Barriers to Circular Supply Chain Adoption: A Perspective of Electric Battery Industries of Bangladesh

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Research Article

Keywords: CSC Adoption Barriers, Electric Battery Industries, Contextual Relationship, PESTEL Framework, ISM-MICMAC Analysis, Cause-Effect Analysis.

DOI: https://doi.org/10.21203/rs.3.rs-800036/v1

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Abstract

The demand for electric batteries is increasing day by day in Bangladesh because of the increasing demand for electric vehicles and energy storage supporting power systems. There are 25 companies in Bangladesh that are trying to meet this rising demand. Since toxic materials such as lead (Pb) and sulphuric acid (H$_2$SO$_4$) are used in electric batteries, the supply chain of the industry needs to be more circular. The aim of this study is to explore the barriers of implementing Circular Supply Chain (CSC) in Electric Battery Industries (EBIs) of Bangladesh. Related barriers were defined using the PESTEL (Political, Economic, Social, Technological, Environmental and Legal) framework, and the contextual relationship among the identified barriers was developed using Interpretive Structural Modelling (MICMAC i.e., Cross Impact Matrix Multiplication Applied to Classification technique), followed by a cause-effect analysis of the driving barriers to determine the root causes. Lack of sustainable development planning, lack of knowledge about the environment, health, and future generations, lack of coordination among industries and supply chain partners, increased competition, lack of investment in technological innovation, and low quality of circulated products are the root causes of the driving barriers to implementing CSC in Bangladesh's EBIs. The government and the supply chain partners of EBIs should take holistic approach on sustainable development. The results would help in the implementation of CSC, making it easier to achieve sustainable development by introducing economic growth, improving the environment, and creating more job opportunities.

1. Introduction

In previous several years, researchers have emphasized on different aspects of Circular Supply Chain Management (CSCM) such as drivers, barriers, practices, models etc. Since drivers and barriers of CSC vary in different context, they need to be investigated in the respective cases (Farooque et al., 2019). Now the drivers and barriers have been studied in different geographical regions and different industrial setups. For instance, textile industries of Bangladesh (Tumpa et al., 2019) and Finland (Flink, 2017), leather industries of Bangladesh (Moktadir, Rahman, et al., 2018), Indian context (Mangla et al., 2018), information technologies (IT) and electronic industries of China (Park et al., 2010), retail industries of Finland (Aminoff and Kettunen, 2016), Indian manufacturing industries (Gupta, Kusi-Sarpong and Rezaei, 2020), building sector of developing countries (Bilal et al., 2020; Hart et al., 2019) mining sector (Singh et al., 2020) etc. Although some studies have been conducted on textile (Tumpa et al., 2019) and leather industries (Moktadir et al., 2018; Moktadir et al., 2020) of Bangladesh but there is a gap in Electric Battery Industries (EBIs) context.

EBIs is one of the most growing industrial sectors in Bangladesh. According to Hasan (Hasan, 2020), “In Bangladesh, there are 25 local firms in production which meet 90% of the local demand. The domestic market size is about 80,000,000,000 Taka. Every year the domestic demand is growing at 10–12%. Besides, Bangladesh exports electric batteries in more than 70 countries.” So, there is a great opportunity for Bangladesh in this sector. But there are some challenges too.

The most important challenge of this sector is that few harmful materials like lead (Pb) and dilute sulphuric acid (H$_2$SO$_4$) are used in these industries (Enayetullah et al., 2006). These materials are harmful for both human being and environment. According to the Institute of Health Metrics Evaluation, due to lead exposure Bangladesh has the world’s fourth-highest rate of death (Selim, 2021). Different health effects caused by lead pollution are cancer, kidney dysfunction, high blood pressure etc. and the environmental effects of lead pollution are decrease of soil fertility, water pollution, air pollution etc. (Uddin, 2019). Sulphuric acid may cause harm to skin and sensitive organs while come into contact (Koehler, 2019). If this factor is not considered, the development of this blessing sector will be unsustainable.

The supply chain of EBIs of Bangladesh is unsustainable. According to Rahman (2021), “There are about 1100 informal and illegal recycling establishments all over the Bangladesh which recycle the lead by unregulated small-scale operators. During this process, vaporised lead contamination occurs in the air while being discarded acid pollutes the environment.” Since direct recycling process is illegal, this process is performed in hidden way (Chakraborty, 2020). Hence the supply chain of these industries should be more sustainable. CSC as a powerful tool of sustainable supply chain can be utilized in this sector.
Though CSC has many benefits, there are many barriers to implement it. For the successful implementation of CSC in EBIs of Bangladesh, the barriers need to be explored first. Now the research question is, “What are the root barriers of the CSC adoption in EBIs of Bangladesh?” It is important to identify the root barriers so that the implementation of CSC in EBIs of Bangladesh becomes easier, beneficial and sustainable.

So, the objective of this research is to identify the root barriers of implementing CSC in EBIs of Bangladesh.

This research is an initial step in the way of sustainability of EBIs of Bangladesh. The contributions of this study are as follows:

- A three layered model is constructed for identifying the root causes.
- The application of the proposed model is shown in the context of EBIs of Bangladesh.
- This research will help the supply chain partners of EBIs of Bangladesh to adopt appropriate strategies to implement CSC and the government of Bangladesh can take necessary steps to overcome the major challenges in the way of sustainability.

