Analysis of Circular Economy Enablers in Manufacturing Context for Indian Industries: A ELECTRE method Ranking Process

Sharma, Manoj
Poornima University

Narayan Lal Jain
Poornima University

Jayant Kishor Purohit
Banasthali University

https://doi.org/10.5109/7148437

出版情報：Evergreen. 10 (3), pp.1156-1168, 2023-09. 九州大学グリーンテクノロジー研究教育センター
バージョン：

Analysis of Circular Economy Enablers in Manufacturing Context for Indian Industries: A ELECTRE method Ranking Process

Manoj Sharma[1*], Narayan Lal Jain[2], Jayant Kishor Purohit[3]
[1]Poornima University, Jaipur, Rajasthan, India
[2]Poornima University, Jaipur, Rajasthan, India
[3]Banasthali University, Tonk, Rajasthan, India

*Author to whom correspondence should be addressed:
E-mail: 64manoj@gmail.com

(Received July 15, 2023; Revised August 30, 2023; accepted September 4, 2023).

Abstract: In the era circular economy, a nation's ability to sustainably grow its manufacturing sector is crucial for overall economic development. Therefore, in order to make the industrial sector sustainable and competitive, technologies must be developed with the circular economy in mind. The bulk of manufacturing companies in India fall under the category of small and medium-sized enterprises, which are acknowledged as the foundation of the economy since they generate a sizable portion of the country's GDP. The foundation of modern civilization's economy is the manufacturing sector. This paper attempts to re-examine the idea of a manufacturing-based circular economy system through a review of the scientific literature. In the context of Indian industries, the study pinpointed enablers that support the implementation of the circular economy. These enablers were categorized into six clusters. A survey questionnaire was formulated and the collected data was scrutinized to confirm the validity of these supporting factors. The majority of the manufacturing industries in India fall under the category of small and medium enterprises. A survey questionnaire was sent to the respondents through email, and personal visits were made to nearby industries. Cronbach's alpha count is used to evaluate the validity of important enablers. An expert panel of manufacturing industry managers and technical personnel validates these enablers as affecting how developing countries adopt CE, assigns weights to the enablers, and uses the ELECTRE Method to determine the final ranking of the enablers. The findings imply that technical (ETE) and financial (EFI) enablers are the main enablers for adopting the circular economy within India's industrial sectors. Through this study, the industries are better equipped to comprehend the enablers to the circular economy and develop practical implementation plans.

Keywords: circular economy, environmental, economic, enablers, 3R’s, 4R’s, social

1. Introduction

In the modern era of industrialization, there have been growing business issues over ecological matters caused by industrialization and the arrival of new equipment and machinery. Various researches have been accomplished throughout the preceding decades that represent the past, present, and upcoming conditions of the earth[16)]. There are worries over the weakening of the ozone layer, natural resources, and further harmful ecological consequences. As the human inhabitants of this globe are escalating, the related requirements are also greater than ever. As the need for goods are enhancing; the required manufacturing is also mounting, which ultimately affects the natural arrangements, resources, and ecosystems. These matters make the demand higher than ever before to concentrate on ecological hazards stimulated by industries[30)]. In view of the fact that after the Revolutionary Industrialization, manufacturing industries have been evolving more beneficial business frameworks and strategies to improve what has conventionally been believed to be their principal aims of rising monetary earnings and the turnout of sources. On the other hand, during the last fifteen years, there has been a rising understanding of how current industrial practices affect the environment and the general public. As a result, the traditional industrial viewpoint, which was previously characterized by a linear economic paradigm, is coming under increased criticism from both the government and public[3)]. The scarceness of reserves and the generation of dissipation without ample clearance are global worries associated with the linear economic and manufacturing model. These features are currently used in the industry involved with processing raw materials into end products. Resources are gathered inside this linear economic structure as raw materials, which are subsequently sent to real manufacturing facilities where they are refined into a variety of goods[12]. Due to the linearity of the current manufacturing models, these negative ecological issues have forced businesses in this sector to deal with pressures related to following environmental regulations as well as problems with cost instability and a supply threat brought on by a growing resource shortage[17]. As a way of addressing the environmental, social, and financial imperatives or stimulating situations offered by current production processes, the idea of the circular economy has been gradually gaining prominence and receiving global attention. In contrast to linear corporate strategies, the circular economy idea promotes a self-contained, cyclical flow of resources, raw materials, and energy across the whole economic framework. Environmentalists contend that circularity-based models have the ability to reduce the need for expensive raw materials, reduce energy use, and reduce environmental effects while not impeding on economic, social, and technical advancement[24].

The expansion of resource engagement in the economic cycle is important to circular business models (CBMs), notably within manufacturing systems. In order to achieve this aim, revitalizing techniques must be used to extend the useful life of items, repurpose them for the creation of new ones, and reintegrate their raw materials into the economy via procedures like recycling, replication, and reuse. Therefore, CE advises that manufacturing business models be revitalized in terms of intent, purpose, and blueprint, and that manufacturing value chains be reallocated as they switch from linear to circular manufacturing business models. It was necessary to conduct a thorough, systematic investigation to ascertain how CE norms and processes were being implemented from the standpoint of manufacturing[4]. Through a comprehensive investigation of the literature, this study aims to pinpoint the main enablers to adopting a circular economy in the manufacturing context for Indian industries. The paper is divided into six sections and set up as shown below. The prior evaluations of the circular economy in the scientific literature are included in Section 2. The classification of enablers are researched and summarized in tables in Section 3 in order to create a multi-perspective framework. The research methodology is described in Section 4, and the results and discussion in Section 5. The study's conclusion in Section 6. Finally, section 7 shows the future scope and limitations. Figure 1 also provides a structure for the research investigation.

The research questions for this study are given below:

RQ.1: What are the key enablers of circular economy in the manufacturing context for Indian industries?

RQ.2: How can validate these enablers of the circular economy in the manufacturing context for Indian industries?

RQ.3: How can give a ranking to these enablers of the circular economy in the manufacturing context for Indian industries?

2. Literature Review

The main goal of the literature review in this analysis is to investigate the "Circular Economy" idea in industrial situations. The detailed analysis of the literature clarifies the existing situation, the advancement made so far, the questions addressed, and the initiatives done up to this point. The goal of this study's reevaluation of the existing research is to look at how a manufacturing facility can achieve circularity in manufacturing by using its dynamic capabilities. Circular Manufacturing (CM) is emerging as one of the most rising fields of study in modern times.

