as recycling, refurbish, reuse, remanufacturing and reduce. JCOC can manage the advantage of economies of scale in recycling and perform this operation totally within the centre. Similarly, refurbishing or recovering activities are conducted within this centre.
- However, some specific circular operations, such as remanufacturing, are conducted within the related producer of the cluster; hence JCOC may send the necessary part back to the producer to be reused or remanufactured.
- Recycling is the process of collecting and processing materials that would otherwise be thrown away, then turning them into the same or lower quality new products. Outputs can be used by the producers of the cluster to benefit the cost advantage of recycled material. On the other hand, the ecosystem will benefit from saving resources. Recycling will turn waste into a resource. Extending product lifetimes will help preserve natural resources.
- Repurposing, remanufacturing and refurbishing operations will produce parts and components for the producers of the cluster by processing discarded products. All of these operations will be performed in the CBC, resulting in savings including transportation, processing and other related cost items. Added and retained value will be generated by these processes; otherwise, those materials would be thrown away and environmental problems would be exacerbated.
- Repair and reuse functions will perform operations to repair defective products. Repaired products can be used by the same or alternative companies. Again, the results will be both in cost

savings for the companies of the cluster and benefits for the ecosystem as a whole by reducing waste and saving resources.

- Joint Circular Material Warehouse (JCMW): JCMW is a storage and distribution unit for refurbished, repaired and recycled materials which will be reused and remanufactured by the inner layer of the cluster. There are several advantages of the proposed unit for the companies of the cluster; these include cost savings of using refurbished and repaired parts and components, distribution benefits, material handling, inventory cost advantages, as well as economies of scale advantage provided by an efficient and effective joint unit. On the other hand, the contribution of refurbishing, repairing and recycling functions to warehousing management will support the transition process to a circular economy by increasing circularity.
- Joint Tool Centre (JTC): JTC is a unit proposed to perform the manufacturing process in which the size, profile or exterior properties of parts are changed by removing any excess material for machining. Recycled machine tools such as cutting tools, grinding wheels or drilling materials will be provided by JCMW to be processed by JTC. Repairing, refurbishing and reuse of machine tools will be an advantage for cluster producers in terms of cost, easy access and distribution.
- Joint Maintenance and Reliability Centre (JMRC): JMRC is a unit that will focus on maintenance management and the impact of maintenance on equipment reliability. The centre will offer some practical suggestions on how to assure and improve reliability through better maintenance. Repair and reuse functions will benefit from this service through the maintenance of defective products. The centre will also prepare preventive maintenance programmes for companies of the cluster, with service being presented to CBC as a whole.
- Joint Quality Control Centre (JQCC): JQCC is a unit providing a wide range of cost-effective quality control services and solutions to companies across the CBC. The centre will offer services to provide an objective and independent analysis of quality issues about products that are processed by circular operations such as refurbishing or remanufacturing activities. Also, the centre will provide the conformance of quality standards of products to international quality standards, requirements of consumers, industry standards, plus internal policies and procedures. Total quality management as a philosophy of CBC can be realised, with quality control techniques being industrialised to establish the observation methods and activities that will fulfil CBC requirements. JQCC will present quality control training courses that are designed specifically to teach quality management issues so that companies of the cluster can place a strong focus on continuously improving their efforts to achieve quality.
- Waste and Emission Reduction Centre (WERC): This centre will deal with decreasing the environmental impact of the cluster in terms of reducing waste and emissions. The centre brings the necessary know-how and technologies required to meet the needs of the companies within the cluster. The technology selection, adaptation and implementation processes will be supported by this centre. In addition, this centre will contribute to follow up and control the carbon footprint and emission figures of the companies as well as the amount of waste produced.
- Circular Education Centre (CEC): The circular economy and sustainability are recent topics within business management; this requires teaching and training for the implementation of these topics to benefit both managers and employees. This centre will be responsible for preparing related course materials, conducting educational programmes and providing training programmes and trainees specific to the needs of the cluster. The circular education centre will also provide a cost advantage for educational needs based on economies of scale for the companies within the cluster.
- Resource Efficiency Centre (REC): This centre will focus on the resource melioration of the cluster in several ways. The resource efficiency centre can provide necessary resources such as raw materials, energy and human resources. Resources can be procured for all members of the cluster to ensure the advantages of quantity discounts and efficient resource utilisation. In addition, from a human resources point of view, the temporary or permanent exchange of experienced staff on a circular economy can be used to improve the labour efficiency of the cluster.