Rest of the paper is structured as follows. The applied methods are described briefly in Chap. 2. In Chap. 3, research methodology is proposed and a case study is conducted to the intended case. Chapter 4 presents the results and a brief discussion is shown in Chap. 5. Finally, the research is concluded, by giving suggestions for future research in the Chap. 6.

2. Material And Methods

2.1 PESTEL Framework

At first, possible barriers should be identified. Most of the researchers have taken their initial input from the literature reviews (Govindan and Hasanagic, 2018; Hart et al., 2019; Mangla et al., 2018; Moktadir et al., 2018; Ozkan-Ozen, Kazancoglu and Kumar Mangla, 2020) and very few barriers from the expert panel’s opinions (Moktadir et al., 2020). But most of them have not used any structural framework. As a consequent they have not included many important factors in their initial point. For example, Mangla et al., (Mangla et al., 2018) did not considered any environmental barriers. Even though recently some researchers have structurally taken their initial input (Hart et al., 2019; Singh et al., 2020), they overlapped some points i.e. did not properly separate them. Both Hart et al.,(Hart et al., 2019) and Singh et al.,(Singh et al., 2020) overlapped technological, legal and internal factors. To overcome this problem, both external and internal barriers have been considered in this research. The PESTEL framework has been applied to understand the big picture in which the organisation is working (Issa, Chang and Issa, 2010). PESTEL stands for Political, Economic, Social, Technological, Environmental, and Legal. For the establishment of the CSC model, the PESTEL framework was used so that all types of barriers can be taken and the selection of the related barriers becomes easier (Carl Dalhammar, 2019).

- Political Barriers: The extent to which the government and government policies interfere in a particular sector is determined by political barriers. Government policy, political stability or uncertainty in domestic and global markets, trade sanctions, fiscal incentives and taxation, labor laws, and environmental law are all examples of this. Companies must be able to adapt to current and future regulations and change their business strategies accordingly. (Carl Dalhammar, 2019)
- Economic Barriers: These factors have a direct effect on the economy, which in turn has an impact on a company's profitability and ability to conduct business. Economic growth, job rates, interest and exchange rates, inflation, consumer disposable income, raw material and energy costs, and so on are all factors. (Carl Dalhammar, 2019)
- Social Barriers: These socio-cultural factors influence consumers' needs and desires, and advertisers are particularly interested in them. They include demographics, education levels, general health status, behaviours and attitudes, and other characteristics as well as shared values and attitudes of the consumer population. (Carl Dalhammar, 2019)
- Technological Barriers: Technology advances rapidly and has a direct effect on how goods are produced and distributed. The way goods and services are manufactured and distributed, as well as how consumers are interacted with, are all
affected by technological factors. Changes in automation and robotics, as well as emerging and mobile technology developments, are all factors to consider. (Carl Dalhammar, 2019)

- Environmental Barriers: These variables have to do with the effects of environmental conditions and constraints. Environmental factors have become more relevant as a result of growing environmental consciousness, both among government officials and among consumers. Concerns over resource depletion, waste, carbon footprint, climate change, and other issues push businesses to adopt more ethical and sustainable practices. CSR (Corporate Sustainability and Responsibility) strategies are becoming more important as more customers demand ethical and sustainably sourced goods. (Carl Dalhammar, 2019)

- Legal Barriers: Regulations on jobs, consumer rights, health and safety regulations, advertising, privacy, product-labelling, warranties, and trade restrictions are only a few examples of legal considerations. It is self-evident that businesses must be aware of the legal limits under which they can function. This is especially difficult when an organization operates on a global scale, since each country has its own set of rules and regulations. (Carl Dalhammar, 2019)

## 2.2 ISM-MICMAC Analysis

There are different multi-criteria decision analysis (MCDA) approach like Best Worst Method (BWM), Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Interpretive Structural Modelling (ISM), DEMATEL (Decision Making Trial and Evaluation Laboratory), Graph Theory, Structural Equation Modelling (SEM) etc. to prioritise and find out the interrelationship among the identified barriers. In literature BWM (Gupta, Kusi-Sarpong and Rezaei, 2020; Moktadir et al., 2020), ISM-MICMAC (Bilal et al., 2020; Mangla et al., 2018), AHP (Kumar, Singh and Kumar, 2021), ANP (Ozkan-Ozen, Kazancoglu and Kumar Mangla, 2020), DEMATEL (Zhang et al., 2019) and Graph Theory (Moktadir, Ali, et al., 2018) have been used in sustainable and circular economy context. According to Moktadir et al., (2018) BWM, AHP, ANP and SEM do not provide interdependence of the variables. They also argued that Graph theory is also unable to identify the interaction of the sub-factors. But ISM-MICMAC approach gives a well-structured interactive interaction among the variables (Bilal et al., 2020; Mangla et al., 2018). On the other hand, some researchers have taken different strategy. They have used hybrid model for better understanding of the interaction among barriers of the CSC. For example, Singh et al.,(Singh et al., 2020) have adopted AHP to prioritise the barriers and Graph Theory to find out the intensity of the barriers. But they did not investigate the interaction among the barriers. So, the driving barriers need to be identified and the interactive interaction among the barriers should be captured. ISM-MICMAC approach fulfil the purpose completely (Mangla et al., 2018). To investigate the interaction among the barriers, ISM-MICMAC approach has been used in this study.

