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Modeling Barriers in Circular Economy Using TOPSIS: Perspective of Environmental Sustainability & Blockchain-IoT Technology

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Abstract

Climate change poses a real risk, as does a shortage of resources to accommodate the world's rising population. Every nation is trying to produce maximum without caring for the environment. As a result, the circular economy (CE) is critical to the long-term sustainability of society, business and the environment. Government and policymakers are forcing industries and organizations to adopt or establish CE in their businesses to protect the environment. However, the concept of CE is unclear, and there are various hurdles and barriers to adopting a CE in industries and organizations. For a sustainable environment, CE barrier management plays a crucial role. This paper aims to explore and prioritize barriers to establishing a CE. A detailed methodological literature review is carried out to explore the twenty-nine barriers in CE. The various barriers to CE are prioritized using the Multi-criteria decision-making methods Order of Preference by Similarity to Ideal Solution (TOPSIS). Based on the TOPSIS barrier of increased emission and pollution while recycling was found to be a top rank and the barrier of tedious environmental regulations and lack of government support was found to be at the lowest rank. The top priorities are the barriers to increasing emission and pollution while recycling, radically changing production, and lack of public participation in using recycled products. The Blockchain-IoT architecture and strategies are developed to mitigate all these barriers. As in CE, resources are not ending as these are recyclables since products are made to last several life cycles. Product's lifespans are extended by maintaining, repairing and re-manufacture to reduce carbon footprints in the environment. This barrier ranking will help supply chain professionals and business executives analyze the failure to implement CE in industries. Strategies and architecture based on blockchain-IoT will also help in mitigating the barrier in CE. This study will give new dimensions for the adaption of CE in industries. CE will create sustainable ecosystems for soil, air and water. These sustainable ecosystems provide a long and healthy life for all living things on this planet.

Keywords- Circular economy (CE), Circular supply chain (CSC), Internet of things (IoT), Blockchain, TOPSIS.

Nomenclature and Abbreviations

The list of nomenclatures and abbreviations used in the research work is shown in Table 1.

Table 1. Nomenclature and abbreviations.

Abbreviation	**Full Meaning**
AW	Attribute weight
CE	Circular economy
CBM	Circular Business model
CP	Cost of the product
CSC	Circular supply chain
DM	Decision makers
EN	Effect on the environment
GSCM	Green supply chain Management
IOT	Internet of Things
IS*	Ideal solution
I4.0	Industry 4.0
MCDM	Multiple-criteria decision-making
NIS’	Negative ideal solution
PQ	Product quality
TOPSIS	Technique for order performance by similarity to ideal solution
WSDM	Weighted standardized decision matrix

1. Introduction

In today's world, governments and politicians are under increasing pressure to reform society to become more sustainable by better resource management and closing loops in the production, consumption, and disposal phase of products (Ghisellini et al., 2016; Dubey et al., 2018; Govindan and Hasanagic, 2018; Mishra et al., 2018; Kopnina, 2019; Pieroni et al., 2019). Because there is a considerable risk of the effects of climate change and a lack of resources to meet the world's growing population. Hence, a circular economy (CE) plays a crucial role in making society and industry sustainable (Geissdoerfer et al., 2018; Ngan et al., 2019; Tseng et al., 2019). CE is currently superficial, unclear and unorganized, but several governments and business sectors promote it around the globe to avoid environmental degradation, resource scarcity and price volatility (Genovese et al., 2017; Bodar et al., 2018; Korhonen et al., 2018; Whicher et al., 2018). Many organizations did not care about environmental issues because it would not affect their profit and competitiveness (Ormazabal et al., 2018). CE is a concept that connects resource consumption and trash residuals to turn traditional linear patterns of financial advancement and production into a circular system (Bilitewski, 2012; de Angelis et al., 2018). In CE, cleaner production practices product optimization is achieved by reducing input and using maximum natural, renewable and recyclable resources (Sousa-Zomer et al., 2018).

Industry sustainability is achieved by integrating the CE concept into GSCM for the optimal balance of monetary, communal, and eco-friendly benefits (Zeng et al., 2017; Liu et al., 2018). It reduces the negative effects of production and consumption processes on the environment (Genovese et al., 2017; Kazancoglu et al., 2018). Manufacturing industries are adopting GSCM globally with CSC. The products are reused, recycled and remanufactured, which helps for environmental sustainability (Mangla et al., 2018). Adopting lean SCM practices and green manufacturing reduces waste and supply chain costs (Jadhav et al., 2013a; Jadhav et al., 2013b; Jadhav et al., 2015). There is a strong linkage between CE and IoT technology in the SCM background and project risk management (Rajput and Singh, 2019; Rane et al., 2019). It also helps redesign the business organization for innovation to improve agility in operations (Rane and Narvel, 2021). The supply of critical raw materials has a major issue in their supply chain. It negatively impacts the industry and the economy (Gaustad et al., 2018). To operate SCM in CE effectively, in various uncertainties, risk/barrier management plays a very important role (Ho et al., 2015; Dandage et al., 2018a).

Climate change poses a real risk, as does a shortage of resources to accommodate the world's rising population. As a result, the CE is critical to the long-term sustainability of society, business and the environment. The CE is a framework for systems-level solutions addressing pollution, waste, biodiversity loss, and climate change. Our current linear system must be transformed into CE, including resource management, product creation and consumption, and material disposal. In CE, resources are not ending as these are recyclables since products are made to last several life cycles. Products' lifespans are extended by maintaining, repairing and re-manufacture by reducing carbon footprints in the environment. There are various hurdles and barriers to adopting a CE in industries and organizations. For the sustainable development of CE, barrier management plays a crucial role. So, in this study, barriers to CE are explored and prioritized by the MCDM-TOPSIS method. Later Most prominent barriers are identified to avoid the failure of CE. Blockchain–IoT architecture and strategies are developed to mitigate all these barriers. It will give new dimensions for the adaption of CE in industries. CE will create sustainable ecosystems for soil, air and water. These sustainable ecosystems provide a long and healthy life for all living things on this planet.

2. Literature Survey

A survey of several related publications from journals identified by a significant and reputable publisher was carried out. The publications were generally divided into several categories on a broader basis, and the survey highlights and proves the usefulness of our study work.

2.1 Literature Survey on Circular Economy

The Circular Business model (CBM) is particularly appealing. It promotes the recognition of value creation models and supply chains toward sustainable manufacturing to boost the efficiency of resource usage and urban and industrial waste (Ghisellini et al., 2016; Mishra et al., 2018; Hofmann, 2019; Simon 2019;). Cleaner manufacturing methods enable CE practices to be applied at the micro-level, including waste management, utilization, and assistance. Sousa-Zomer et al. (2018) and Pieroni et al. (2019) reviewed various approaches for an innovative business model for CE and sustainability. Unal and Shao (2019) examined the taxonomy of CE deployment strategies in terms of the relative relevance of material health, material recycling and reuse, renewable energy, water management, and social fairness in the CE. Korhonen et al. (2018) conducted a critical analysis of environmental sustainability. Whicher et al. (2018) established an innovation theory to map design for a CE ecosystem. Heyes et al. (2018) developed a business model for the service industry using information and communication technology. Logit regression revealed that economic forces were the highest effective in persuading linear businesses to use CBM (Gusmerotti et al., 2019). Ngan et al. (2019) suggested a model using the Fuzzy Analytic Network Process to quantify the priority weights of the sustainability indicators to provide advice for industry stakeholders transitioning to the CE. Multi-functional computer models, such as AI, are required to facilitate monitoring, simulation, forecasting, and optimization for decision-making in conjunction with connecting industry 4.0 and CE to maximize production and resource efficiency (Rajput and Singh, 2019; Tseng et al., 2019). Genovese et al. (2017) proposed a categorization of CE business models based on customer value intention and value network, which was tested in some pilot case studies and the ability to adapt CE. D`Amato et al. (2017) found a correlation between environmental sustainability and Green Economy with CE and Bio economy concepts. Hankammer et al. (2019) identified the consumer need for job-to-be-done theory for the circular electronics business model.