According to Fink (1998), writing audits is a deliberate, explicit, and replicable strategy for identifying, rating, and interpreting the current group of recorded archives[10]. The essential tactic for gathering historical information about the exploration region is thought to be a literature review. To identify areas where there are research gaps, this study includes a thorough evaluation of the literature on the circular economy (Sharma et al., 2022). The literature review has been completed throughout with extensive use of the electronic database. From 2000 to 2023, the data aggregation for the writing has been examined. In the 1990s, the circular economy idea was first put out. On the whole, the literature review search yielded 320 pieces of writing, which were cautiously tested for replication. Eventually, 120 objects were chosen for the assessment after a systematic sorting of their title, abstract, methodological analysis, and ending. These selected papers/articles were believed to be substantial as they dealt straightaway with manufacturing circularity. A few research papers dealing with circular economy concepts and applications appeared in the reviewed literature between 2011 and 2020. It is only in the past couple of years (2017-2020) that a noteworthy quantity (approximately 85%) of research work has been executed in this matter.

Up to 2022, the Chinese steel production cycle's manufacture volume, reprocessing activities, and overall iron ore utilization were projected using dynamic material flow analysis[21]. They evaluated steel services, seeing stockpile utilization per capita as a key determinant in future development. To foresee how steel manufacturing enterprises would react to the idea of the circular economy, the whole steel cycle is illustrated. Jiliang and Chen (2013) developed a composite "Circular Economy Index System (CEIS)" by analysing the development characteristics of the circular economy among all connected enterprises within the manufacturing industry chain. The actions taken here were in accordance with the trends and requirements of sustainable supply chain management[13]. A tool developed by the "mixed-integer linear programming (MILP) paradigm" is proposed by (Accorsi et al., 2015) and is used to strategically build a multi-echelon closed-loop supply network[2]. Pagotto and Halog (2015) used developments in data envelopment analysis and material flow analysis to evaluate the eco-efficiency performance of several Australian agri-food association sectors[20]. This guidebook offers advice for firms on environmental and financial matters. The results of this study show that, in order to accomplish the goals of a circular economy, the current component design is now faced with the challenge of anticipating social, economic, and environmental needs[30]. (O'Connor et al., 2016) provided a method to manage the difficulties caused by an exposed unworkable material inventory network, keying out the mechanical review and progress anticipated to advance supportable hardware through the use of green engineering and the notion of a "Circular Economy[19]." (Azevedo et al., 2017) proposed an index to evaluate the circularity and sustainability of manufacturing firms[5]. (Cooper, 2019) focused on the durability of boxes made of rigid board[8]. The claim that "layered board is an eco-friendly material designed for merchandise bundling is examined considering carbon impression, water impression, and Life Cycle information delivered because of extensive investigations expounded by specific bodies and researchers. Circular economy (CE) academic methodologies, practices, and reception cases were covered in the examination structure. After examining various CE implementation strategies and key standards, the focus turns to the crucial issue of creating devices for CE adoption. A study was conducted on the availability of the circular economy concept within Indian Micro, Small, and Medium-Sized Enterprises[14,30]. In their investigation, they said that their goal was to develop a comprehensive Theory of Planned Behaviour model (ETPB) to examine small organizations' perspectives on the circular economy. (Yang et al., 2018) conducted research on plan of action development for circular supply chains and advised that item administration frameworks (PSS) plans of action can increase the circularity of supply chains by esteem creation in internal circles of chains, encompassing broad and flowing down circles[32]. An exploratory contextual analysis was performed on a prominent Chinese manufacturing company that operates using a conventional product-based business structure, along with an examination of three different Product-Service System (PSS) business models[26]. Achieving sustainable operational management relies on the significance of the service and policy framework, while the facilitation of product life cycle management stands out as a primary driver of circular practices[33]. By reimagining trash as a useful resource, the circular economy philosophy aims to reduce greenhouse gas emissions. Enhancing the flow of materials and optimizing their management can be manifested in multiple ways, such as extending the lifespan of products, minimizing material wastage, reutilizing products and materials through circulation, and substituting emission-heavy components with alternatives that have lower carbon footprints[34].

Through the literature survey, it was found that while the vast majority of research papers discuss circular economy reception benefits, the literature emphasizing a structure that aids in the circular economy reception process in production organizations is still inadequate. Within the context of manufacturing, there are limitations to how circular economy facilitators are recognized. Determination of the intensity of influence of the circular economy enablers are extremely significant for the circular economy adoption process. Therefore, based on the opinions of experts from both industries and academia, 22 enablers that are extremely significant to the circular economy were ultimately chosen (as indicated in Table 2). These enablers also support our study's goals. The majority of the articles are connected to China, Brazil, and a few developed nations. On the other hand, there is a paucity of literature and study on the circular economy in India. Through the use of the ELECTRE method ranking approach, this research offers the first examination of the enablers the adoption of a circular economy within the manufacturing sector of Indian enterprises. The incorporation of both a thorough literature review and expert insights in the assessment methodology provides strong support for the significance of this study.

3. Circular Manufacturing Enablers

The circular economy in the manufacturing sector has swiftly gone from esoteric discussions to standard consideration. White papers, scholarly articles, Reports, and recommendations are being created at a breakneck pace. There are several approaches to considering the constraints and facilitators of more information and examples of circular manufacturing can be found in the literature. (Vermunt et al., 2019) classified enablers into two categories, first is Hard - technological and economic—and the second is Soft- institutional and social[31]. (Kirchherr et al., 2017) divide topics into four categories: cultural, market, regulatory, and technological, with the cultural category covering most of the "soft" aspects. The category is useful in recognizing four fronts where work should be made to continue toward CM, despite the fact that allocation is not always straightforward[28]. (Kumar et al., 2019) conduct a thorough assessment of the CM literature and identify a variety of socio-political, economic, legal, and environmental challenges and potential for CM implementation. The discoveries feature important enablers, possibilities, and advantages of Circular Economy for the UK and EU manufacturing industries[9]. Cultural, Regulatory, Financial, Environmental, Technological, and Supply chain management are six categories of enablers into which all of those found in the literature may be classified.