There is a well acceptance of ISM-MICMAC technique in literature. The application of ISM-MICMAC technique in some relevant areas are shown in Table 1.

| Sl. No. | Application area of ISM-MICMAC technique | References |
|---------|------------------------------------------|------------|
| 1       | Logistics in reverse                     | (Ravi and Shankar, 2005) |
| 2       | Management of a green supply chain       | (Agi and Nishant, 2017) |
| 3       | Sustainable supply chain management      | (Raut, Narkhede and Gardas, 2017) |
| 4       | Circular supply chain management         | (Mangla et al., 2018) |
| 5       | Circular economy in building sector      | (Bilal et al., 2020) |

The stages in the ISM-MICMAC approach are as follows (Haleem et al., 2016), which are discussed in the light of the challenges of implementing CSC in Bangladesh's EBIs (Mangla et al., 2018).

i. Using a literature review and expert feedback, identify the initial variables in relation to the research issue (barriers to CSC adoption in Bangladeshi EBIs).
ii. Establish pair-wise relations between defined barriers to build a Structural Self-Interaction Matrix (SSIM).

iii. Using SSIM, construct an Initial Reachability Matrix (IRM). To construct the Final Reachability Matrix, transivity is checked (FRM). For more information on transivity, readers can review the research of Agarwal, Shankar and Tiwari (2007) and Attri, Dev and Sharma (2013). The FRM is then used to measure driving and dependency power by summing the rows and columns, respectively.

iv. The reachability sets and antecedent sets for each element are extracted from the FRM and used to determine different levels. A specific barrier is grouped with other barriers that are influenced by that specific barrier in the reachability sets. The antecedent sets, on the other hand, combine a specific barrier with other barriers that influence that specific barrier. The intersection set is generated by combining these two sets.

v. The identified barriers are then subjected to a MICMAC analysis, which is a graph depicting the driving and dependency power of the variables. The barriers are divided into four groups based on their driving and dependency power (driving, autonomous, dependent and linkage).

vi. A digraph based on FRM relations is sketched for visual representation of the barriers and their interdependence. It is created with the help of nodes and edge lines.

vii. Finally, the ISM-based structural model is developed with the help of the digraph.

The flow diagram of the ISM-MICMAC analysis for the research problem is demonstrated in Fig. 1.

2.3 Cause-Effect Analysis

Finally, the driving barriers from the result of ISM-MICMAC approach need to be analysed so that the root causes behind the driving barriers can be identified. Although some researchers recently wanted to apply cause-effect diagram in CSC (Ozkan-Ozen, Kazancoglu and Kumar Mangla, 2020), nobody applied it yet. Hence there is a research gap.

Cause-effect diagram is also called Fishbone diagram or Ishikawa diagram. It is one of seven basic quality tools. The purpose of this diagram is to represent the relationship between the causes and effect (Transactions, Fabi and Domaga, 2017). The general procedure to draw a cause-effect diagram is given below:

i. By the agreement on a problem statement (effect), it is written in a box at the centre right of the drawing area and a horizontal arrow is drawn running to it.

ii. The major categories of causes of effect are written as branches from the main arrow.

iii. Then the possible causes of each category are determined by brainstorming and written as a branch of relevant category.

iv. The deeper levels of causes are produced until the group runs out of ideas.

3. Research Methodology

3.1 Proposed Research Framework

The proposed framework for identifying, prioritising and analysing the major barriers of CSC implementation of EBIs in Bangladesh have been shown in Fig. 2. This framework is not only applicable but also has reliable nomenclature (Baines, Kay and Hamblin, 1994; Platts and Gregory, 1990). Suggestions given by Platts and Gregory (1990) and from the identified research gaps have been used in this research framework.

The research framework consists of the following phases:

a. At first, the initial barriers have been taken from the literature.

b. Then the barriers have been classified using the PESTEL framework so that the selection of all the possible barriers becomes easier and appropriate for the expert panel.
c. A survey was conducted among the experts for selecting the barriers of ISM-MICMAC approach.

d. Then the contextual relationship among the barriers have been explored using ISM-MICMAC technique. Online surveys were conducted among the expert panel in this stage.

e. Finally, the cause-effect analysis has been done for the purpose of finding out the major causes of the driving barriers. Expert panel’s opinions also helped in this stage a lot.

In the subsequent section, the proposed research framework has been applied for the intended research problem.

3.2 Application of Proposed Research Framework

The major barriers of CSC implementation have been identified in context of EBIs of Bangladesh. For that purpose, the initial barriers have been categorised with the help of PESTEL framework. The initial barriers were collected from existing literature. Then the expert panel have chosen the utile barriers. The opinions of the expert panel were collected by an online survey with the help of “Google Form”. After that, the contextual relationship amongst the barriers was established by means of ISM-MICMAC technique. Finally, the cause-effect diagram was applied to find out the major barriers from the driving barriers.

The information for this study was gathered from two leading battery manufacturing industries of Bangladesh called “Confidence Batteries Limited” and “Rohimafrooz Batteries Limited”. Both the industries use ‘Recycling’ as the circular strategy. These industries were chosen based on the principle of convenience sampling. Initially nine experts were selected for the surveys and four experts gave their valuable opinion to select and analyse the barriers of CSC adoption in EBIs of Bangladesh. The expert panel consisted of one manager, one deputy manager and two senior executives. In terms of experience, expertise, and decision-making, they are highly qualified.