Geissdoerfer et al. (2018) discussed and prepared the structure for the sustainability performance of CBM and CSC for implementing it at an industry level (de Angelis et al., 2018). Batista et al. (2018) developed a typical form based on four self-sustaining supply chain narratives:

- Reverse logistics
- Green distribution networks
- Self-sustaining supply chain management
- Closed-loop supply networks

Gaustad et al. (2018) examined the monitoring of critical material supply chain issues in circularity strategies. The deployment of recycling solutions has the potential to reduce risk. Zeng et al. (2017) & Genovese et al. (2017) discovered that organizational pressure strongly influences SCM and SSC design in CE. Zhu et al. (2010) investigated various manufacturing firms regarding environmental-oriented supply chain collaborations and CE practices. Subramanian and Gunasekaran (2015) reviewed cleaner practices at multiple SCM levels and CE levels. Sehnem et al. (2019) examined important success variables for CE adoption utilizing focus enterprises from emerging markets. Thakker and Rane (2018) used a stage-gate method and KPIV and KPOV to implement a green vendor acquisition strategy in the automotive industry.

Almagtome et al. (2020) proposed a method to evaluate the performance of sustainable energy consumption by an integrated reporting framework. Corporate energy performance indicators provide financial and non-financial information.

2.2 Literature Survey on CE and Industry 4.0 Technology

The relationship between Industry 4.0 (I4.0) and CE impacts the economic and ecological effectiveness of the reverse logistics network and the market spread of green products (Dev et al., 2020). Cezarino et al. (2019) investigated the association between I4.0 and CE in emerging countries. It advocates for integrating industrial policies and funding in the refurbishing operation throughout the supply chain. Hybrid categories such as Circular I4.0 and Digital CE provide a novel framework and favourable impact on product lifecycle management (Rosa et al., 2020). Advanced businesses have experts in merging CE principles with parts of the sharing economy. Emerging I4.0-related technologies actively expose the sharing economy as it is applied to product innovation (Jabbour et al., 2020).

Tseng et al. (2019) evolved the CE model by employing self-sustaining manufacturing systems with matrix-like structures. De Sousa Jabbour et al. (2018) developed a roadmap to improve CE principles in organizations through integrating I4.0 techniques and the CE. The circularity of materials inside supply chains can be unlocked by advanced digital technology. Nascimento et al. (2019) investigated how I4.0 technologies may be combined with CE practices to reuse and recycle waste materials such as discarded metal or e-waste. Lin (2018) presented a smart manufacturing method to implement I4.0 in the CE of the glass recycling sector by investigating item's decision-making data systems and data-driven innovations. Dev et al. (2020) developed an operations blueprint for a sustained reverse supply chain by combining I4.0 and CE concepts. Pham et al. (2019) addressed the significant I4.0 variables accelerating CE. In CE implementation, I4.0 provides an enabling foundation for the sharing economy. I4.0 assists in increasing productivity by eliminating waste and boosting the effectiveness of production processes through more precise real-time planning.

Chauhan et al. (2019) used I4.0 to solve CE problems. The (SAP-LAP) linkages architecture is used to examine the applicability of I4.0 methods in resolving challenges in contemporary CE business models. Top management is the most important actor in combining the usage of I4.0 to attain sustainable development and help enhance the CE performance indicators. Abdul-Hamid et al. (2020) created a model to comprehend the problems of Industry 4.0 in CE to achieve social, economic, and environmental sustainability. I4.0 challenges in CE were gathered, and the fuzzy Delphi Method and ISM were used to establish interrelationships to minimize obstacles. Yadav et al. (2020) created a framework connecting SSCM issues with solution measures. For framework testing, a hybrid BWM-ELECTRE technique was used. The case study results demonstrate that managerial and organizational problems are mostly blamed for SSCM adoption failures. Bag et al. (2020) examined the hurdles, drivers, difficulties, and opportunities for I4.0 technology adoption in self-sustaining production and CE capabilities. Bag et al. (2020) evaluated the impact of I4.0 resources on green remanufacturing and smart logistics sustainability. Compared to networked and instrumented logistics, I4.0 has a significantly favourable effect on intelligent logistics. The trend in logistics in the fourth industrial revolution era is toward an intelligent logistics system. As a result, understanding how I4.0 resources influence smart logistics, i.e., integrated transportation, interrelated supply chain, and intelligent logistics, becomes critical.

Blockchain is meant to guarantee that data is securely kept and updated in an unchangeable manner. Blockchain technology may benefit the CE by lowering transaction costs, improving supply chain performance and communication, and lowering carbon emissions (Upadhyay et al., 2021). Kouhizadeh et al. (2019) examine how blockchain technology might help reform and develop the CE. They evaluated and discussed blockchain applications in various industries, at varied acceptance levels, and for different organizational uses. Rane and Potdar (2021) developed a blockchain-IoT Integrated architecture that optimizes the flow of real-time capture, storage, and accessible data and knowledge and minimizes person-dependent operations across the enterprise.

2.3 Literature Survey on Risk/Barriers in the Circular Economy

One of the most significant challenges to building CSC is the cost of collecting, treating, and segregating products, components, and materials (Mishra et al., 2018). Risk management measures have reduced the risk cycle associated with emission and electronic scrap (Lahl and Zeschmar-Lahl, 2013). Bodar et al. (2018) presented risk management in CE chains of reuse resources containing hazardous materials for sustainability and safety. Future changes in policy frameworks and self-help activities that assist a successful CE transition will benefit from it. Dubey et al. (2018) provided a conceptual approach for top management commitment to moderate external influences and CE supplier relationship management methods. Mangla et al. (2018) analyzed barriers using the combined ISM and MICMAC approach. The findings have helped transform supply chains through economic development, focusing on global warming and generating employment. Mahpour (2018) and Ormazabal et al. (2018) identified barriers in waste management to save cost. Issues with agency and ownership, a lack of sustainability integration, and the unknown effects of migrating toward CE have been eliminated. Gaustad et al. (2018) investigated how industries analyze and monitor their sensitivity to fundamental material supply chain challenges and provide circularity options. CE saves the economy, and energy consumption improves social responsibility by using just in time in manufacturing. Kirkire et al. (2015) and Rane et al. (2016) investigated the hazards associated with medical product development. They developed a methodology to reduce risk in the medical product manufacturing industry. Rane et al. (2016) analyzed the HR barriers to successful lean implementation in manufacturing industries.