4. Research Methodology

A hypothetical map of research methodology is used in this research paper. This practical study article focuses on finding the enablers that make it easier for Indian firms to adopt the circular economy in their manufacturing sectors. The findings have potential relevance for policymakers and management staff by offering insights into developing methods for integrating the circular economy within the manufacturing framework of Indian firms. According to the frequency of enabling occurrences documented in research publications, the industrial landscape of Indian businesses has 22 enablers relevant to the circular economy. These enablers are then divided into six different groupings. A survey questionnaire was developed, and the results was then analysed in order to support the validity of the discovered enablers. Figure 1 shows the whole research approach.

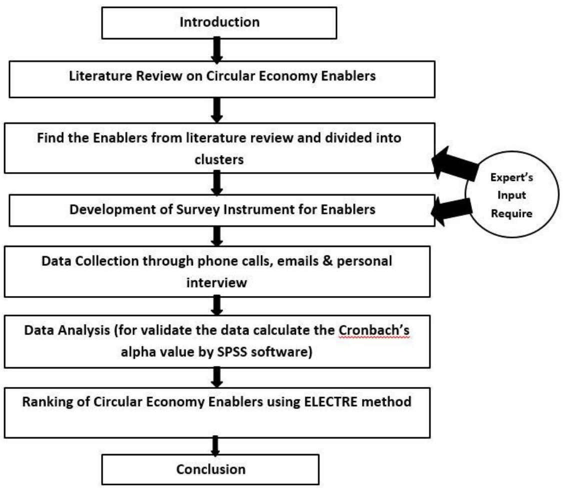

Fig. 1 General research methodology

4.1 Development of survey instrument for enablers

The use of survey based analysis for reporting issues and data collection. Based on the 22 enablers identified in the literature review, a survey instrument was also designed but was restricted to two parts[1]. Questions on broad industry information were asked in the first section of the survey instrument, second part contained queries associated with understanding, approach, and enablers towards circular economy in the manufacturing context for Indian Industries. Respondents in the study were asked about the enablers referred to in the survey instrument in terms of the effect observed on enablers of the implementation of a circular economy. It was decided to use a 5-point Likert scale with points in order to collect comments throughout the ranking process. On the scale, extremely low effect is represented by 1, low impact by 2, medium impact by 3, and strong impact by 4, and very high impact by 5. To ensure the effectiveness of the survey questionnaire, a pre-test or pilot test may be conducted. It was completed in two stages and only involved a small sample of respondents[25]. When selecting academics and experts for a survey focused on identifying enablers of circular economy in Indian manufacturing industries, it's essential to ensure their expertise is directly applicable to the subject matter and that their insights enhance the survey's credibility and dependability. It's advisable to seek out individuals with a robust background encompassing both circular economy principles and the intricacies of the Indian manufacturing landscape. These experts should possess a deep understanding of the unique potentials and challenges associated with circular practices within the Indian context, along with a comprehensive grasp of sustainability, resource efficiency, and waste management. An effective approach is to assess their publication history to determine if they have authored relevant articles, research papers, or books concerning circular economy dynamics, sustainability considerations, or the Indian manufacturing sector. Moreover, consider experts who have hands-on involvement in collaborating with Indian manufacturing enterprises. This involvement could span advisory roles, collaborative research endeavors, or direct engagement in circular economy initiatives. For added authenticity and gravitas, explore individuals affiliated with esteemed universities, research institutions, or reputable organizations in India, known for their impactful contributions to the fields of manufacturing, circular economies, or sustainability.

Survey questions in this study were directed to industries such as electronics and electrical equipment, automotive, chemicals, packaging, food and beverage, plastics and polymers, machinery and equipment, as well as the leather industry. In the first phase, five experts from academia were asked to significantly assess a draft of the survey questionnaire. Based on the evaluation we got from academia, a few things were modified to improve their particularity and clarity. The secondary pre-test phase included managing the questionnaire by experts from industries. The experts were approached to finish the revised survey opinion poll and point out any ambiguities or other complexity they experienced in responding to the questions. It was also communicated to the experts, who were asked to suggest any recommendations they deemed suitable. After the pre-test, the survey instrument was checked on the basis of the experts' remarks. The phraseology was improved to make the final survey questionnaire more effective and assure the objectives of data collection. The experts have at least ten years of experience in the specific field of organizational improvements.

4.2 Data Collection for enablers

The majority of the manufacturing industries in India fall under the category of small and medium enterprises. 150 survey questionnaires were sent to the respondents (managers, owners, engineers, and supervisors) through email, and personal visits were made in nearby industries. The purpose of the survey and its outcome were informed and discussed, and the confidentiality of respondents was ensured. The end goal was to drive respondents to settle on a selective and unequivocal decision. A response rate of about 84% was obtained for enablers, yielding 126 sound responses. The responses were collected from a number of respondents on the basis of their experience; minimum of one year and a maximum of forty years in the manufacturing sector.