- Circular Design Centre (CDC): Design plays a crucial role in the circular economy to achieve the anticipated advantages of circularity. The efficiency and effectiveness of circular operations such as reuse, remanufacturing, recycling and recover depend on the type of raw materials, components and fixtures used in the product. The success of recycling activities is related with the ease of disassembling operations where the design stage should be developed by considering and enabling the ease of recycling processes. This centre can also decrease the cost of design changes to minimise the environmental impact that may occur in later stages of production processes.

All of the above-mentioned units and functions have been proposed to support the transition process from Business Cluster to Circular Business Cluster (CBC) by reducing waste, minimising raw material needs, protecting natural resources, reducing emissions and finally satisfying 6R principles of Circular Economy.

4. Prioritising the centres of the Circular Business Cluster (CBC) model

The proposed innovative circular economy business model for logistics and supply chain management post-pandemic will enhance collaborative relationships towards a circular economy.

A case study was organised in order to check the proposed 'Circular Business Cluster Model'.

Limited resources may hamper full implementation of the proposed model. Thus, the centres can be prioritised for an effective use of resources towards the realisation of the model. The results of the prioritisation will provide managers and decision-makers with a tool regarding the initialisation and realisation of the proposed model.

The proposed model includes eleven centres; these are Joint Collection and Classification Centre (JCCC), Joint Circular Operations Centre (JCOC), Joint Circular Energy Centre (JCEC), Resource Efficiency Centre (REC), Waste and Emission Reduction Centre (WERC), Circular Education Centre (CEC), Circular Design Centre (CDC), Joint Quality Control Centre (JQCC), Joint Maintenance and Reliability Centre (JMRC), Joint Tool Centre (JTC) and Joint Circular Material Warehouse (JCMW). The centres were evaluated by the Fuzzy Best-Worst Method (BWM) to find the relative weights.

Multi-criteria decision-making (MCDM) methods are popular when dealing with decision-making problems. MCDM techniques are used to weigh selection criteria or to select the best option among various alternatives.

Best-Worst Method (BWM) was developed by Rezaei (2015). In this study, BWM is used to find the criteria weights. It is integrated with fuzzy set theory (Zadeh 1965) in order to minimise the subjectivity and vagueness in the decision-making process. The reason for using fuzzy BWM is that in BWM, fewer pairwise comparisons are made than in AHP or ANP. The solution can be found in less time and with less effort. Furthermore, the BWM approach incorporates a mathematical modelling, making it more accurate than other approaches. The next sub-section summarises the properties of the fuzzy BWM method.

4.1. Fuzzy Best-Worst Method (BWM)

The steps of BWM are as follows:

Step 1: Definition of a criteria set: The criteria were defined as $\{c_1, c_2, \ldots c_n\}$.

Step 2: Definition of the criteria that have the greatest and the lowest importance level: Criteria with the greatest and the lowest importance can be shown as c_B and c_W, respectively.

Step 3: Comparison of the most important criterion with others: The linguistic judgments of decision-makers are modified to triangular fuzzy numbers. Best-to-Others vector is determined through the comparison of most important criterion with others. Best-to-Others vector can be expressed as $\widetilde{A}_B = (\widetilde{a}_{B1}, \widetilde{a}_{B2}, \ldots, \widetilde{a}_{Bn})$.

Step 4: Comparison of each criterion with the least important criterion: Similarly, the linguistic judgments of decision-makers are modified to fuzzy numbers. Others-to-Worst vector is determined through the comparison of each criterion with the least important one. Others-to-Worst vector can be expressed as $\widetilde{A}_W = (\widetilde{a}_{1W}, \widetilde{a}_{2W}, \ldots, \widetilde{a}_{nW})^T$.

Step 5: Calculation of the optimal fuzzy weights $\widetilde{w}_1^*, \widetilde{w}_2^*, \ldots, \widetilde{w}_n^*$: The optimal fuzzy weights of criteria are $\widetilde{w}_B/\widetilde{w}_j = \widetilde{a}_{Bj}$ and $\widetilde{w}_j/\widetilde{w}_W = \widetilde{a}_{jW}$ for each pair. The maximum absolute differences $\left|\frac{\widetilde{w}_B}{\widetilde{w}_j} - \widetilde{a}_{Bj}\right|$ and $\left|\frac{\widetilde{w}_j}{\widetilde{w}_W} - \widetilde{a}_{jW}\right|$ for all j values should be determined. All j values are formulated as a minimisation model $\widetilde{w}_B$, $\widetilde{w}_j$, and $\widetilde{w}_n$ are triangular fuzzy numbers.