2.4 Literature Survey on TOPSIS

Various methods, such as multi-criteria decision making (MCDM), are used to rank or prioritize risks, traits, barriers and options based on their significance. MCDM methods are important tools for researchers and practitioners to evaluate, assess, and compare alternatives from various industries (Behzadian et al., 2012; Rodríguez et al., 2017). MCDM is a strong tool frequently used in technical and business applications to solve unstructured problems or difficulties with various contradictory criteria (Sasi and Digalwar, 2015). MCDM methods are used to solve decision problems. The TOPSIS works satisfactorily across different application areas to solve decision problems (Behzadian et al., 2012).

TOPSIS was developed for solving MCDM problems (Singh et al., 2016). In order to choose or rank options that should simultaneously be the farthest from the ideal positive solution and the closest to the ideal negative solution, TOPSIS was utilized (Kuo, 2017; Dutta et al., 2019).

Liao and Kao (2011) used TOPSIS to solve supplier selection problems. Dos Santos et al. (2019) also used TOPSIS for green supplier selection. TOPSIS was used by Zhang et al. (2012) to evaluate independent logistics companies. Fuzzy TOPSIS was utilized by Memari et al. (2019) to select the best sustainable supplier. de Farias Aires et al. (2019) proposed a solution for avoiding rank reversal cases in the TOPSIS algorithm. Mahpour (2018) used the fuzzy TOPSIS approach to prioritize the barriers to CE adoption in building and managing renovation garbage. Dandage et al. (2018a) employed the TOPSIS approach to rank risk categories in multinational projects. Kirkire et al. (2018) employed TOPSIS to rank risk sources during medical device development. Dandage et al. (2018b) used TOPSIS to rank heavy models and the best original equipment manufacturer. El Alaoui (2020) builds a fuzzy TOPSIS model to measure an overall performance indicator for CE. Compared to other MCDM techniques, the TOPSIS Method offers the best and quickest decision to real-world issues. The ability to quantify the relative performance of each alternative in a clear mathematical manner, as well as its superior comprehension and processing efficiency, are all strong points.

The literature shows that the concept of CE is unclear to the organization and society. However, still, governments are forcing to adopt CE in industries. CE presents a new economic potential by decreasing waste, fostering innovation, and generating jobs. Circular business models encourage sharing, reusing, repairing and remanufacturing present goods and products. A CE will help minimize waste since its entire model revolves around the sustainable management of materials in the environment by encouraging the use of renewable resources, promoting the reuse of goods and materials, and promoting sustainable practices. CE helps to manage materials more effectively. Adoption of CE in industries is not an easy task. There are various barriers to adopting a CE in industries and organizations. For the transformation from a linear economy to CE, barrier management plays a very crucial role. So, in this study, barriers to CE are explored and prioritized by the MCDM-TOPSIS method. Later Most prominent barriers are identified to avoid the failure of CE. Blockchain–IoT architecture (Industry 4.0 technology) and strategies are developed, which help to mitigate all these barriers. It will give new dimensions for the adaption of CE in industries. CE will create sustainable ecosystems for soil, air and water. These sustainable ecosystems provide a long and healthy life for all living things on this planet.

2.5 Research Gaps

According to the detailed literature review, there are very high expectations from CE in the current period. However, from the recent research and industrial scenario, it is seen that the concept of CE is unclear. Following research gap is identified.

(i) There are various hurdles and barriers to the adaption of a CBM.
(ii) For the sustainable development of CE, barrier management plays a crucial role.
(iii) This paper presents an exploration of a barrier to CE.
(iv) All barriers are prioritized by the TOPSIS method.
(v) Later this work also proposes blockchain–IoT architecture and strategies to mitigate these barriers. It will give new dimensions for the adaption of CE in industries.

2.6 Expert Inputs for Problem Definition

The following points come up during a discussion with experts.

(i) The concept of CE is unstructured and unclear.
(ii) A high amount of cost is required for converting liner businesses into CBM.

(iii) Unsupportive and lack of commitment in corporate culture for transforming into CBM.
(iv) Less Consumer demand for circular products due to high cost.
(v) The current linear design is insufficient to recycle the product.
(vi) Running machines and infrastructure is insufficient to transfer into CBM.

2.7 Problem Definition

Government and policymakers are forcing industries and organizations to adopt or establish CE in their businesses to protect the environment. However, the concept of CE is unclear, and many barriers to adopting CE in industries. This research explores and prioritizes barriers to CE by the MCDM-TOPSIS method. Blockchain–IoT architecture and strategies are developed to mitigate all concern barriers.

2.8 Research Objectives

(i) To explore the barriers to implementing CE in industries.
(ii) To prioritize the barriers using the TOPSIS method to identify the most prominent barriers.
(iii) To develop Blockchain-IoT-based strategies to mitigate all the barriers to avoid the failure of CE.

3. Research Methodology

3.1 Research Methods Flow Chart

The research methodology flowchart is shown in Figure 1. This flowchart is adopted to achieve the objectives of this research work.

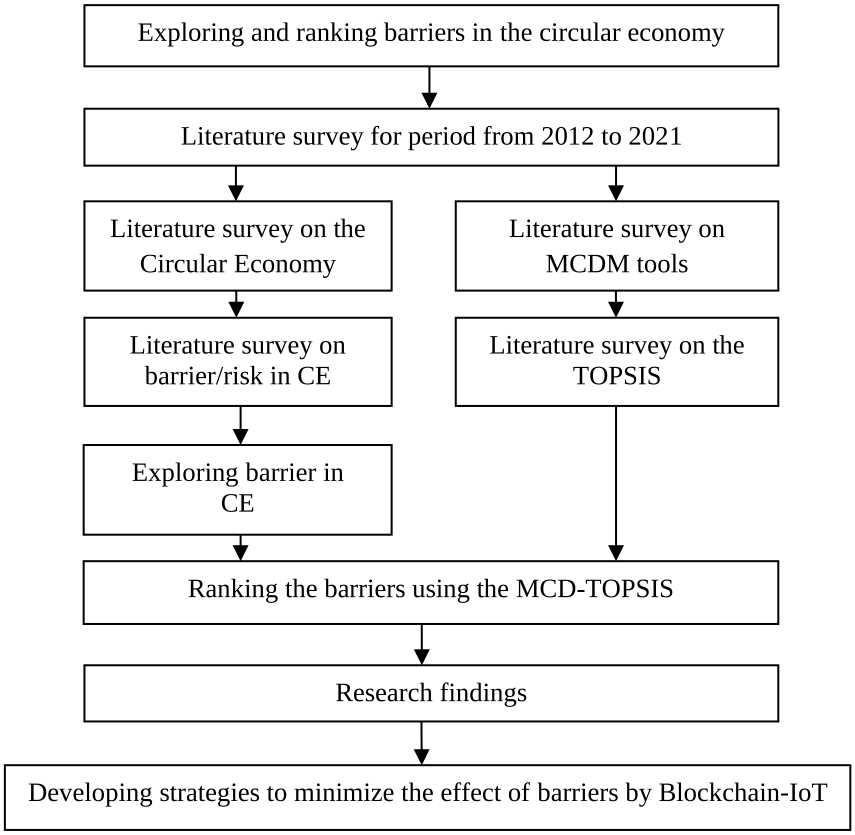

Figure 1. Research methodology.