4.3 Data analysis

The reliability and validity of the survey data meant for analysis should be given the greatest attention. The consistency or degree to which the survey questions used to gather enablers give the same information from a person on several times, suggesting similar data under comparable settings, is reliability. On the other hand, it is believed that one of the key indicators of data dependability is how well the enablers really gauge the variable they are meant to measure. Cronbach's alpha serves as a widely embraced metric for gauging internal consistency and reliability in evaluating the coherence of responses across items within a questionnaire or scale. It gauges the degree to which items within a set effectively measure an underlying construct. Several factors contribute to researchers' inclination toward utilizing Cronbach's alpha to gauge the dependability of their measurement scales, as well as reasons why they might not opt for alternative tools. **Established metric:** Cronbach's alpha has garnered substantial recognition within the domains of psychometrics and research methodology. Its well-established reputation makes it a prevalent choice among researchers. **Simplicity in computation:** The calculation of Cronbach's alpha is comparably uncomplicated, necessitating only rudimentary statistical procedures. It generates a single coefficient that expresses the degree of internal coherence of a group of items, making it a useful metric for assessing the accuracy of a measuring scale. **Ease of interpretation:** Ranging between 0 and 1, the alpha coefficient allows for direct interpretation, with higher values indicating heightened internal consistency. This straightforwardness facilitates the interpretation of scale reliability. **Versatility across scale types:** Cronbach's alpha accommodates a diverse array of scale types, encompassing Likert scales, semantic differential scales, and more. This adaptability renders it suitable for various research contexts. **Emphasis on consistency:** Cronbach's alpha predominantly emphasizes the uniformity of items within a scale, ensuring their alignment in measuring a shared underlying construct. This proves especially pivotal when crafting composite scales or indices[11)]. The data were analyzed using SPSS statistical software. Every single set of enabler Cronbach's alpha values was computed. For each item across all collected replies for each scale within the survey, the Cronbach's alpha value was calculated in order to determine internal consistency and assess the validity of the questionnaire. The range of Cronbach's alpha is 0 to 1, and values greater than 0.70 may indicate good internal consistency[11)]. An acceptable Cronbach's alpha value is one that is just somewhat below 0.60[6)]. Nonetheless, when the alpha values are notably low, it may necessitate the removal of certain components to modify the value. But in order to validate data, judge whether sample sizes are appropriate, and build a correlation matrix, relationships between variables must be established. The Corrected Item Total Correlation (CITC) test evaluates the correlation metrics of a particular item and emphasizes that if an assessment item deviates from the norm, it should be deleted. No single component or parameter from the data set was removed during the analysis in order to make it better. Table 1 displays the enablers that collected Cronbach's alpha values. The Cronbach's alpha score for the key enablers is 0.8726, which is regarded acceptable and indicates the reliability of the data[7)].

Table 1. Results for Cronbach's alpha value by SPSS 16.0 for factors (Flynn et al., 1994)

Enablers	K (No. of Varience Vi)	sum of Varience Vi	Total of Enablers Vt	alpha value
Cultural Enablers	6.0000	7.2841	34.0617	0.9424
Regulatory Enablers	3.0000	4.2749	10.8453	0.8970
Financial Enablers	4.0000	4.4953	13.7400	0.8966
Environmental Enablers	2.0000	3.1860	5.1723	0.7434
Technological Enablers	4.0000	5.5707	16.3937	0.8647
Supply Chain Enablers	3.0000	4.6051	11.2796	0.8917
Key enablers for circular economy				**0.8726**

4.4 Combining, Coding and Finalizing Key Variables

Based on literature reviews, preliminary surveys, and articles, one such area of investigation is to find out the role of Indian manufacturing industries towards attaining circular economy from existing linear economy model. "The intention of this research is to evaluate the current level and identify enabling factors for circular economy adoption, particularly in Indian industries. More than 100 unique references to enablers in forming an economy that is more circular were identified and classified in a survey of writing on enablers in the development of a much more circular economy[29]. While numerous technological and regulatory enablers exist, it appears that cultural and financial / market difficulties are the fundamental enablers in favor of a much more circularly constructed environment. The industrial sector's circular economy has swiftly risen from the fringes to the foreground of public discourse. Rapidly generated reports, white papers, scholarly publications, and recommendations. All of the enablers described in the research may be classified into six categories: cultural, regulatory, financial, environmental, technological, and supply chain management as shown in Table 2.

Table 2. Categorization and coding of CM Enablers (Rezaei, 2015; Sadjadi and Karimi, 2018)

Sr. No.	Circular Manufacturing Adoption Enablers		Code
	Major Categories	**Sub Enablers**	
1	**Cultural Enablers**	Motivated Leadership	ECU01
2		Company environmental culture	ECU02
3		Coordination with client on significance of CE	ECU03
4		Collaboration with businesses to promote the CE agenda	ECU04
5		Value chain engagement activities through long term relationships	ECU05
6		Top management's environmental awareness	ECU06
7	**Regulatory Enablers**	Policy support for skills and innovation	ERU01
8		Regulatory reform	ERU02
9		Incentives for CE for manufacturing firms	ERU03
10	**Financial Enablers**	Whole Life Costing	EFI01
11		Take the easy wins as fragmented approach	EFI02
12		Enormous scale of the materials available	EFI03
13		Growing prices of resources	EFI04
14	**Environmental Enablers**	Resource scarcity threat	EEN01
15		Possibility to prevent negative environmental impacts	EEN02
16	**Technological Enablers**	adoption of the 6 R's inside the organization	ETE01
17		Opportunities for improved operations within organisation through DFX practices	ETE02
18		Opportunities for efficient supply chain through reverse supply chain	ETE03
19		Enhanced information management plateforms	ETE04
20	**Supply Chain Enablers**	Availability of suitable supply chain partners for circularity	ESC01
21		Blockchain technology driven product traceability	ESC02
22		Geographical proximity	ESC03

4.5 Approach taken for present research work

A thorough writing audit is completed to distinguish the key CM enablers and the arrangement measures expected to defeat them. Afterward, these elements are classified and introduced to the specialists of the industries for finalization. In light of the specialists' criticism, a system is created and tried using the ELECTRE approach. As needs be, the outcomes however acquired are adopted as contributions for the ELECTRE strategy alongside the master inputs for a matched examination of enablers for circular manufacturing. By observing the guideline system of ELECTRE, enablers are positioned in order to recognize the high need arrangement measures. This research further shows relationship of enabling factors by depicting how these first concern CM enablers will aid in overcoming CM barriers. At last, the research result is examined, as well as the study's significance for academics and practitioners.

4.6 Calculation the Weights of CM Enablers

The Methodology for Order Preference by Similarity to an Ideal Solution (TOPSIS) and the Step-wise Weight Assessment Ratio Analysis (SWARA) are two decision-making techniques provided by the Multiple Criteria

Decision Making (MCDM) approach to evaluate options according to the presence of characteristic loads. The applicability of any MCDM technique, however, is determined by the nature of the chosen issue[18]. Because there are so many difficulties (attributes) and solution measures (alternatives) in this scenario, ELECTRE looks to be the most suited strategy for the operation. Many scholars debated whether the PROMETHEE technique was more significant than the ELECTRE approach. However, it's noted that in the PROMETHEE technique, the relationship between two factors is either 0 or 1; however, in actuality, such relationships are not conceivable. To achieve enhanced outcomes, the ELECTRE methodology utilizes the relationship percentage between the two variables. ELECTRE has an advantage over other outranking algorithms since it can compare a collection of alternatives independently for each characteristic. As a result, the enablers weights determined in the previous step are used as input in this stage. The following is the normal technique for conducting the ELECTRE approach.