3.2.1 Classification of the Initial Inputs

At first the initial barriers have been taken from the literature. These barriers are shown in Table 2 (Ozkan-Ozen, Kazancoglu and Kumar Mangla, 2020). Classification of the initial input helps to cover all the possible barriers. If the initial barriers are selected randomly, there is a possibility to miss some of the important variables. To overcome the shortcoming, PESTEL framework is a suitable tool.
| Sl. No. | Barriers                                                                 | References                           |
|--------|---------------------------------------------------------------------------|--------------------------------------|
| 1      | Lack of industry incentives for ‘greener’ activities                      | (Mangla et al., 2018)                |
| 2      | Lack of rules and regulations about the environment                       |                                      |
| 3      | The indifference of management and lack of planning for CSC adoption      |                                      |
| 4      | Lack of favorable tax systems for supporting CSC                          |                                      |
| 5      | Lack of environmental certification systems                                |                                      |
| 6      | Lack of middle and lower level managers’ support and involvement in promoting ‘greener’ products |                                      |
| 7      | Lack of customer consciousness and involvement around CSC activities      |                                      |
| 8      | Poor demand for environmentally preferred technologies                    |                                      |
| 9      | Inadequate technology transfer initiatives                                 |                                      |
| 10     | Lack of awareness and consciousness about CSC among the organizational members |                                      |
| 11     | Inadequate training and improvement programs for SC (Supply Chain) members and HR (Human Resources) | (Bressanelli et al., 2018)          |
| 12     | Ineffective management of CSC concepts                                    |                                      |
| 13     | Unsystematic information systems                                          |                                      |
| 14     | Lack of coordination and collaboration amongst the SC partners            |                                      |
| 15     | Low financial benefits in the short-run                                   |                                      |
| 16     | Lack of transportation and infrastructure                                  | (Bressanelli et al., 2018)          |
| 17     | Uncertainty of return flows                                               |                                      |
| 18     | Lack of suitable supply chain partners                                    |                                      |
| 19     | Cultural concerns (linear mindset of the customers)                       |                                      |
| 20     | Lack of eco-efficient technological processes                             |                                      |
| 21     | Lack of technological improvement                                         |                                      |
| 22     | Lack of data privacy and security                                         |                                      |
| 23     | Lack of vision                                                            | (Saroha, Garg and Luthra, 2018)     |
| 24     | Lack of standard systems                                                  |                                      |
| 25     | Higher initial cost                                                       |                                      |
| 26     | Lack of funding                                                           |                                      |
| 27     | Higher production cost                                                    |                                      |
| 28     | Inadequacy in information sharing among the SC partners                   |                                      |
| 29     | Unskilled workers                                                         |                                      |
| 30     | Inadequate information about the best available technology                | (Pan et al., 2015)                  |
| Sl. No. | Barriers                                                                 | References                                      |
|--------|--------------------------------------------------------------------------|------------------------------------------------|
| 31     | Lack of local technologies                                               |                                                |
| 32     | Difficulty of selecting cost-efficient technology                        |                                                |
| 33     | Internal bureaucracy for implementing CSC                                |                                                |
| 34     | Lack of environmental effect measurement (certification)                 | (Levering and Vos, 2019)                       |
| 35     | Lack of transparency within the stakeholders                              |                                                |
| 36     | High costs to develop circular alternatives                              |                                                |
| 37     | Lack of standard method for performance indicators about evaluating CSC  | (Govindan and Hasanagic, 2018)                 |
| 38     | Lack of clear vision about CSC                                           |                                                |
| 39     | Lack of economic incentives to implement CSC                             |                                                |
| 40     | Higher costs of recycled materials than the virgin materials              |                                                |
| 41     | Lack of technology for tracking circulated materials                      |                                                |
| 42     | Difficulty to maintain the product quality throughout the lifecycle      |                                                |
| 43     | Challenges to design circulated products                                 |                                                |
| 44     | Difficulty to take proper decision for implementing CSC                  |                                                |
| 45     | Lack of information systems for tracking circulated products             |                                                |
| 46     | Lack of leadership and management towards CSC                           |                                                |
| 47     | Unfavorable organizational structure to implement CSC                     |                                                |
| 48     | Inadequacy in triumphant business models and frameworks to adopt CSC     |                                                |
| 49     | Lack of interest towards CSC                                             |                                                |

**External Barriers**

- **Political Barriers:** Many countries are taking initiative for promoting CSC. For example, to promote CSC, Sweden has lowered value added tax (VAT) on repair services and labour taxes for repair work. (Carl Dalhammar, 2019). In Bangladesh, however, there are no strict regulations about CSC. As a result, in the sense of Bangladesh’s EBIs, this is a critical category.

- **Economic Barriers:** Since organisations give top priority to their economic growth, these factors should be considered carefully.

- **Social Barriers:** The success of any business is entirely dependent on customer satisfaction. As a result, every company strives to please its customers. Customers’ requirements are, after all, what quality is known as.

- **Technological Barriers:** Now-a-days, it is the age of science and technology. So, businesses rely heavily on this factor.

- **Environmental Barriers:** Since CSC is an emerging research topic, there are few confusions among the researchers about the environmental benefits. So, these factors need to be analysed in respect to different circular business model.