3.2 Barriers in Circular Economy

From extensive literature surveys and expert input from industry, twenty-nine barriers are identified in adapting CE in industries and organizations. All these barriers are shown in Table 2.

Table 2. Barriers in circular economy.

	Category	Name of barrier	Authors
1	Financial	B1- Increase in environmental cost B2- More financial investment B3- More manufacturing and recycling cost B-4 More Cost of energy consumption	(Beccarello and Di Foggia, 2018; Kazancoglu et al., 2018; Schroeder et al., 2018).
2	Legal	B5- Tedious Environmental regulations and lack of government support	(Genovese et al., 2017)
3	Organizational and management	B6-Lack of incorporating environmental management B7-Lack of cooperation with customers B8-More infrastructure and manpower B9-Lack of a structured policy B10-The change of business cases without the guarantee for success	(Xu et al., 2009, Beccarello and Di Foddia, 2018; Bodar et al., 2018; Kazancoglu et al. 2018; Nadeem et al. 2018)
4	Operational and manufacturing	B11- Lack of machines for recycling toxic and hazardous materials B12- Radically change production B13- Lack of waste reduction Practices	(Zhu et al., 2010; Kazancoglu et al., 2018)
5	Safety	B14- Recycling of hazardous material B15- Health issues, creates safety problems/social security while recycling hazardous material	(Xu et al., 2009; Pan et al., 2015; Bodar et al., 2018; Han et al., 2018)
6	Design	B16- Lack of circular design approach	(Kazancoglu et al., 2018)
7	Social	B17-Lack of public participation to use the recycled product B18-Changing consumer demands	(Nadeem et al., 2018)
8	Technical	B19- Lack of proper recycling technology	(Nadeem et al., 2018)
9	Inventory	B20- Hazardous and unrecyclable material B21-Supply of critical raw materials	(Pan et al., 2015; Bodar et al., 2018; Gaustad et al., 2018)
10	Supplier selection	B22- Lack of cooperation from suppliers	(Zeng et al., 2017)
11	Packaging	B23- Recycling of packaging materials B24- Poor cooperation with customers and suppliers in packaging	(Zhu et al., 2010; Beccarello et al., 2018)
12	Logistics	B25- Increase in reverse transportation cost B26- Movements of hazardous wastes and their disposal	(Zhu et al., 2010; Bodar et al., 2018; Kazancoglu et al., 2018)
13	Environmental	B27- Increase emission and pollution B28- Increase e-waste	(Pan et al., 2015; Han et al., 2018; Kazancoglu et al., 2018)
14	Energy	B29- More energy consumption	(Pan et al., 2015)

1: Financial

B1- Increase in Environmental Cost- The environmental cost can increase due to the higher scrap recycling and disposal cost. Additional costs can also increase for environmentally-friendly products and materials (Kazancoglu et al., 2018). E-waste is the highest growing waste internationally (Schroeder et al., 2018).

B2- More Financial Investment- More investment is required to install new machines to recycle scrap and rework (Kazancoglu et al., 2018).

B3- More Manufacturing and Recycling Cost- Cost of manufacturing is increased by replacing a liner system with a circular system (Beccarello and Di Foggia, 2018; Kazancoglu et al., 2018).

B4- More Cost for Energy Consumption- Consumption of energy is increased for recycling the waste (Kazancoglu et al., 2018).

2: Legal

B5- Tedious Environmental Regulations and Lack of Government Support- CSC may have top-down government support due to tedious environmental regulations (Genovese et al., 2017).

3: Organizational and Management

B6- Lack of Incorporating Environmental Management- Commitment from managers, employees and eco-services can play an important role in CE (Kazancoglu et al., 2018).

B7- Lack of Cooperation with Customers- Without proper cooperation from customers, it is not easy to develop green suppliers, design, production, procurement, products, and marketing (Kazancoglu et al., 2018; Nadeem et al., 2018).

B8- More Infrastructure and Manpower- More infrastructure can be required for new machinery and processes per CE Models (Xu et al., 2009).

B9- Lack of a Structured Policy- Without a structural policy, CE is not adopted at the industrial and consumer level (Nadeem et al., 2018).

B10- The Change of Business Cases Without the Guarantee for Success- There will be no guarantee for success by converting linear business models into CBM (Bodar et al., 2018).

4: Operational and Manufacturing

B11- Lack of Machines for Recycling Toxic and Hazardous Materials- Special purpose machines can be required to recycle toxic and hazardous Materials (Zhu et al., 2010; Kazancoglu et al., 2018).

B12- Radically Change Production- Existing set linear production system is to change with a circular production system (Zhu et al., 2010).

B13- Lack of Waste Reduction Practices- Waste reduction and pollution monitoring equipment can be required in CE (Kazancoglu et al., 2018).

5: Safety

B14- Recycling of Hazardous Material- Hazardous substances have re-entered the environment by reusing or recycling waste materials (Xu et al., 2009; Bodar et al., 2018; Han et al.,2018).

B15- Health Issues Create Safety Problems/Social Security While Recycling Hazardous Material- Using chemically bounded and hazardous chemical materials increase health and public barriers (Pan et al., 2015; Bodar et al., 2018; Han et al., 2018).

6: Design

B16- Lack of Circular Design Approach- Whole business model is to be redesigned as per the circular approach (Kazancoglu et al., 2018).

7: Social
B17- Lack of Public Participation in Using a Recycled Product- Public participation is one of the barriers without which adopting a circular economy is not possible (Nadeem et al., 2018).

B18- Changing Consumer Demands- Consumers are not accepting the products produced from recycled materials due to the wrong perception like durability and performance (Nadeem et al., 2018).

8: Technical
B19- Lack of Proper Recycling Technology- Still, proper and efficient technology is not available for recycling materials (Nadeem et al., 2018).

9: Inventory
B20- Hazardous and Unrecyclable Material- The presence of hazardous materials or substances in the inventory is the major hurdle in CE (Pan et al., 2015; Bodar et al., 2018; Gaustad et al., 2018).

B21- Supply of Critical Raw Materials- Critical material supply is a potential issue in CE. Its disruptions can negatively impact organizations and economies (Gaustad et al., 2018).

10: Supplier Selection
B22- Lack of Cooperation from Suppliers- Without proper cooperation from suppliers, environmental and social benefits cannot be achieved (Zeng et al., 2017).

11: Packaging
B23- Recycling of Packaging Materials- In CE, packaging waste management plays a key role. It required a different financial mechanism (Beccarello and Di Foggia, 2018).

B24- Poor Cooperation with Customers and Suppliers in Packaging- Poor cooperation with suppliers for reducing packaging leads to damage CE (Zhu et al., 2010).

12: Logistics
B25- Increase in Reverse Transportation cost- The cost of transportation increased due to reverse logistics, i.e., recycling, reproducing, and rewording (Zhu et al., 2010; Kazancoglu et al., 2018).

B26- Movements of Hazardous Wastes and Their Disposal- Moving and transporting critical material is challenging (Bodar et al., 2018).