4.6.1 Create the decision table

It provides a paired comparison of all available options (enablers) and the attributes they present. It aids in the development of the chosen problem's hierarchical structure.

4.6.2. Calculate the concordance matrix

It's crucial to distinguish between advantageous and non-beneficial aspects after categorizing issues. The maximum value is wanted for every positive quality, while the most minimal value is wanted for each non-beneficial attribute. All impediments are non-beneficial in the context of the current situation, and hence must be removed. The concordance list C (b1, b2) can be explained in the following manner, where b1 represents the alternative score and wj denotes the attribute weight for each function f (b1).

$$C(b_1, b_2) = \sum_{j=1}^{M} wj * cj(b_1, b_2)$$

It's crucial to highlight that the notation C(b1,b2) indicates the comparative significance of one arrangement metric over another.

4.6.3. Calculate the discordance index as follows:

Initially, the veto threshold (vj) is established, indicating that the impact strength of a1 compared to a2 can be disregarded when the value of the second enabler surpasses the sum of the first enabler and the veto threshold. Each arrangement measure dj(b1,b2) has a discordance index that may be calculated as follows:

$$D_j(b_1, b_2) = \begin{cases} 0, & if\ fj(b1)+pj \geq fj(b2) \\ 1, & if\ fj(b1)+vj \leq fj(b2) \\ \frac{fj(b2)-pj-fj(b1)}{vj-pj} & if\ else \end{cases}$$

Utilizing the aforementioned technique, distinct comparisons are conducted for both the main group and each individual sub-group. Table 3 shows the comparisons of major group Enablers to Best to others. Table 4 shows the square root of the weighted matrix. It also shows the final weights determined for the major group Enablers. Table 5 displays a normalized decision matrix, while Table 6 presents a weighted normalized decision matrix. The threshold Value Cth=0.5023 comes from Table 7 concordance matrix, and the threshold value Dth=0.7793 comes from Table 8 discordance matrix. Table 9 shows the concordance supremacy matrix, and Table 10 shows the discordance supremacy matrix. Table 11 displays the global dominance matrix, and Table 12 displays net superior and inferior for ranking in which technological (ETE) and financial enablers (EFI) are the most prominent. These main enablers are helpful for achieving the circular economy.

4.7. Analysis

Analysis of enablers by the ELECTRE method is given below:

Table 3 shows the comparisons of major group Enablers to Best to others. It also shows the final weights determined for the major group Enablers. Determine the applicable factors for the decision issue. Allocate values to each factor to signify their respective significance. These values can be ascertained through consultations with involved parties or employing quantitative approaches such as the Best Worst Method (BWM).

Table 3. Comparison of major group Enablers to Best to others

		B1	B2	B3	B4	B5	B6
		Cultural Barriers	**Regulatory Barriers**	**Financial Barriers**	**Environmental Barriers**	**Technological Barriers**	**Supply Chain Barriers**
Criteria Weight		0.214851	0.214875968	0.218122	0.08191208	0.192756991	0.07748196
Alternatives	**Cultural Enablers**	70	40	30	70	20	20
	Regulatory Enablers	30	80	50	60	50	50
	Financial Enablers	40	50	80	70	70	60
	Environmental Enablers	50	50	40	80	60	50
	Technological Enablers	50	60	60	70	80	70
	Supply Chain Enablers	30	40	50	70	70	80

Table 4 shows the square root of the weighted matrix in which sum up the values of the indicators within this square by columns. Afterward, calculate the square root of the total sum. Proceed to divide each value of the indicators by this square root.

Table 4. Square root of the weighted matrix

	B1	B2	B3	B4	B5	B6
E1	4900	1600	900	4900	400	400
E2	900	6400	2500	3600	2500	2500
E3	1600	2500	6400	4900	4900	3600
E4	2500	2500	1600	6400	3600	2500
E5	2500	3600	3600	4900	6400	4900
E6	900	1600	2500	4900	4900	6400
Sum	13300	18200	17500	29600	22700	20300
SQRT	115.325626	134.9073756	132.287566	172.0465053	150.6651917	142.478068

Tables 5 and 6 exhibit a normalized decision matrix and a weighted normalized decision matrix, respectively. In the latter matrix, the weight of each indicator in a column is applied to every value of the corresponding alternatives' indicators. This process yields the weighted values of the indicators for the alternatives.

Table 5. Normalized decision matrix

	B1	B2	B3	B4	B5	B6
E1	0.60697698	0.296499727	0.22677868	0.406866736	0.132744662	0.14037248
E2	0.26013299	0.592999453	0.37796447	0.348742916	0.331861656	0.3509312
E3	0.34684399	0.370624658	0.60474316	0.406866736	0.464606318	0.42111744
E4	0.43355498	0.370624658	0.30237158	0.464990555	0.398233987	0.3509312
E5	0.43355498	0.44474959	0.45355737	0.406866736	0.530978649	0.49130368
E6	0.26013299	0.296499727	0.37796447	0.406866736	0.464606318	0.56148993

Table 6. Weighted normalized decision matrix

Weights	0.214851	0.214875968	0.218122	0.08191208	0.192756991	0.07748196
	B1	B2	B3	B4	B5	B6
E1	0.13041	0.06371	0.04947	0.03333	0.02559	0.01088
E2	0.05589	0.12742	0.08244	0.02857	0.06397	0.02719
E3	0.07452	0.07964	0.13191	0.03333	0.08956	0.03263
E4	0.09315	0.07964	0.06595	0.03809	0.07676	0.02719
E5	0.09315	0.09557	0.09893	0.03333	0.10235	0.03807
E6	0.05589	0.06371	0.08244	0.03333	0.08956	0.04351

Establish preference thresholds for individual criteria in tables 7 and 8. These thresholds define the acceptable performance levels for each criterion. During this stage, evaluate pairs of alternatives based on their performance on each criterion. For the concordance analysis, determine whether one alternative is preferred over another based on a particular criterion. For the discordance analysis, pinpoint instances where one alternative significantly outperforms the other, requiring consideration of a discordance threshold.