- **Legal Barriers:** Recently many EBIs of Bangladesh are exporting their products in more than 70 countries of the world like Singapore, Australia, Russia, India, Chile, Middle East etc. (Hasan, 2020). Therefore, these types of barriers are relevant to the intended case.

**Internal Barriers**
Internal barriers are the barriers that are related to the internal operations and management of the organisations. There are many internal barriers which many organizations are facing for the implementation of circular business (Vermunt et al., 2019). Since a new model of closed-loop is adopted by the organisation, it has to change many things (Singh et al., 2020). There are several circular business models available, including product-as-a-service, resource recovery, product life extension, circular supply, and hybrid models (Vermunt et al., 2019) and strategies like reducing, reusing, recycling, recovering etc. (Kirchherr et al., 2018). The barriers vary depending on the circular business models and strategies employed. Hence appropriate internal barriers of CSC implementation in context of EBIs of Bangladesh also need to be considered.

In Table 3, the classification of the initial barriers is shown.
| Types of Barriers | Barriers |
|------------------|---------|
| Political        | 1. Lack of rules and regulations about the environment  
|                  | 2. Lack of favorable tax systems for supporting CSC  
|                  | 3. Lack of environmental certification systems |
| Economic         | 1. Low financial benefits in the short-run  
|                  | 2. Higher initial cost  
|                  | 3. Lack of funding  
|                  | 4. Higher production cost  
|                  | 5. High costs to develop circular alternatives  
|                  | 6. Lack of economic incentives to implement CSC  
|                  | 7. Higher costs of recycled materials than the virgin materials |
| Social           | 1. Lack of customer consciousness and involvement around CSC activities  
|                  | 2. Poor demand for environmentally preferred technologies  
|                  | 3. Cultural concerns (linear mindset of the customers) |
| Technological    | 1. Inadequate technology transfer initiatives  
|                  | 2. Unsystematic information systems  
|                  | 3. Lack of eco-efficient technological processes  
|                  | 4. Lack of technological improvement  
|                  | 5. Lack of standard systems  
|                  | 6. Inadequate information about the best available technology  
|                  | 7. Lack of local technologies  
|                  | 8. Difficulty of selecting cost-efficient technology  
|                  | 9. Lack of standard method for performance indicators about evaluating CSC  
|                  | 10. Lack of technology for tracking circulated materials  
|                  | 11. Challenges to design circulated products  
|                  | 12. Inadequacy in triumphant business models and frameworks to adopt CSC |
| Environmental    | 1. Lack of environmental effect measurement (certification) |
| Legal            | 1. Lack of data privacy and security  
|                  | 2. Warranty issues with circulated products  
|                  | 3. Lack of health and safety standards in CSC  
|                  | 4. Uncertainty of return flows |
| Types of Barriers | Barriers |
|------------------|---------|
| Internal         | 1. Lack of industry incentives for ‘greener’ activities  
                     2. The indifference of management and lack of planning for CSC adoption  
                     3. Lack of middle and lower level managers’ support and involvement in promoting ‘greener’ products  
                     4. Lack of awareness and consciousness about CSC among the organizational members  
                     5. Inadequate training and improvement programs for SC members and HR  
                     6. Lack of effective planning and management for CSC concepts  
                     7. Lack of coordination and collaboration amongst the SC partners  
                     8. Lack of transportation and infrastructure  
                     9. Lack of suitable supply chain partners  
                    10. Lack of vision  
                    11. Inadequacy in information sharing among the SC partners  
                    12. Unskilled workers  
                    13. Internal bureaucracy for implementing CSC  
                    14. Lack of transparency within the stakeholders  
                    15. Lack of clear vision about CSC  
                    16. Difficulty to maintain the product quality throughout the lifecycle  
                    17. Difficulty to take proper decision for implementing CSC  
                    18. Lack of information systems for tracking circulated products  
                    19. Lack of leadership and management towards CSC  
                    20. Unfavorable organizational structure to implement CSC  
                    21. Lack of interest towards CSC |

### 3.2.2 Contextual Relationship among the Identified Barriers

#### Selection of Initial Barriers

The barriers that have been chosen by 50% or more experts were selected as the input for ISM. Selected 16 barriers are shown in the Table 4.
### Table 4
Initial barriers for ISM model

| Barriers                                                                 | Experts’ Opinion (%) |
|--------------------------------------------------------------------------|----------------------|
| Lack of rules and regulations about the environment (B1)                 | 75%                  |
| Lack of favorable tax systems for supporting CSC (B2)                    | 50%                  |
| Low financial benefits in the short-run (B3)                            | 75%                  |
| Higher costs of recycled materials than the virgin materials (B4)        | 50%                  |
| Lack of customer consciousness and involvement around CSC activities (B5)| 75%                  |
| Cultural concerns (linear mindset of the customers) (B6)                | 50%                  |
| Inadequate technology transfer initiatives (B7)                         | 50%                  |
| Unsystematic information systems (B8)                                   | 50%                  |
| Lack of technology for tracking circulated materials (B9)               | 50%                  |
| Inadequacy in triumphant business models and frameworks to adopt CSC (B10)| 50%                  |
| Lack of environmental effect measurement (certification) (B11)          | 100%                 |
| Warranty issues with circulated products (B12)                          | 75%                  |
| Lack of industry incentives for ‘greener’ activities (B13)              | 75%                  |
| The indifference of management and lack of planning for CSC adoption (B14)| 50%                  |
| Lack of awareness and consciousness about CSC among the organizational members (B15)| 50%                  |
| Lack of effective planning and management for CSC concepts (B16)        | 50%                  |

Description of the initial barriers is shown in [Appendix A](#).