The following mathematical model was developed:

$$\textit{Minimise} \ \max\left\{\left|\frac{\widetilde{w}_B}{\widetilde{w}_j} - \widetilde{a}_{Bj}\right|\right\}, \left\{\left|\frac{\widetilde{w}_j}{\widetilde{w}_W} - \widetilde{a}_{jW}\right|\right\}$$

$$s.t. \begin{cases} \sum_{j=1}^{n} R(\widetilde{w}_j) = 1 \\ l_j^w \leq m_j^w \leq u_j^w \\ l_j^w \geq 0 \\ j = 1, 2, \ldots, n \end{cases}$$

$$\widetilde{w}_B = (l_B^w, m_B^w, u_B^w), \widetilde{w}_W = (l_W^w, m_W^w, u_W^w), \widetilde{w}_j = (l_j^w, m_j^w, u_j^w)$$

This model can be converted to the following mathematical model:

Minimise ξ

$$s.t. \begin{cases} \sum_{j=1}^{n} R(\widetilde{w}_j) = 1 \\ l_j^w \leq m_j^w \leq u_j^w \\ \left|\frac{\widetilde{w}_B}{\widetilde{w}_j} - \widetilde{a}_{Bj}\right| \leq \xi \\ \left|\frac{\widetilde{w}_j}{\widetilde{w}_W} - \widetilde{a}_{jW}\right| \leq \xi \\ l_j^w \geq 0 \\ j = 1, 2, \ldots, n \end{cases}$$

$$\xi = (l^\xi, m^\xi, u^\xi)$$

It can be supposed that $\widetilde{\xi}^* = (k^*, k^*, k^*)$ and $k^* \leq l^\xi$ when $l^\xi \leq m^\xi \leq u^\xi$. Then, the model can be written as

Minimise ξ

$$s.t.\begin{cases} \sum_{j=1}^{n} R(\widetilde{w}_j) = 1 \\ l_j^w \leq m_j^w \leq u_j^w \\ \left| \dfrac{l_B^w, m_B^w, u_B^w}{l_j^w, m_j^w, u_j^w} - (l_{Bj}, m_{Bj}, u_{Bj}) \right| \leq (k^*, k^*, k^*) \\ \left| \dfrac{l_j^w, m_j^w, u_j^w}{l_W^w, m_W^w, u_W^w} - (l_{jW}, m_{jW}, u_{jW}) \right| \leq (k^*, k^*, k^*) \\ l_j^w \geq 0 \\ j = 1, 2, \ldots, n \end{cases}$$

Optimal fuzzy weights $(w_1^*, w_2^*, \ldots, w_n^*)$ can be obtained by solving this model.

4.2. Implementation and results

The implementation is conducted to reveal the prioritisation of the centres within the proposed model. The eleven centres are evaluated by experts and decision-makers who are potentially inherent in the prospective realisation of the proposed model. Representatives from various stakeholders are considered and included in the study. Table 1 details the roles and details of the experts who have contributed to the study.

The experts were requested to complete the pairwise comparisons of fuzzy BWM to provide brief information related to the aim and use of the method as well as the steps of the method. The calculations are conducted based on the responses of the experts according to the steps of the methodology given in Section 4.1.

The weights of the evaluation centres were found using fuzzy BWM. Table 2 shows the relevant weights.

The findings reveal that the most important centre to develop Circular Business Cluster is Joint Collection and Classification Centre (JCCC) with a weight of 0.384, followed by Joint Circular Operations Centre (JCOC) and Circular Design Centre (CDC) with weights of 0.192 and 0.110, respectively. It is normal to find Collection and Classification Centre (JCCC) as the most important

Table 1. Information about participants.