Table 7. Concordance matrix (Threshold Value C_{th}=0.5023)

	E1	E2	E3	E4	E5	E6
E1		0.297	0.256	0.215	0.257	0.363
E2	0.703		0.215	0.472	0.215	0.431
E3	0.744	0.785		0.596	0.259	0.785
E4	0.785	0.528	0.404		0.189	0.512
E5	0.744	0.785	0.741	0.811		0.882
E6	0.637	0.637	0.215	0.488	0.118	

Table 8. Discordance matrix (Threshold Value D_{th}=0.7793)

	E1	E2	E3	E4	E5	E6
E1		0.855	1.000	1	1.000	0.858
E2	1.000		1	0.780	1	0.402
E3	0.678	0.966		0.282	0.565	0.220
E4	0.7281	1.000	1.000		1.000	0.443
E5	0.485	0.8299	1.000	0.144		0.146
E6	1.000	1.000	1.000	1.000	1.000	

Tables 9 and 10 present the computed concordance and discordance indices for each alternative, which are then compared against all other alternatives. These indices combine the individual metrics to provide a comprehensive assessment of how each alternative performs. They serve as tools to numerically express the level of preference or disagreement among the alternatives.

Table 9. Concordance supremacy matrix

	E1	E2	E3	E4	E5	E6
E1		0.000	0.000	0	0.000	0.000
E2	1.000		0	0.000	0	0.000
E3	1.000	1.000		1.000	0.000	1.000
E4	1	1.000	0.000		0.000	1.000
E5	1.000	1	1.000	1.000		1.000
E6	1.000	1.000	0.000	0.000	0.000	

Table 10. Discordance supremacy matrix

	E1	E2	E3	E4	E5	E6
E1		1.000	1.000	1	1.000	1.000
E2	1.000		1	1.000	1	0.000
E3	0.000	1.000		0.000	0.000	0.000
E4	0	1.000	1.000		1.000	0.000
E5	0.000	1	1.000	0.000		0.000
E6	1.000	1.000	1.000	1.000	1.000	

In Table 11, the concordance and discordance indices are combined to derive overall indices for each alternative. This process offers a thorough evaluation of the alternatives, encompassing all criteria. Arrange the alternatives in order of their calculated Concordance-Discordance indices (CDi). The alternative with the greatest CDi value attains the top rank, followed by the alternative with the second-highest CDi value, and so on.

Table 11. Global dominance matrix

	E1	E2	E3	E4	E5	E6	Sum of 1's	Rank
E1		0.000	0.000	0	0.000	0.000	0	**3**
E2	1.000		0	0.000	0	0.000	1.000	**2**
E3	0.000	1.000		0.000	0.000	0.000	1.000	**2**
E4	0	1.000	0.000		0.000	0.000	1.000	**2**
E5	0.000	1	1.000	0.000		0.000	2.000	**1**
E6	1.000	1.000	0.000	0.000	0.000		2.000	**1**

Table 12. Net superior and inferior for ranking

	Net Superior	**Ranking Superior**	**Net Inferior**	**Ranking Inferior**	**Average Rank**	**Final Ranking**
E1	-2.225	6	0.822	4	5	**3**
E2	-0.996	5	-0.47	3	4	**2**
E3	1.338	2	-2.289	1	1.5	**1**
E4	-0.163	3	0.9641	5	4	**2**
E5	2.923	1	-1.959	2	1.5	**1**
E6	-0.878	4	2.932	6	5	**3**

The global weights are optimal, and all sub-groups are double-checked regarding consistency. The results of global weights and rankings for circular manufacturing enablers are shown in Table 12. Examine the prioritized roster of alternatives to facilitate well-informed choices. Alternatives holding superior ranks are regarded as more advantageous due to their better performance across the specified criteria

5. Results and Discussion

In this context, the most significant, moderately important, and least crucial enablers were analyzed. The stated rankings for enablers were derived using the ELECTRE approach and are shown in table 12 here. A total of 22 enablers related to the circular economy within the manufacturing scope of Indian industries were identified based on their frequency in research literature. To validate these enablers, a survey questionnaire was formulated and the collected data underwent thorough analysis. The majority of the manufacturing industries in India come under the category of small and medium enterprises. 150 respondents were contacted through email surveys, and industry representatives in the field were visited in person. A response rate of about 84% was received for the 126 sound responses for enablers. Cronbach's alpha count using SPSS statistical software for key enablers is found as 0.8726 so the value is considered fair. An expert panel (managers, owners, engineers, and supervisors) of the manufacturing industry validates these enablers as affecting how developing countries adopt CE, assigns weights to the enablers, and uses the ELECTRE Method to determine the final ranking of the enablers. The findings indicate that technical (ETE) and financial (EFI) aspects are the primary two enablers for introducing the circular economy within India's industrial domains. The medium ranking enablers are Regulatory enablers (ERU) and environmental enablers (EEN). The least significant enablers are cultural enablers (ECU) and supply chain enablers (ESC). The study illustrates the concerns, enablers within the Indian manufacturing industries through the employment of the ELECTRE method in circular economy. To effectively establish circular economy in Indian manufacturing industries, it is imperative to secure unwavering commitment from top-level management, and employees should receive education and proficiency in circular economy methodologies. Hence, policymakers and stakeholders can craft essential survival strategies by means of effective communication, motivating employees, and cultivating a supportive environment.

6. Conclusion

The present research aims to outline 22 significant enablers, drawing from literature sources and expert input. Subsequently, these enablers are evaluated using Cronbach's alpha values. The ELECTRE method is employed to ascertain the final rankings of these enablers. Notably, the primary enablers for implementation of circular economy within India's manufacturing sectors are identified as technical (ETE) and financial (EFI) aspects. Regulatory enablers (ERU) and environmental enablers (EEN) receive a moderate ranking. Conversely, cultural enablers (ECU) and supply chain enablers (ESC) are deemed the least influential hindrances.