13: Environmental
B27- Increase Emission and Pollution- While recycling the by products from different processes like flue emission gases, fly and bottom ash are generated. It can create a barrier to the environment (Pan et al., 2015; Kazancoglu et al., 2018).

B28- Increase e-Waste- Cu, Sb, Cd, Zn and Co is added to the environment due to recycling e-waste. It seriously affects human health (Han et al., 2018).

14: Energy
B29- More Energy Consumption- Additional Energy can require for waste recycling and treatment (Pan et al., 2015).

4. Ranking Barriers using MCDM- TOPSIS Method

We adopted the Delphi method to select the most prominent fourteen barriers from twenty-nine barriers from the literature survey and expert inputs, which is shown in Table 3.

Table 3. Barrier in circular economy.

S. No.	Name of barrier
B1	More financial investment
B2	Tedious Environmental regulations and lack of government support
B3	Lack of incorporating environmental management and customer
B4	Radically change production
B5	Health issues, creates safety problems/social security while recycling hazardous material
B6	Lack of circular design approach
B7	Lack of public participation to use recycled product
B8	Lack of proper recycling technology
B9	Hazardous and unrecyclable material
B10	Lack of cooperation from suppliers
B11	Recycling of packaging materials
B12	Increase in reverse transportation cost
B13	Increase emission and pollution while recycling
B14	More energy consumption

Four Experts from different sectors are selected as Decision Makers (D.M.). The criteria to rate the different barriers of CE consist of impact on the cost of the product (CP), effect on the environment (EN), Green supply chain Management activities (GSCM) and product quality (PQ). We asked DM to give a rating to each barrier by considering the above four criteria. On a ten-point scale, DM ranks the barriers for each criterion. The barrier has a one-to-ten impact on the criterion, with one being the least and ten being the most. Responses collected from four experts (DM) are summarized in Table 4.

Step 1: Formation of decision matrix

Table 3 displays D.M.'s comments depending on the effect of each barrier on CE's failure to meet the specified four criteria. The attribute weight (AW) is the average of all D.M. ratings for each criteria. The final decision matrix, shown in Table 5, illustrates the AW for each barrier concerning each criterion.

Step 2: Standardization of decision matrix

As shown in Table 6, each value of the final decision matrix is divided by the root of the sum of the squares of the values in the associated row for standardization.

Step 3: Weighted standardized decision matrix (WSDM)

The WSDM is formed by multiplying AW to each rating shown in Table 6. The WSDM is shown in Table 7.

Step 4: To find IS and NIS Ideal solution

Ideal Solution (IS): It is a collection of the highest values from each criterion row in the WSDM. As a result, by referring to the data in Table no 7,

(IS) = [2.37, 2.72, 2.34, 2.56]

Negative Ideal Solution (NIS): It is a collection of the lowest values from each criterion row in the WSDM. As a result, by referring to the data in Table 7,

Negative Ideal solution (NIS) = [1.76, 1.79, 1.69, 1.61]

Table 4. Responses collected from DM's.

B1: More financial investment

	Decision Makers				AW
	I	II	III	IV	
CP	8	8	7	7	7.5
EN	8	7	6	8	7.25
GSCM	9	7	8	8	8
PQ	9	8	7	8	8

B2: Tedious environmental regulations and lack of government support

	Decision Makers				AW
	I	II	III	IV	
CP	7	6	7	6	6.5
EN	7	7	6	7	6.75
GSCM	7	8	6	7	7
PQ	6	6	7	7	6.5

B3: Lack of incorporating environmental management and customer

	Decision Makers				AW
	I	II	III	IV	
CP	8	7	8	8	7.75
EN	8	9	8	9	8.5
GSCM	9	8	9	9	8.75
PQ	7	7	6	6	6.5

B4: Radically change production

	Decision Makers				AW
	I	II	III	IV	
CP	8	9	7	8	8
EN	8	9	9	9	8.75
GSCM	6	7	8	8	7.25
PQ	8	9	9	9	8.75

B5: Creates health issues, safety problems/social security while recycling hazardous material

	Decision Makers				AW
	I	II	III	IV	
CP	6	7	7	7	6.75
EN	9	8	9	9	8.75
GSCM	7	7	7	6	6.75
PQ	7	6	7	7	6.75

B6: Lack of circular design approach

	Decision Makers				AW
	I	II	III	IV	
CP	9	9	9	8	8.75
EN	6	7	6	6	6.25
GSCM	9	9	9	9	9
PQ	8	9	9	9	8.75

BC7: Lack of public participation to use recycled product

	Decision Makers				AW
	I	II	III	IV	
CP	8	8	9	9	8.5
EN	7	7	8	8	7.5
GSCM	8	9	9	8	8.5
PQ	9	9	9	8	8.75

B8: Lack of proper recycling technology

	Decision Makers				AW
	I	II	III	IV	
CP	8	9	9	9	8.75
EN	8	7	8	8	7.75
GSCM	7	7	7	7	7
PQ	8	8	8	7	7.75

B09: Hazardous and unrecyclable material

	Decision Makers				AW
	I	II	III	IV	
CP	8	8	8	9	8.25
EN	9	9	9	9	9
GSCM	8	9	9	9	8.75
PQ	6	7	7	6	6.5

B10: Lack of cooperation from suppliers

	Decision Makers				AW
	I	II	III	IV	
CP	8	9	9	9	8.75
EN	8	8	7	8	7.75
GSCM	8	9	8	8	8.25
PQ	8	8	8	9	8.25

B11: Recycling of packaging materials

	Decision Makers				AW
	I	II	III	IV	
CP	9	9	9	8	8.75
EN	8	8	8	9	8.25
GSCM	8	8	7	8	7.75
PQ	6	5	7	5	5.75

B12: Increase in reverse transportation cost

	Decision Makers				AW
	I	II	III	IV	
CP	9	9	8	9	8.75
EN	9	8	9	8	8.5
GSCM	9	9	9	9	9
PQ	5	6	6	5	5.5

B13: Increase emission and pollution while recycling

	Decision Makers				AW
	I	II	III	IV	
CP	8	9	9	9	8.75
EN	10	9	10	9	9.5
GSCM	9	8	8	9	8.5
PQ	8	7	8	8	7.75

B14: More energy consumption

	Decision Makers				AW
	I	II	III	IV	
CP	8	8	8	7	7.75
EN	9	9	9	9	9
GSCM	6	7	8	5	6.5
PQ	4	5	6	7	5.5

Table 5. Final decision matrix.

	Barriers													
Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
CP	7.5	6.5	7.75	8	6.75	8.75	8.5	8.75	8.25	8.75	8.75	8.75	8.75	7.75
EN	7.25	6.75	8.5	8.75	8.75	6.25	7.5	7.75	9	7.75	8.25	8.5	9.5	9
GSCM	8	7	8.75	7.25	6.75	9	8.5	7	8.75	8.25	7.75	9	8.5	6.5
PQ	8	6.5	6.5	8.75	6.75	8.75	8.75	7.75	6.5	8.25	5.75	5.5	7.75	5.5

Table 6. Standardized decision matrix (SDM).