#### Development of Structural Self-Interaction Matrix (SSIM)

The relationship among the selected 16 barriers have been identified by the help of experts’ opinion. The relationship was ‘lead to’ type relation i.e., whether a particular barrier leads to another particular barrier? This pairwise comparison represents the direction of relation between the barriers. Some well-known symbols (Mangla et al., 2018) have been used in this step. They are as follow:

- **V** – Barrier i will help to get to barrier j
- **A** – Barrier j will help to get to barrier i
- **X** – Barriers i and j will help to get each other
- **O** – There are no relation between barriers i and j

The Structural Self-Interaction Matrix is demonstrated in the Table 5.
### Table 5
Structural Self-Interaction Matrix (SSIM)

| Barriers | B16 | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7 | B6 | B5 | B4 | B3 | B2 |
|----------|-----|-----|-----|-----|-----|-----|-----|----|----|----|----|----|----|----|----|
| B1       | V   | O   | V   | V   | O   | V   | O   | O  | V  | V  | V  | O  | V  | O  | V  |
| B2       | V   | O   | X   | X   | O   | O   | O   | O  | O  | O  | O  | O  | O  | V  | V  |
| B3       | A   | A   | V   | V   | O   | O   | A   | A  | A  | A  | O  | O  | A  | O  | A  |
| B4       | A   | A   | V   | O   | O   | O   | O   | A  | A  | O  | O  | O  | O  | O  | O  |
| B5       | A   | O   | O   | X   | A   | A   | A   | O  | O  | V  | O  | X  |   |   |   |
| B6       | O   | V   | X   | X   | A   | A   | O   | O  | O  | O  | O  | O  | O  | O  | O  |
| B7       | O   | V   | V   | V   | O   | V   | V   | V  | V  | V  |   |   |   |   |   |
| B8       | X   | O   | X   | X   | O   | V   | O   | X  |   |   |   |   |   |   |   |
| B9       | V   | O   | V   | V   | O   | O   | O   | O  |   |   |   |   |   |   |   |
| B10      | X   | A   | X   | X   | O   | A   |   |   |   |   |   |   |   |   |   |
| B11      | X   | X   | X   | X   | X   | O   |   |   |   |   |   |   |   |   |   |
| B12      | O   | O   | V   | V   |   |   |   |   |   |   |   |   |   |   |   |
| B13      | V   | X   | X   |   |   |   |   |   |   |   |   |   |   |   |   |
| B14      | V   | X   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| B15      | V   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

**Development of Initial Reachability Matrix (IRM)**

The IRM was generated by replacing the entries in SSIM with binary numbers (0 and 1). The replacement logics are as follows:

- For every V in SSIM, we put ‘1’ in (i, j) entry and ‘0’ in (j, i) entry.
- For every A in SSIM, we put ‘0’ in (i, j) entry and ‘1’ in (j, i) entry.
- For every X in SSIM, we put ‘1’ in both (i, j) and (j, i) entries.
- For every O in SSIM, we put ‘0’ in both (i, j) and (j, i) entries.

The IRM is demonstrated in the Table 6.
Table 6
Initial Reachability Matrix (IRM)

| Barriers | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 | B13 | B14 | B15 | B16 |
|----------|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|
| B1       | 1  | 1  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 0   | 1   | 1   | 1   | 0   | 1   |     |
| B2       | 0  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0   | 0   | 0   | 1   | 1   | 0   | 1   |
| B3       | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0   | 0   | 0   | 1   | 1   | 0   | 0   |
| B4       | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 1   | 0   | 0   |
| B5       | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 0   | 0   | 0   | 1   | 0   | 0   | 0   |
| B6       | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 1   | 1   | 1   | 0   |
| B7       | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 1  | 1  | 1   | 1   | 0   | 1   | 1   | 1   | 0   |
| B8       | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 0   | 1   | 0   | 1   | 1   | 0   | 1   |
| B9       | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 1  | 1  | 0   | 0   | 0   | 1   | 1   | 0   | 1   |
| B10      | 0  | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 1   | 0   | 0   | 1   | 1   | 0   | 1   |
| B11      | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 1   | 1   | 0   | 1   | 1   | 1   | 1   |
| B12      | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 1   | 1   | 1   | 0   | 0   |
| B13      | 0  | 1  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 1   | 1   | 0   | 1   | 1   | 1   | 1   |
| B14      | 0  | 1  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 1   | 1   | 0   | 1   | 1   | 1   | 1   |
| B15      | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 1   | 1   | 0   | 1   | 1   | 1   | 1   |
| B16      | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 1  | 0  | 1   | 1   | 0   | 0   | 0   | 0   | 1   |

Development of Final Reachability Matrix (FRM)