It's important to acknowledge that the outcomes of this study could diverge due to variations in measurement techniques employed to identify impediments to the circular economy, as well as the influence of specific case organizations on expert opinions. The criteria for selection and measurement may differ across organizations, thus resulting in varying rankings from one business to another. The circular economy underscores a closed-loop approach that enables the cyclic flow of resources, energy, and raw materials within the broader economic framework, distinguishing it from linear economic models. While a majority of research papers emphasize benefits of circular economy, there remains a gap in the literature regarding a structured approach that aids the integration of circular economy principles into production organizations. The recognition of enablers for the circular economy within the manufacturing context is constrained. Finding the key enablers is crucial for accelerating the adoption of the circular economy, particularly in developing nations. Notably, a significant portion of existing research pertains to China, leaving a scarcity of literature on circular economy enablers from other emerging nations like India.

7. Future Scope and Limitations

The results suggest that the government plays a substantial role in fostering the circular economy within supply chains, primarily driven by the considerable upfront investment costs. Additionally, as numerous businesses prioritize financial gains over other considerations, environmental issues are frequently sidelined. Hence, it becomes crucial for the government to establish laws and regulations that compel companies to align with the principles of the circular economy. Following a reliability examination, a total of 22 enablers were included in this research. The number of criteria might then be raised in order to expand the range of insights, although this task could be difficult and time-consuming. This research inquiry acknowledged limitations, including the reliance on expert judgment and personal interviews to establish the relationships between the study's criteria and measures. For improved outcomes, other methods can also be used, like DEMATEL, MAUT, VIKOR, TOPSIS, PROMETHEE, BWM and many more. This study's limitations included the fact that expert opinions and personal interviews were used to determine how the study's criteria and measurements related to one another. The circular economy idea needs to get more social and consumer acceptance, too. These constitute major enablers to adoption of circular economy, and managers and decision-makers may benefit much from knowing these factors. Managers should be aware of the organizational catalysts required for the circular economy's effective integration. Future studies might extend the framework to include a wider range of stakeholders, add other organizational theoretical frameworks, or modify this structure to meet the needs of a particular nation.

References

1) F. Abu, H. Gholami, M. Z. Mat Saman, N. Zakuan, and D. Streimikiene, “The implementation of lean manufacturing in the furniture industry: A review and analysis on the motives, barriers, challenges, and the applications,” Journal of Cleaner Production, vol. 234, pp. 660–680, Oct. 2019, doi: https://doi.org/10.1016/j.jclepro.2019.06.279.
2) R. Accorsi, R. Manzini, C. Pini, and S. Penazzi, “On the design of closed-loop networks for product life cycle management: Economic, environmental and geography considerations,” Journal of Transport Geography, vol. 48, pp. 121–134, Oct. 2015, doi: https://doi.org/10.1016/j.jtrangeo.2015.09.005.
3) M. Agyemang, S. Kusi-Sarpong, S. A. Khan, V. Mani, S. T. Rehman, and H. Kusi-Sarpong, “Drivers and barriers to circular economy implementation,” Management Decision, vol. 57, no. 4, pp. 971–994, Apr. 2019, doi: https://doi.org/10.1108/md-11-2018-1178.
4) A. K. Ali, Y. Wang, and J. L. Alvarado, “Facilitating industrial symbiosis to achieve circular economy

using value-added by design: A case study in transforming the automobile industry sheet metal waste-flow into Voronoi facade systems," Journal of Cleaner Production, vol. 234, pp. 1033–1044, Oct. 2019, doi: https://doi.org/10.1016/j.jclepro.2019.06.202.

5) Achmad T. Nugraha, Gunawan Prayitno, Abdul W. Hasyim, and Fauzan Roziqin, "Social Capital, Collective Action, and the Development of Agritourism for Sustainable Agriculture in Rural Indonesia," *Evergreen*, vol. 8(1) pp. 1–12 (2021) doi: https://doi.org/10.5109/4372255.
6) D. G. Bonett and T. A. Wright, "Cronbach's alpha reliability: Interval estimation, hypothesis testing, and sample size planning," Journal of Organizational Behavior, vol. 36, no. 1, pp. 3–15, Oct. 2014, doi: https://doi.org/10.1002/job.1960.
7) G. A. Churchill, "A Paradigm for Developing Better Measures of Marketing Constructs," Journal of Marketing Research, vol. 16, no. 1, pp. 64–73, Feb. 1979, doi: https://doi.org/10.1177/002224377901600110.
8) J. Cooper, "Briefing: Developing a more circular economy model for wine packaging and delivery," Proceedings of the Institution of Civil Engineers - Waste and Resource Management, vol. 172, no. 2, pp. 40–41, May 2019, doi: https://doi.org/10.1680/jwarm.19.00007.
9) P. K. Dey, C. Malesios, S. Chowdhury, K. Saha, P. Budhwar, and D. De, "Adoption of circular economy practices in small and medium-sized enterprises: Evidence from Europe," International Journal of Production Economics, vol. 248, p. 108496, Jun. 2022, doi: https://doi.org/10.1016/j.ijpe.2022.108496.
10) D. FINK, "Guidelines for the Successful Adoption of Information Technology in Small and Medium Enterprises," International Journal of Information Management, vol. 18, no. 4, pp. 243–253, Aug. 1998, doi: https://doi.org/10.1016/s0268-4012(98)00013-9.
11) B. B. Flynn, R. G. Schroeder, and S. Sakakibara, "A framework for quality management research and an associated measurement instrument," Journal of Operations Management, vol. 11, no. 4, pp. 339–366, Mar. 1994, doi: https://doi.org/10.1016/s0272-6963(97)90004-8.
12) T. Helmer Pedersen and F. Conti, "Improving the circular economy via hydrothermal processing of high-density waste plastics," Waste Management, vol. 68, pp. 24–31, Oct. 2017, doi: https://doi.org/10.1016/j.wasman.2017.06.002.
13) Z. Jiliang and Z. Chen, "Building and Application of a Circular Economy Index System Frame for Manufacturing Industrial Chain," Research Journal of Applied Sciences, Engineering and Technology, vol. 5, no. 24, pp. 5646–5651, May 2013, doi: https://doi.org/10.19026/rjaset.5.4250.
14) Y. Kalmykova, M. Sadagopan, and L. Rosado, "Circular economy – From review of theories and practices to development of implementation tools," Resources, Conservation and Recycling, vol. 135, no. 135, pp. 190–201, Aug. 2018, doi: https://doi.org/10.1016/j.resconrec.2017.10.034.
15) J. Kirchherr, D. Reike, and M. Hekkert, "Conceptualizing the circular economy: an analysis of 114 definitions," Resources, Conservation and Recycling, vol. 127, no. 0921-3449, pp. 221–232, Dec. 2017, doi: https://doi.org/10.1016/j.resconrec.2017.09.005.
16) V. Kumar, I. Sezersan, J. A. Garza-Reyes, E. D. R. S. Gonzalez, and M. A. AL-Shboul, "Circular economy in the manufacturing sector: benefits, opportunities and barriers," Management Decision, vol. 57, no. 4, pp. 1067–1086, Apr. 2019, doi: https://doi.org/10.1108/md-09-2018-1070.
17) M. Moreno, R. Court, M. Wright, and F. Charnley, "Opportunities for redistributed manufacturing and digital intelligence as enablers of a circular economy," International Journal of Sustainable Engineering, vol. 12, no. 2, pp. 77–94, Aug. 2018, doi:https://doi.org/10.1080/19397038.2018.1508316
18) V. S. Narwane, V. S. Yadav, R. D. Raut, B. E. Narkhede, and B. B. Gardas, "Sustainable development challenges of the biofuel industry in India based on integrated MCDM approach," Renewable Energy, vol. 164, pp. 298–309, Feb. 2021, doi: https://doi.org/10.1016/j.renene.2020.09.077.
19) M. P. O'Connor, J. B. Zimmerman, P. T. Anastas, and D. L. Plata, "A Strategy for Material Supply Chain Sustainability: Enabling a Circular Economy in the Electronics Industry through Green Engineering," ACS Sustainable Chemistry & Engineering, vol. 4, no. 11, pp. 5879–5888, Oct. 2016, doi: https://doi.org/10.1021/acssuschemeng.6b01954.
20) M. Pagotto and A. Halog, "Towards a Circular Economy in Australian Agri-food Industry: An Application of Input-Output Oriented Approaches for Analyzing Resource Efficiency and Competitiveness Potential," Journal of Industrial Ecology, vol. 20, no. 5, pp. 1176–1186, Nov. 2015, doi: https://doi.org/10.1111/jiec.12373.
21) S. Pauliuk, T. Wang, and D. B. Müller, "Moving Toward the Circular Economy: The Role of Stocks in the Chinese Steel Cycle," Environmental Science & Technology, vol. 46, no. 1, pp. 148–154, Dec. 2011, doi: https://doi.org/10.1021/es201904c.
22) J. Rezaei, "Best-worst multi-criteria decision-making method," Omega, vol. 53, pp. 49–57, Jun. 2015, doi: https://doi.org/10.1016/j.omega.2014.11.009.
23) S. J. Sadjadi and M. Karimi, "Best-worst multi-criteria decision-making method: A robust approach," Decision Science Letters, pp. 323–340, 2018, doi: https://doi.org/10.5267/j.dsl.2018.3.003.
24) R. Sarc, A. Curtis, L. Kandlbauer, K. Khodier, K. E.