Experts	Position	Total work experience in years
1	Personnel from Ministry of Environment and Urban Planning of Turkey	12
2	Personnel from Ministry of Environment and Urban Planning of Turkey	8
3	Personnel from Ministry of Industry and Technology of Turkey	9
4	Personnel from Ministry of Industry and Technology of Turkey	7
5	Personnel from Ministry of Trade of Turkey	11
6	Personnel from Ministry of Trade of Turkey	7
7	Personnel from The Union of Chambers and Commodity Exchanges of Turkey (TOBB) (Chamber of Commerce)	8
8	Personnel from The Union of Chambers and Commodity Exchanges of Turkey (TOBB) (Chamber of Commerce)	8
9	Personnel from The Union of Chambers and Commodity Exchanges of Turkey (TOBB) (Chamber of Industry)	9
10	Personnel from The Union of Chambers and Commodity Exchanges of Turkey (TOBB) (Chamber of Industry)	7
11	Academics	25
12	Academics	18
13	Academics	11
14	Representatives from Organised Industrial Zones	17
15	Representatives from Organised Industrial Zones	14

Table 2. Respective weights of centres.

Centres	Weights
Joint Collection and Classification Centre (JCCC)	0.384
Joint Circular Operations Centre (JCOC)	0.192
Joint Circular Energy Centre (JCEC)	0.096
Resource Efficiency Centre (REC)	0.041
Waste and Emission Reduction Centre (WERC)	0.061
Circular Education Centre (CEC)	0.024
Circular Design Centre (CDC)	0.110
Joint Quality Control Centre (JQCC)	0.024
Joint Maintenance and Reliability Centre (JMRC)	0.016
Joint Tool Centre (JTC)	0.009
Joint Circular Material Warehouse (JCMW)	0.042

centre because other activities are directly related with collection and classification activities. Also, analysis of the results demonstrate that Collection and Classification Centre (JCCC), Joint Circular Operations Centre (JCOC) and Circular Design Centre (CDC) have a total of nearly 70% of weight importance. This means that design and operations activities are critical in developing a Circular Business Cluster.

5. Discussion and implications

With the COVID-19 pandemic devastating lifestyles throughout the world, countries are now searching for new initiatives to stimulate economic development (A'Adamo, Gastaldi, and Morone 2020). Green agreements as well as climate-neutral and environmentally sustainable governance proposals, are some of the initiatives recommended under a green recovery concept (Lahcen et al. 2020; Yadav, Mangla, et al. 2020). With this in mind, the concept of a circular economy might be an appropriate option to provide green recovery. Circular economy and industrial symbiosis concepts can be integrated around new business models to enhance waste minimisation, promote circular activities and provide green recovery.

Therefore, in this study, a Circular Business Cluster Model was proposed to combine the advantages of both clustering and the circular economy.

The proposed Circular Business Cluster Model is generic and further discussions can be conducted from different perspectives. First of all, since the model is novel, there is a potential risk of resistance to change from stakeholders of existing linear business models. To overcome this difficulty, the benefits of the proposed model should be highlighted to persuade stakeholders to change.

Secondly, since the proposed model is complicated, the establishment of new entities is necessary; therefore, an incremental expansion strategy can be recommended. In other words, a step-by-step transformation process can be more realistic and advantageous for realisation of the Circular Business Cluster Model.

Thirdly, decisions to determine the necessary administrative structure for this model, such as cooperative, business entity or semi-public arrangement, is another area for discussion. Experts in organisational management can develop alternatives for the administration of the proposed Circular Business Cluster Model.

Fourthly, the existence of a lot of entities and their inter-relationships produces a mass of data to be processed. In order to manage this data, the need for a management information system supported by big data analytics can be discussed.

Fifthly, the complex network structure and related flows of materials and information, together with the amount of data to be processed, necessitate discussing the establishment of a traceability system.

Finally, the existence of a large number of internal and external institutions requires building trust among all parties. Hence, a discussion of information transparency is a requisite to enhancing the level of trustworthiness.

Implications are suggested for both theoretical and managerial perspectives.

5.1. Theoretical implications

5.1.1. Industrial symbiosis

The CBC model integrates both classical units of the business cluster and circular functions with units from the viewpoint of mutual benefits and concerns; this results in a symbiotic relationship. This type of relationship is industrial symbiosis and the proposed model includes the exchange of circular materials and by-products, circular knowledge and technology know-how in addition to water, energy, materials and by-products.

5.1.2. Transaction cost

The proposed CBC model provides transaction cost savings to clusters in terms of collection, distribution, storage and material handling, inventory control, manufacturing, quality control, maintenance, tooling, education, resource utilisation and waste.