	Barriers													
Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
CP	0.246	0.213	0.254	0.263	0.222	0.287	0.279	0.287	0.271	0.287	0.287	0.287	0.287	0.254
EN	0.238	0.221	0.279	0.287	0.287	0.205	0.246	0.254	0.295	0.254	0.270	0.279	0.311	0.295
GSCM	0.268	0.235	0.293	0.243	0.226	0.302	0.285	0.235	0.293	0.277	0.260	0.302	0.285	0.218
PQ	0.293	0.238	0.238	0.320	0.247	0.320	0.320	0.283	0.238	0.302	0.210	0.201	0.283	0.201

Table 7. Weighted standardized decision matrix (WSDM).

	Barriers													
Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
CP	2.031	1.760	2.099	2.167	1.828	2.370	2.302	2.370	2.234	2.370	2.370	2.370	2.370	2.099
EN	2.079	1.935	2.437	2.509	2.509	1.792	2.150	2.222	2.580	2.222	2.365	2.437	2.724	2.580
GSCM	2.078	1.818	2.273	1.883	1.753	2.338	2.208	1.818	2.273	2.143	2.013	2.338	2.208	1.688
PQ	2.340	1.902	1.902	2.560	1.975	2.560	2.560	2.267	1.902	2.414	1.682	1.609	2.267	1.609

Step 5: Separation from ideal solution (IS) (Si^*)

The IS value is subtracted from each criterion for all related values for separating IS from WSDM. It is the square root of the sum of all separation values from IS for those barriers, shown in Table 8.

Table 8. Separation from IS.

	Barriers													
Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
CP	0.115	0.372	0.073	0.041	0.294	0.000	0.005	0.000	0.018	0.000	0.000	0.000	0.000	0.073
EN	0.411	0.616	0.080	0.045	0.045	0.862	0.325	0.248	0.020	0.248	0.126	0.080	0.000	0.020
SCM	0.069	0.272	0.005	0.209	0.344	0.000	0.017	0.272	0.005	0.039	0.107	0.000	0.017	0.424
PQ	0.048	0.433	0.433	0.000	0.342	0.000	0.000	0.086	0.433	0.021	0.771	0.904	0.086	0.904
Si*	0.802	1.301	0.769	0.543	1.012	0.928	0.589	0.778	0.690	0.555	1.002	0.992	0.321	1.192

Step 6: Separation from negative ideal Solution NIS (Si’)

As a result, referring NIS value is subtracted from each criterion for all related values for separating NIS from WSDM. The separation from NIS for each barrier is the square root of the sum of all values of separation from NIS for that barrier which is shown in Table 9.

Table 9. Separation from NIS (Si’).

	Barriers													
Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
CP	0.074	0.000	0.115	0.165	0.005	0.372	0.294	0.372	0.225	0.372	0.372	0.372	0.372	0.115
EN	0.083	0.021	0.418	0.516	0.516	0.000	0.130	0.187	0.624	0.187	0.331	0.418	0.872	0.624
GSCM	0.151	0.016	0.340	0.037	0.004	0.420	0.268	0.016	0.340	0.205	0.104	0.420	0.268	0.000
PQ	0.534	0.085	0.085	0.902	0.133	0.902	0.902	0.432	0.085	0.646	0.005	0.000	0.432	0.000
Si'	0.917	0.350	0.979	1.273	0.811	1.302	1.263	1.003	1.129	1.187	0.901	1.100	1.394	0.860

Step 7: To find closeness to IS

Closeness values to IS are shown in Table 10.

Table 10. Closeness to ideal solution.

	Barriers													
Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Si*	0.802	1.301	0.769	0.543	1.012	0.928	0.589	0.778	0.690	0.555	1.002	0.992	0.321	1.192
Si'	0.917	0.350	0.979	1.273	0.811	1.302	1.263	1.003	1.129	1.187	0.901	1.100	1.394	0.860
(Si*+Si')	1.719	1.651	1.748	1.816	1.823	2.230	1.852	1.781	1.819	1.742	1.903	2.092	1.715	2.052
Si'/(Si*+Si')	0.533	0.212	0.560	0.701	0.445	0.584	0.682	0.563	0.621	0.681	0.474	0.526	0.813	0.419
Rank	**9**	**14**	**8**	**2**	**12**	**6**	**3**	**7**	**4**	**5**	**11**	**10**	**1**	**13**

Step 8: Ranking of barriers

Table 11 shows the ranking of considered fourteen barriers based on their closeness to IS.

Table 11. Ranking of barriers in circular economy based on TOPSIS.

Rank	Barriers	
1	B 13	Increase emission and pollution while recycling
2	B 4	Radically change in production
3	B 7	Lack of public participation to use recycled product
4	B 09	Hazardous and unrecyclable material
5	B 10	Lack of cooperation from suppliers
6	B 6	Lack of circular design approach
7	B 8	Lack of proper recycling technology
8	B 3	Lack of incorporating environmental management and customer
9	B 1	More financial investment
10	B 12	Increase in reverse transportation cost
11	B 11	Recycling of packaging materials
12	B 5	Creates health issues, safety problems/social security while recycling hazardous material
13	B 14	More energy consumption
14	B 2	Tedious Environmental regulations and lack of government support

5. Results

As explained in section 3, fourteen barriers are selected from the literature survey and expert's inputs. Various prominent barriers must be considered while implementing CE in industries since it harms their success. The MCDM-TOPSIS technique ranks the fourteen CE-specific barriers in order of relative ranking. The TOPSIS approach was used to rank the feedback gathered by four DM on the effect of fourteen barriers on the CE based on four criteria: product cost, impact on the environment, green supply chain management, and product quality.

The maximum relative closeness to the ideal solution shows that the particular barrier has the maximum impact during the implementation of CE for the industries. Hence, barriers like increased emission and pollution while recycling are at the top rank, whereas tedious environmental regulations and lack of government support are at the lowest. The top five barriers are increased emission and pollution while recycling, radically changing production, lack of public participation in recycled products, hazardous and unrecyclable material and lack of cooperation from suppliers.

6. Discussions

CE is essential to the long-term sustainability of society, business and the environment. The CE resolves environmental issues like pollution, waste, biodiversity loss, and climate change. Products' lifespans are extended by maintaining, repairing and re-manufacture. It helps for reducing carbon footprints in the environment. The literature shows that the concept of CE is unclear to the organization and society. However, still, governments are forcing to adopt CE in industries. CE presents a new economic potential by decreasing waste, fostering innovation, and generating jobs. Adoption of CE in industries is not an easy task. There are various barriers to adopting a CE in industries and organizations. For the sustainable development of CE, barrier management plays a crucial role. The MCDM -TOPSIS method results show that barriers like the Increase in emission and pollution while recycling is at the top rank, and tedious environmental regulations and lack of government support are at the lowest. Top-ranked barriers include increased emission and pollution while recycling, radically changing production, lack of public participation in using a recycled product, hazardous and unrecyclable material and lack of cooperation from suppliers, which must be paid more attention to while adapting or implementing CE in industries. A CE will help minimize waste since its entire model revolves around the sustainable management of materials in the environment by encouraging the use of renewable resources, promoting the reuse of goods and materials, and promoting sustainable practices. CE helps to manage materials more effectively.