The IRM was transformed into FRM using the transitivity rule. Transitivity rule represents nothing but the indirect links between two barriers. For example, barrier B1 leads to barrier B2 but not barrier B3. On the other hand, barrier B2 drives barrier B3. So, there is an indirect link between the barriers B1 and B3. This indirect link is represented by bolded one i.e., 1. The FRM is shown in the following Table 7. The driving power (DR_p) was calculated by adding up the FRM's row entries, and the dependence power (DE_p) was calculated by adding up the FRM's column entries.
Table 7
Final Reachability Matrix (FRM)

| Barriers | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 | B11 | B12 | B13 | B14 | B15 | B16 | DRp |
|----------|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|
| B1       | 1  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 14  |
| B2       | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 0  | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 12  |
| B3       | 0  | 1  | 1  | 0  | 1  | 1  | 0  | 1  | 0  | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 11  |
| B4       | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 0  | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 12  |
| B5       | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 13  |
| B6       | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 0  | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 12  |
| B7       | 0  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1  | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 14  |
| B8       | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 13  |
| B9       | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 13  |
| B10      | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 0  | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 12  |
| B11      | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 0  | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 12  |
| B12      | 0  | 1  | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 1   | 1   | 1   | 1   | 1   | 1   | 1   | 11  |
| B13      | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 13  |
| B14      | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 13  |
| B15      | 0  | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 0  | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 12  |
| B16      | 0  | 0  | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1   | 1   | 0   | 1   | 1   | 1   | 1   | 12  |
| DEp      | 1  | 15 | 15 | 14 | 16 | 16 | 16 | 16 | 16 | 16   | 16   | 16   | 16   | 16   | 16   | 199 |

Level Partitioning

After the construction of FRM, the barriers have been partitioned into different levels to know the relative importance. At first the reachability set and the antecedent set have been constructed from the FRM. A specific barrier was grouped with other barriers that are influenced by that specific barrier in the reachability sets. The antecedent sets, on the other hand, combine a specific barrier with other barriers that influence that specific barrier. The intersection set was then generated by combining the reachability and antecedent sets. This process is carried out for each obstacle. Finally, the obstacles have been leveled with which the reachability and intersection sets are similar. If a barrier has been leveled, it can no longer be used. The iterations are shown in (Appendix B).

The barriers' final levels are listed in Table 8.
| Sl. No. | Level Number | Barriers |
|--------|--------------|----------|
| 1      | 1st          | • Low financial benefits in the short-run  
• Higher costs of recycled materials than the virgin materials  
• Lack of customer consciousness and involvement around CSC activities  
• Cultural concerns (linear mindset of the customers)  
• Unsystematic information systems  
• Inadequacy in triumphant business models and frameworks to adopt CSC  
• Lack of environmental effect measurement (certification)  
• Lack of industry incentives for ‘greener’ activities  
• The indifference of management and lack of planning for CSC adoption  
• Lack of awareness and consciousness about CSC among the organizational members  
• Lack of effective planning and management for CSC concepts |
| 2      | 2nd          | • Lack of favorable tax systems for supporting CSC |
| 3      | 3rd          | • Lack of technology for tracking circulated materials  
• Warranty issues with circulated products |
| 4      | 4th          | • Lack of rules and regulations about the environment  
• Inadequate technology transfer initiatives |

**MICMAC Analysis**

The MICMAC study assists in getting a deeper understanding of the causes and implications of the troublesome issues (Mangla et al., 2018). Based on the driving and dependency power, MICMAC analysis divides the barriers into four different categories. According to Mangla et al., (2018), they are as follows:

1. **Autonomous:** These barriers are characterized by low driving and dependency power (lower left quadrant), as well as being fairly detached from the system.
2. **Dependent:** Poor driving power and high dependency power (lower right quadrant); and coming on top of an ISM-based hierarchical model are among these obstacles. These barriers should be considered essential since their heavy dependency indicates that they require the elimination of all other barriers in order to implement CSC concepts.
3. **Linkage:** The barriers which have strong driving and dependence power (upper right quadrant) are categorised as linkage, which are located in the centre of the ISM-based hierarchical model. Since these obstacles are unpredictable, they require careful study, and practitioners should keep an eye on them at all levels of implementation.
4. **Drivers:** These barriers have high driving power and low dependence power (upper left quadrant); and located at the bottom of the ISM model.

The MICMAC analysis diagram is demonstrated in the following Fig. 3.

**Development of Digraph and ISM Model**

The digraph is a structural model constructed using the FRM (Mangla et al., 2018). The digraph for the intended problem is shown in Fig. 4.
The digraph was then converted into an ISM-based model by placing the barriers in the appropriate nodes. The ISM model is presented in Fig. 5.

The MICMAC diagram shows that there are four driving barriers called “Lack of rules and regulations about the environment (B1)”, “Inadequate technology transfer initiatives (B7)”, “Lack of technology for tracking circulated materials (B9)” and “Warranty issues with circulated products (B12)”. Among the four driving barriers, “Lack of rules and regulations about the environment (B1)” and “Inadequate technology transfer initiatives (B7)” drive “Lack of technology for tracking circulated materials (B9)”.

Finally, the cause-effect analysis has been conducted to find out the root causes of the driving barriers.

### 3.2.3 Cause-Effect Analysis

Here the effect was “Less CSC practices in EBIs of Bangladesh” and the causes were identified in respect to the driving barriers of ISM. The cause-effect diagram is shown in Fig. 6.