5.1.3. Externalities

The proposed CBC model assures many outcomes to third parties in terms of externalities. These include electric energy to interconnect systems, training and certification programmes to benefit society, a more livable social environment due to reduced emissions and carbon footprint, increasing circular awareness within society, a cleaner environment for inhabitants of the cluster's hinterland as well as better pollution prevention.

5.1.4. Partnership and alliance

The proposed CBC model enhances partnership and cooperation among parties of the cluster. As indicated in the model, most of the circular units have been arranged as joint entities to promote and support collaboration and cooperation under a partnership and alliance concept. For instance, the JCCC requires the participation of all parties within the inner layer of the model to embrace the 6Rs of circular economy, thus providing circular advantages to participants.

5.2. Managerial implications

The managerial implications are presented in two parts. Initially, the managerial implications regarding the proposed CBC model are given. Afterwards, the managerial implications based on prioritisation are stated.

5.2.1. Matrix organisation

The organisational structure of the proposed model is the main aspect of the model. There are classical and proposed circular units in the CBC model. Thus, a robust integration of these units from the traditional cluster and circular cluster should be maintained. Instead of the traditional functional organisational structural model, a matrix organisational model must be adopted in order to meet the holistic nature of the proposed circular business model.

5.2.2. Joint units

The joint units can be organised as independent business companies or joint ventures. However, in order to achieve the promised efficiency and effectiveness of the proposed model, establishing joint ventures by embracing all parties within the boundaries of the model is recommended.

5.2.3. Project management tools

According to the proposed CBC model, most activities will be conducted as a project. Hence, project management tools and techniques are another crucial area for the success of the proposed model. The managers of projects must be skilled in both technical and human relations aspects of leading a team.

5.2.4. Cost-benefit analysis

The proposed model facilitates cost savings for the companies; therefore, a cost-benefit analysis must be conducted to determine the net effect of the model on the overall profitability of the circular business cluster as a whole.

5.2.5. Marketing

Marketing managers of companies within the proposed model should be trained based on the contributions of the circular model towards environmental and social sustainability. Thus, they can design their marketing activities based on the promises of the circular cluster that both their products and companies belong to.

Based on the results of the prioritisation, the following managerial implications are asserted.

Joint Circular Energy Centre (JCEC), one of the highest priority units of the proposed model, will have several managerial implications. Industrial wastes will make a significant contribution to sustainable energy consumption driven by the proposed JCEC to meet growing power demand in clusters through pioneering solutions that are continuously developing. JCEC will develop the best solutions and expertise to improve operational efficiency and protect the investment in the cluster by extending asset life.

Many advantages of present cost savings are being missed in industry today due to the perception that certain kinds of waste cannot be recovered. JCEC will utilise waste recovery solutions for those industrial users in the cluster wishing to reduce operating costs and carbon emissions. On the other hand, renewable energy power utilisation, another opportunity generated by JCEC for cluster companies, is growing as an alternative to bring down costs and assure a clean energy future.

Joint Collection and Classification Centre (JCCC) is the second highest priority unit of the Circular Business Cluster model. Waste is a material or substance which is no longer suited for its intended use. In business clusters, industrial wastes such as textiles, plastics, chemicals, ash, nuclear and others are often highly resistant and take a long time to decompose. Defining and classifying wastes based on requirements of the Circular Business Cluster related to the environment and human health are therefore important in order to provide proper and effective waste management for the business cluster. For the generator or holder, assessing whether a material is waste or not is important in identifying waste processes.

On a more detailed level, a variety of definitions and classification approaches for waste management are used globally; these can be followed by the JCCC. Materials and substances that are directed for recycling or reuse are often regarded as waste since the generator or holder throws them away. Thus, they will only be stated as waste if certain procedures are completed and documented by the JCCC.

Defining and classifying waste sometimes necessitates a case-by-case decision; this can be assessed accurately by a well-organised and qualified collection centre. For example, industrial by-products, such as semi-finished parts and components, can on certain conditions be regarded as non-waste.

Joint Circular Operations Centre (JCOC) is the core unit of the Circular Business Cluster with its qualified seven operations (7R). This unit, together with the collection and classification centre, will generate synergy and will contribute to the circularity of the business cluster. This centre will perform recovery of useful materials such as valuable metals, glass, paper, plastics, and wood from the selected and classified waste stream, so they may be incorporated into the production processes of cluster companies to generate new products.