For the transformation from a linear economy to CE, barrier management plays a very crucial role. Blockchain–IoT architecture (Industry 4.0 technology) and strategies are developed, which help to mitigate all these barriers. The following sub-section mentions a detailed explanation of all blockchain IoT strategies. This action plan will mitigate the high-ranked barriers while adapting the CE to protect the environment, minimize the cost of the product, maintain good product quality, and sustainable green supply chain management. It will give new dimensions for the adaption of CE in industries. CE will create sustainable ecosystems for soil, air and water. These sustainable ecosystems provide a long and healthy life for all living things on this planet.

6.1 Blockchain –IoT Architecture for CE

Blockchain is a digital database that records relevant data from IoT devices in connected blocks to create an official record of activities in real-time. The CE can benefit from blockchain-IoT technology that can help with sustainable resource management, reducing waste and product recycling and reuse. Blockchain-IoT technology lowers overhead costs, improves supply chain performance and transparency, and reduces carbon footprint. It also encourages the use of circular designs.

The Blockchain-IoT architecture for CE is shown in Figure 2. Blockchain-IoT technology can create transparent digital supply chains by providing an unchangeable record of transactions that confirm the provenance of products until it reaches the end-users. It creates faith in all stakeholders. It also improves the communication and efficacy of organizations. Policymakers and top management can track all of this information and data. With customers increasingly demanding ethical and sustainable products, blockchain companies have a unique chance to adapt to this market trend. The blockchain-IoT based enables the tracing critical suppliers and products once they leave the plant. They allow us to see where a product ends up and how it will be reused and recycled in real-time. It also improves the tracking, calculation, and optimization of banned materials such as the plastic used for packaging. Government authorities or policymakers can control the emission level that helps to maintain a sustainable environment. Blockchain-IoT also increases resource value, allowing for a new natural resource trading system and rewarding individuals to adopt Circular activities. Blockchain–IoT helps reduce energy consumption during manufacturing and logistics support to reduce carbon footprint.

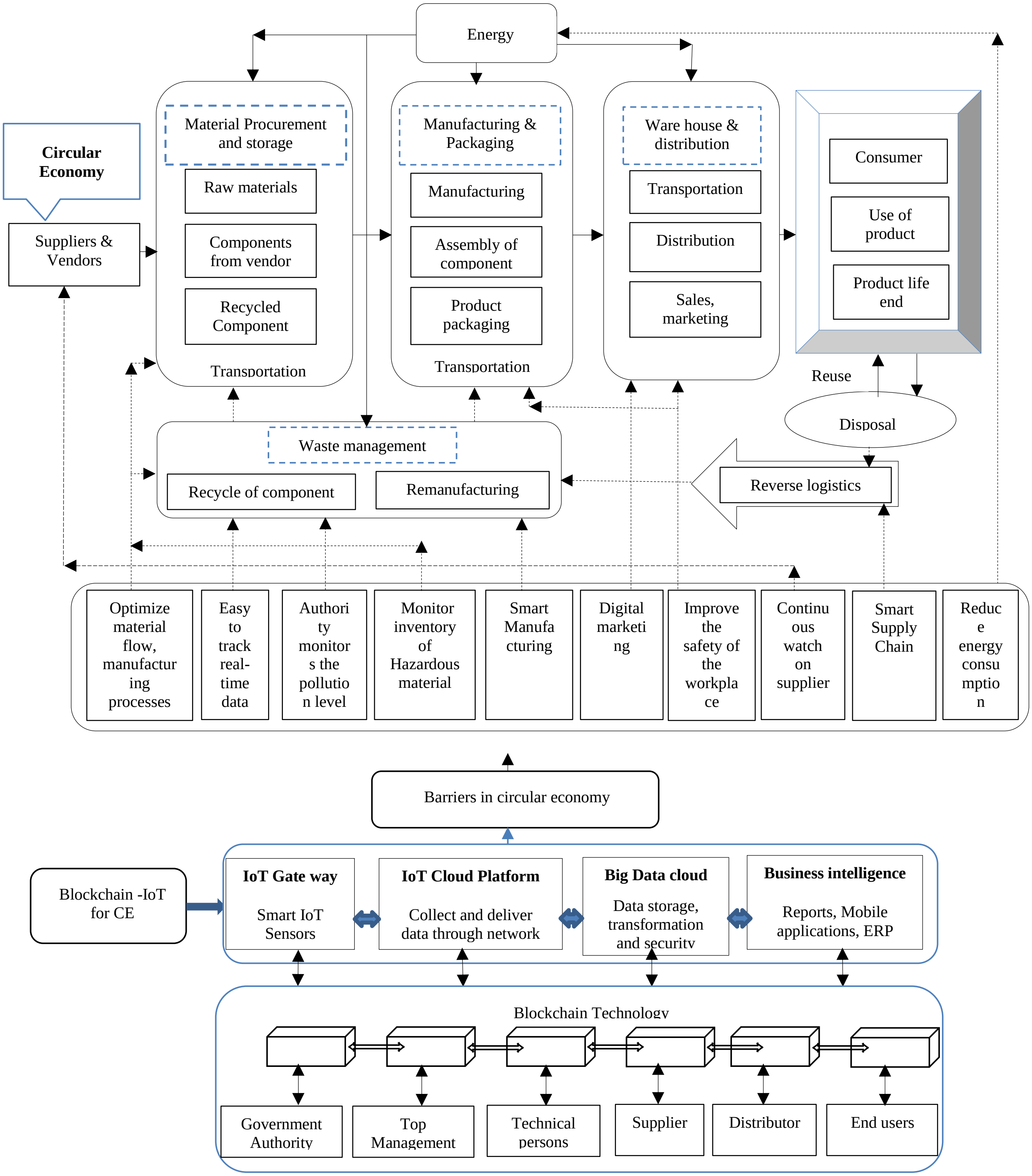

Figure 2. Blockchain–IoT architecture for CE.

6.2 Blockchain- IOT Based Strategies to Mitigate Barriers in CE

B1- More financial investment- In CE, there is a barrier to an increase in waste treatment costs, the cost of energy, manufacturing costs, and rework costs. This barrier can be mitigated by using IoT. Proximity, capacitive smart sensors, RFID tags in-store inventory, and robotic manufacturing machines collect data from various points through node MCU. Clouds like Google cloud, Microsoft Azure, and IBM Watson Cloud analyze the data from the blockchain and optimize material flow, manufacturing processes and operations. It can help to reduce wastage and rework. It can also identify the availability and improve the machine's usability to minimize energy consumption and manufacturing and reworking costs.

B2- Tedious Environmental regulations and lack of government support- There are tedious environmental regulations and no longer support government bodies, but government authorities can connect with industries through IoT and Industry 4.0 technologies. They can monitor the pollution level (air quality) with the set threshold. The gas sensors like MQ 131, MQ 7, MG 811, and MK 135 sense the air pollution level, and the big data is delivered continuously to the controller raspberry pi through Node MCU and cloud. Data stored on the blockchain is authenticated and transparent data that government authorities can control. The government air quality performance center monitors big data from the blockchain. It will help complete legal procedures by collecting, analyzing and monitoring existing big data.