Lorber, and R. Pomberger, “Digitalisation and intelligent robotics in value chain of circular economy oriented waste management – A review,” Waste Management, vol. 95, pp. 476–492, Jul. 2019, doi: https://doi.org/10.1016/j.wasman.2019.06.035.

25) R. Shah and P. T. Ward, “Lean manufacturing: context, practice bundles, and performance,” Journal of Operations Management, vol. 21, no. 2, pp. 129–149, Oct. 2003, doi: https://doi.org/10.1016/s0272-6963(02)00108-0.

26) M. Sharma, N. L. Jain, and J. K. Purohit, “A Review of Circular Economy in Manufacturing Sector,” NeuroQuantology, vol. 20, no. 10, pp. 9105–9112, Aug. 2022, doi: https://doi.org/10.14704/nq.2022.20.10.NQ55892.

27) M. Sharma, N. L. Jain, and J. K. Purohit, “Biomedical Waste Management and Circular Economy Actions in the COVID-19 Pandemic Situation in Jaipur District, India,” Advances in Modelling and Optimization of Manufacturing and Industrial Systems, pp. 149–173, 2023, doi: https://doi.org/10.1007/978-981-19-6107-6_12.

28) M. Sharma and J. K. Purohit, “Indicators for Sustainable Manufacturing for Industries – A Review,” presented at the International Conference on Recent Trends and Innovation in Engineering, Science & Technology (ICRTIEST-2019), Dec. 2019, pp. 322–325.

29) M. Sharma and J. K. Purohit, “Achieving Sustainable Mass Customization Capabilities–A Review,” Juni Khyat, vol. 10, no. 6, pp. 299–304, Jun. 2020, doi: https://doi.org/10.46528/JK.2020.V10I06N09.30.

30) J. Singh and I. Ordoñez, “Resource recovery from post-consumer waste: important lessons for the upcoming circular economy,” Journal of Cleaner Production, vol. 134, pp. 342–353, Oct. 2016, doi: https://doi.org/10.1016/j.jclepro.2015.12.020.

31) D. A. Vermunt, S. O. Negro, P. A. Verweij, D. V. Kuppens, and M. P. Hekkert, “Exploring barriers to implementing different circular business models,” Journal of Cleaner Production, vol. 222, pp. 891–902, Jun. 2019, doi: https://doi.org/10.1016/j.jclepro.2019.03.052.

32) Syaiful Rizal Hamid, Chew Boon Cheong, A. Shamsuddin, Nor Ratna Masrom, and Nur Athirah Mazlan, “Sustainable development practices in Services Sector: A case of the Palace Hotel from Malaysia,” *Evergreen*, vol. 8(4) pp. 693–705 (2021) doi: https://doi.org/10.5109/4742113.

33) Behl, Abhishek, et al. “Analysis of Industry 4.0 and Circular Economy Enablers: A Step towards Resilient Sustainable Operations Management.” Technological Forecasting and Social Change, vol. 189, Apr. 2023, p. 122363, https://doi.org/10.1016/j.techfore.2023.122363.

34) Agarwal, Somesh, et al. “Circular Economy Reinforcement to Diminish GHG Emissions: A Grey DEMATEL Approach.” Evergreen, vol. 10(1) pp. 389–403 (2023) https://doi.org/10.5109/6781099. Accessed 27 Aug. 2023.