The required use of raw materials for identical applications is reduced with greater utilisation of recycled materials. Recycling reduces the demand on natural resources for raw materials, while it also facilitates waste materials to be recovered and utilised as valuable resource materials. JCOC will contribute directly to the conservation of natural resources, while reducing energy consumption and emissions. Moreover, the centre will create several economic benefits, cost savings, potential to create jobs and drive growth through the seven operations and knowledge base.

5.3. Policy-maker implications

Policy-makers in many countries are choosing complementary sustainability policies in parallel with productivity and efficiency programmes to achieve the maximum cost-benefit advantage. These policy-makers, governmental bodies, municipalities, NGOs and other institutions appear to recognise that the proposed CBC model, with economy-wide coverage and flexibility, will contribute significantly to cost-effective energy technologies. Complementary policies that are initiated by the proposed context of the model will add value to cluster systems since companies can achieve market success through managerial contributions to circularity and sustainability.

For instance, policy-makers and managers who want to discourse greenhouse gas emissions and challenge climate change will benefit from the ideas behind the CBC model, enriching policy development while adhering to rules and regulations.

Climate policy and targeted energy policies, as well as policies for the effective and efficient use of materials, can be improved with the aim of minimising the cost of meeting national climate goals; such operations can be supported by the proposed CBC model.

6. Conclusion

The scarcity of resources is one of the most critical problems threatening humankind. Thus, there are many published and ongoing studies in different disciplines to explore the efficient use of resources toward sustainability. In that sense, the motivation of this study is to reveal the potential opportunities of a circular economy concept regarding sustainable management.

At the beginning of the research, it was stated that cluster is the most common model in business to utilise resource efficiency and enhance industrial cooperation and collaboration among stakeholders. Existing business clusters have been established and organised based on linear economy principles and operate accordingly. However, the linear structure of business clusters is lacking in consideration of environmental impacts; such a structure, therefore, fails to satisfy the requirements of sustainable management.

Circular activities, waste minimisation, energy savings and efficient use of resources can be realised with the industrial symbiosis generated by new business models. The need arises to integrate clusters as an industrial ecosystem with a circular economy based on industrial symbiosis.

Therefore, within the design of the new model, it is necessary to determine the entities, network relationships, flow of materials and information pathways, stakeholders and business environment for an integrated system.

Accordingly, a novel conceptual model called the ‘Circular Business Cluster Model’ has been developed to adapt both the circular economy and cluster concepts in order to attain long-term sustainability. A Circular Business Cluster Model includes the conceptual framework, network structure, interactions between the cluster components and 6R activities. The combination of the advantages of clustering and circularity creates synergy throughout the supply chain. A case study was conducted to check the applicability of the Circular Business Cluster Model. Eleven centres were examined involving different industries with these centres used as evaluation criteria. The Fuzzy Best-Worst Method (BWM) was used to find the relative criteria weights. The findings reveal that the most important centre to develop the Circular Business Cluster is Joint Collection and Classification Centre (JCCC). The contribution of this paper is to highlight and emphasise the crucial role of circular economy principles to transform a classical business model into an eco-business model.

The most obvious limitation of this study is in the challenges to be faced on the detailed implementation issues; this is due to the fact that the model is currently at the conceptual stage. These challenges will involve the lack of implementation data and the awareness levels of managers within the current clusters. Also, the data collection process includes subjective judgments meaning that the results cannot be generalised. Although the conceptual Circular Business Cluster model is generic in nature, the prioritisation of centres of this model is based on the opinions of experts related to this particular study.

Any future research may concentrate on the development of a model to explore the projected added value that would be generated by the transition from classical cluster to circular cluster. Hence, added value can be appraised in terms of both outcomes and externalities of the proposed CBC. Another future research topic may investigate the relationship between digitalisation and circularity; this would enable the challenges on CBC to be studied from an Industry 4.0 perspective. Also, future possible research could focus on the applicability of the proposed Circular Business Cluster Model in various industries. Additional research may determine the causal relationships among the eleven centres in order to understand the influencing and influenced centres. Case studies in industrial zones and business clusters, such as furniture, agro-food, shoe-making or wine, are suggested as future research areas to put the proposed model into practice.

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