B3- Lack of incorporating environmental management and customer- Lack of management support and cooperation with the customer can be mitigated through IoT and Analytics. The data collected from various motion and position sensors like passive infrared motion sensors, microwave, ultrasonic sensors, potentiometer, proximity sensors, magnetic position sensors etc., are big real-time data that sense the movement or stoppage of parts, machine elements and people. This real-time data is connected through an analytics-driven cloud platform Mobile application through blockchain that will help the management track and monitor day-to-day operations in real-time. It will help to develop a structured policy.

B4- Radically change production- The machinery that handles the hazardous material can be connected through IoT; it can transmit operational information data to the partners, manufacturers, and field engineers through IoT Sensors like MK 135. It will help managers and industry heads remotely manage the industry through the cloud platform. IoT sensors like thermocouples, RTD, Infrared cameras to sense temperature and accelerometers and microphones to sense vibrations and noise for continuous condition-based maintenance monitoring for critical machine tools and processes which handle critical, toxic and hazardous material. IoT manufacturing can monitor the production lines from raw material selection to packaging. It will help reduce waste, conserve energy, reduce machine downtime and reduce the overall cost.

B5- Creates health issues, safety problems/social security while recycling hazardous material- IoT can improve the safety of the workplace. IoT gas sensors like MQ 131, MQ 7, MG 811, and MK 135 sense the air quality and signal the controller like Raspberry Pi and Arduino through Node MCU. Clouds IoT platforms like Google Cloud, Microsoft Azure, IBM Watson Cloud etc., monitor and restrict hazardous processes and workplaces by removing human beings from danger. So, by interfacing IoT sensor data and existing environmental data stored on the blockchain, past events are identified and analyzed for mitigating future risks.

B6- Lack of circular design approach- Different IoT Sensors collect big real-time and transparent data from physical devices, which target identifying the issues in the manufacturing or other means. This IoT cloud data from blockchain helps the designers redesign the business according to the required approach.

B7- Lack of public participation to use recycled product- The needs and requirements of end-users or customers can easily be identified through IoT. The big data from the cloud-like AWS IoT platform, Cisco IoT, and Oracle cloud platform, through blockchain industry management and admin panel, can decide through analytics and plan to motivate customers to use the recycled product through digital marketing. IoT helps manufacture a recycled product at minimum cost by using automation like robotics applications controlled by Google Cloud, Microsoft Azure, IBM Watson Cloud etc. With sensing the different parameters through sensors and node MCU. It can help to sustain in a competitive market. Fastly changing customers, demand can be fulfilled instantly with minimum time by using IoT.

B8- Lack of proper recycling technology- Industries are moving towards manufacturing fuel-efficient and electric vehicles to minimize emission levels. IoT gas sensors like MQ 131, MQ 7, MG 811, and MK 135 sense the emission level and give the signal to a controller like Raspberry Pi and Arduino through Node MCU. Clouds IoT platforms like Google Cloud, Microsoft Azure, IBM Watson Cloud etc. monitor the emission level of different sources, making it easy to monitor and control emission levels through blockchain-IoT. It can help for a smooth changeover to a circular economy.

B9- Hazardous and unrecyclable material- Maximum raw material storage creates the barrier; IoT can mitigate this barrier. Radiofrequency identification (RFID) tags on parts or shipping logistics, smart proximity sensors, product codes and GPS sensors that track inventory records can easily be made on cloud platforms. When there is a demand for components, they will order from suppliers and consumers. IoT applications monitor the inventory supply chain globally through sensors, controllers, cloud and blockchain applications. It provides cross-channel visibility to supply chain professionals and managers regarding realistic material available, work in progress and estimated arrival of new material. It allows for just-in-time concepts. Robotics applications can easily handle hazardous material through artificial intelligence.

B10- Lack of cooperation from suppliers- IoT radio frequency identification (RFID) tags on parts or shipping logistics, smart proximity sensors, monitor and maintain the supply of inventories through cloud platforms. IoT camera sensors can help keep a continuous watch on the suppliers to maintain the quality of the product. Time big data taken from a cloud platform and stored on the blockchain can also help select a proper supplier and enforce the supplier to deliver the right material and components, which helps circular production.

B11- Recycling of packaging materials- Using IoT Smart Sensors for packaging, the manufacturer uses different patterns and codes, which help handle the product from different customers. IoT tracking can also track product damage during transportation due to road, weather and other environmental conditions. Artificial intelligence can use to pack hazardous materials. Using non-recyclable material for packaging can be avoided by proper tracking through IoT smart sensors.

B12- Increase in reverse transportation cost- Using the IoT sensors like IoT radio frequency identification (RFID) tags on parts or shipping logistics, smart proximity sensors, location and other data of components during logistics can track and communicated to supply chain managers and clients through controller raspberry pi and different clouds like Google Cloud, Microsoft Azure, IBM Watson Cloud etc and blockchain. GPS Sensors identify the location of logistics, shortest paths and mode of transportation. It will minimize transportation costs. IoT proximity sensors help to identify empty or half pallets in logistics. The parameters like temperature, humidity and damage of components can be monitored and controlled in transportation using different IoT sensors like thermocouple, RTD, Infrared camera to sense temperature, DHT- 11 to sense humidity and camera sensors.

B13- Increase emission and pollution while recycling- IoT has great potential to monitor transportation, energy consumption and water consumption. It will reduce waste and manage the consumption of inventory. It can detect the pollution level, hazardous substances, chemicals, and gases, which can help keep track to protect the environment. Digital gas sensors like MQ 131, MQ 7, MG 811, and MK 135 sense the air pollution level, and the big data is delivered continuously to the controller raspberry pi through Node MCU. The Admin panel monitors the big data from the blockchain. While recycling the materials increases emission and pollution, IoT systems can be monitored and controlled by using limited energy and resources.

B14- More energy consumption- Energy can be saved using IoT systems to control heat and air conditioning usage in manufacturing and different processes. IoT sensors can save energy in their slip mode. Energy can save by optimizing material flow during manufacturing processes, reducing machine lead time and minimizing rework and scrap by IoT sensor-based robotic applications.

7. Conclusion

The study identifies twenty-nine significant barriers and potential problems in adopting the circular economy. The Delphi method was used to choose the fourteen most prominent barriers from twenty-nine. The MCDM-TOPSIS method was used to rank various barriers. The top-ranked barrier was increased emission and pollution while recycling, and the lowest-ranked barrier was tedious environmental regulations and lack of government support. Exploring various barriers during the planning phase of CE's installation or adoption might help industries design a strategy for transitioning from a linear economy to a CE. To overcome these barriers to CE, blockchain-IoT-based architecture and strategies have been developed. CE professionals will benefit significantly from ranking barriers and strategies for overcoming them, as they will be able to focus and work out according to their ranking. Strategies based on blockchain-IoT will help in mitigating the barrier to CE as Product's lifespans are extended by maintaining, repairing and re-manufacture. It helps to reduce carbon footprints in the environment. Blockchain- IoT technology acts as a driver to CE, but it consists of sensors, microcontrollers and different electronics components. After end of its lifecycle again E- waste is produced. Other Industry 4.0 technologies like AI and machine learning can be used for sustainable CE. This study will give new dimensions for the adaption of CE in industries and different organizations. CE will create sustainable ecosystems for soil, air and water. These sustainable ecosystems provide a long and healthy life for all living things on this planet.

Conflict of Interest

The authors confirm that there is no conflict of interest to declare for this publication.

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