### 4. Result

The ISM model to represent the contextual relationship among the sixteen identified barriers of CSC implementation in EBIs of Bangladesh has been shown in Fig. 5. From the MICMAC diagram, four driving barriers have been identified. Then the cause-effect analysis in respect to these driving barriers has been shown in Fig. 6. Root causes of these driving barriers are also displayed in the Table 9.

| Driving Barriers                              | Root Causes                                        |
|----------------------------------------------|----------------------------------------------------|
| Lack of rules and regulations about the environment | • Lack of sustainable development planning          |
|                                              | • Lack of international conventions and            |
|                                              | • Lack of awareness about environment, health and future generations |
| Inadequate technology transfer initiatives    | • Lack of coordination among industries            |
|                                              | • Increased competitiveness and                    |
|                                              | • Low economic benefits                            |
| Lack of technology for tracking circulated materials | • Lack of investment on technological innovation   |
|                                              | • Lack of coordination among the supply chain partners and |
|                                              | • Lack of technology transfer                      |
| Warranty issues with circulated products     | • Lack of trust                                    |
|                                              | • Low quality and                                  |
|                                              | • Low performance                                 |

### 5. Discussion

The Government of Bangladesh can take proper initiatives for environmental laws and regulations. It can take more sustainable development planning and increase awareness about the environment, health and future generations. Then the implementation of laws and regulation will be easier and fruitful. The EBIs of Bangladesh can play a vital role to increase the
technology transfer initiatives. The coordination among the industries should be increased and the competition should be reduced to get rid of the problem. The technological limitations for tracking circulated products can be removed by increasing investment on technological innovations and increasing coordination among the supply chain partners. So, all the supply chain partners should take responsibilities in this aspect. The warranty issues can be resolved by increasing the quality of the circulated product. The EBIs should take quality improvement initiatives to increase the performance of the circulated products.

6. Conclusion And Future Work

This study shows the contextual relationship among the identified barriers and major causes of less CSC practices in EBIs of Bangladesh have been identified in respect to the driving barriers. The major causes are lack of sustainable development planning, lack of awareness about the environment, health and future generations, lack of coordination among the industries and supply chain partners, increased competition, lack of investment on technological innovation and low quality of circulated products. These are the root barriers that impede the implementation of CSC strategies in EBIs of Bangladesh.

In this research, the three-layered approach was adopted to find out the main barriers. These layers are as follows:

1. PESTEL framework helped to find out the appropriate initial barriers.
2. ISM-MICMAC approach established the contextual relationship and identified the driving barriers.
3. Cause-effect analysis helped to find out the major causes behind the driving barriers.

This is a unique combination of the three well-known tools that helped us to achieve our intended goal.

This study only focuses on the EBIs of Bangladesh. This framework may also be applied in other industrial sectors, which was beyond the scope of the research. CSC as a blessing should applied in every industry.

At the end, this study will help the Government of Bangladesh and the supply chain partners of EBIs of Bangladesh to take proper strategies for the implementation of CSC.

Abbreviations

SCM, Supply Chain Management; CSC, Circular Supply Chain; EBIs, Electric Battery Industries; ISM, Interpretive Structural Modelling; MICMAC, Cross Impact Matrix Multiplication Applied to Classification; C SCM, Circular Supply Chain Management; SC, Supply Chain; CE, Circular Economy; MCDA, Multi-Criteria Decision Analysis; BWM, Best Worst Method; AHP, Analytic Hierarchy Process; ANP, Analytic Network Process; DEMETAL, Decision Making Trial and Evaluation Laboratory; SEM, Structural Equation Modelling

Declarations

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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**Figures**
Data collection from the expert panel

Development of Structural Self-Interaction Matrix (SSIM)

Development of Initial Reachability Matrix (IRM)

Development of Final Reachability Matrix (FRM)

Determining the different levels of reported barriers

MICMAC analysis

Formation of ISM model

Cause-effect analysis

Figure 1
Flowchart of ISM-MICMAC technique

Initial barriers from literature review and expert panel

Application of PESTEL framework

Selection of the barriers which are related to the EBIs of Bangladesh (through the opinions of expert panel)

Exploring contextual relationship amongst the barriers using ISM-MICMAC approach (through the opinions of expert panel)

Cause-effect analysis for identification of root causes of the driving barriers

Feedback for improvement

Any inconsistency?

No

Yes
Figure 3

MICMAC analysis diagram

Figure 4

Digraph of the barriers of CSC adoption
Figure 5

ISM model of the barrier of CSC

- Lack of rules and regulations about the environment (B1)
- Lack of technology for tracking recycled materials (B9)
- Warranty issues with recycled products (B12)
- Inadequate technology transfer
- Inadequate business model and strategies (B7)

Lack of favorable tax systems for supporting CSC (B2)

Low financial benefits in the short-run (B3)

- Higher costs of recycled materials than the virgin materials (B4)
- Lack of customer consciousness and involvement around CSC activities (B5)
- Cultural concerns (linear mindset of the customers) (B6)
- Unsystematic information systems (B8)

Inadequacy in triumphant business models and frameworks to adopt CSC (B10)

- Lack of environmental effect measurement (certification) (B11)
- Lack of industry incentives for 'greener' activities (B13)

The indifference of management and lack of planning for CSC adoption (B14)

- Lack of awareness and consciousness about CSC among the organizational members (B15)
- Lack of effective planning and management for CSC concepts (B16)
Figure 6

Cause-Effect Analysis

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