Thesis Paper
on

"Circular Economy in the Supply Chain Management of Agricultural Development Projects: Evidence from a Developing Country"

Submitted by

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Program: MBA in Supply Chain Management (MSCM)

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Letter of Transmittal

January 03, 2026

To,

Shakila Yesmin
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Subject: Submission of thesis report on "Circular Economy in the Supply Chain Management of Agricultural Development Projects: Evidence from a Developing Country."

Dear Sir,

With due respect, I would like to inform you that it is indeed a great pleasure to have the opportunity for submitting the thesis report according to your instructions entitled on "Circular Economy in the Supply Chain Management of Agricultural Development Projects: Evidence from a Developing Country." which was assigned to me as a partial requirement for the completion of MBA in Supply Chain Management (MSCM) program. Throughout the study I have tried my best to accommodate as much information and relevant issues as possible and tried to follow the instructions that you have suggested. There might be some errors through oversight in the report, I sincerely apologies for such unintentional errors. I would be grateful to you if you kindly consider my unintentional mistakes.

I am grateful to you for your kind guidance and cooperation at every step of my endeavor during the preparation of this report. It would be a great help if you kindly take some time to go through the report and evaluate this.

Sincerely Yours

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Student’s Declaration

I, Md. Raquibuzzaman Khan, a student of MBA in Supply Chain Management (MSCM), ID No: MSCM2501034008 from Sonargaon University (SU) would like to solemnly declaration here that this thesis report on “Circular Economy in the Supply Chain Management of Agricultural Development Projects: Evidence from a Developing Country.” has been authentically prepared by me under supervision of Shakila Yesmin, Lecturer, Department of Business Administration Sonargaon University (SU).

I didn't breach any copyright act internationally. I am further declaring that I did not submit this thesis anywhere for awarding any degree, diploma, or certificate.

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Letter of Authorization

This is to certify that Md. Raquibuzzaman Khan, a student of MBA in Supply Chain Management (MSCM), ID No: MSCM2501034008 under my supervision as a partial requirement for obtaining MBA in Supply Chain Management (MSCM) program degree in Supply Chain Management major. This thesis report on "Circular Economy in the Supply Chain Management of Agricultural Development Projects: Evidence from a Developing Country" can be accepted for evaluation. To the best of my knowledge, the above mentioned work has been conducted by the student himself. Any option and/or suggestion made in this study are entirely that of the author of this thesis paper.

I wish him every success in life.

____

Shakila Yesmin
Lecturer
Department of Business Administration
Sonargaon University (SU)

Acknowledgement

No achievement can be realized in isolation. The absence of personnel renders success unacknowledged. I am exceedingly fortunate to receive earnest guidance and oversight from several individuals. Firstly, I am profoundly grateful to Almighty Allah for bestowing blessings, courage, and the capability to prepare this report.

I am profoundly grateful to Shakila Yesmin, Lecturer, Department of Business Administration Sonargaon University (SU), for his guidance in guiding and completing my thesis report. I am profoundly grateful to her for the scholarly and constructive suggestions that significantly aided in the preparation of this thesis paper titled "Circular Economy in the Supply Chain Management of Agricultural Development Projects: Evidence from a Developing Country." I am profoundly appreciative of all individuals who offered valuable guidance, suggestions, and advice in the collection of information, analysis, and preparation of the thesis paper. I am especially grateful to those whose efforts and cooperation were instrumental in the successful completion of this paper.

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Abstract

The circular economy (CE) is widely recognized as a key enabler of sustainable development goals, yet its adoption within agricultural development projects in developing countries remains limited and fragmented. Agriculture in these contexts faces multifaceted challenges, including climate variability, post-harvest losses, inefficient resource utilization, and weak supply-chain coordination across stages ranging from production to final consumption. Given the critical role of procurement and supply-chain management in optimizing project resources and outcomes, integrating circular economy principles into agricultural project supply chains is both timely and necessary. This study aims to develop a conceptual model integrating circular economy principles with supply-chain management of agricultural development projects, identify the key barriers to circular economy adoption in these supply chains, and analyze the interrelationships among the identified barriers. To achieve these objectives, the research employs a multi-criteria decision-making (MCDM) approach, integrating the modified Delphi method, the Best–Worst Method (BWM), and Interpretive Structural Modeling (ISM) combined with MICMAC analysis. The study identifies seven major categories of barriers—organizational, regulatory, technological, economic and financial, consumer and societal, operational and supply-chain, and environmental—comprising a total of fifty barriers. The analysis highlights ten critical barriers, with organizational and regulatory issues emerging as particularly influential. ISM results reveal that poor cold-chain and storage infrastructure is a highly dependent barrier linked to all others, while insufficient environmental laws and regulations act as a key driving barrier shaping the overall system. MICMAC analysis further confirms the complex interdependencies among barriers, emphasizing the need for a systemic rather than fragmented approach to CE implementation. The findings underscore that organizational barriers—such as short-term project-based approaches, lack of strategic planning, inadequate awareness, absence of performance measurement systems, and weak management support—pose the most significant obstacles to circular supply-chain transformation. Addressing these foundational issues is essential for enabling sustainable, resilient, and inclusive agricultural development. The study contributes to the literature by providing an integrated analytical framework and empirical insights relevant to policymakers, project managers, and development practitioners in developing-country contexts, while also offering directions for future research.

Table of Contents

Abstract ... vii

List of Tables ... x

List of Figures ... x

List of Abbreviations and Acronyms ... xi

Chapter 1: Introduction ... 1

1.1 Background of the Study ... 2

1.2 Research Gap ... 4

1.3 Research Objectives ... 5

1.4 Research Questions ... 6

1.5 Scope of the Study: Conceptual Framework of the Research ... 6

1.6 Limitations of the Study ... 8

Chapter 2: Literature Review ... 9

2.1 Key Concepts ... 10

2.1.1 Circular Economy ... 10

2.1.2 Supply Chain, Supply Chain Management, and Project Supply Chain Management ... 12

2.1.3 Circular Economy in Agriculture ... 15

2.1.4 Circular Economy in Project Management ... 17

2.2 Circular Economy Model in Supply Chain Management in Agricultural Development Projects ... 19

2.3 Barriers to Circular Economy in supply chain management of Agricultural Development Projects ... 23

Chapter 3: Research Methodology ... 25

3.1 Research Philosophy and Approach ... 26

3.2 Methodological Choice and Strategy ... 27

3.3 Analytical Tools ... 27

3.3.1 Modified Delphi Method ... 28

3.3.2 Best Worst Method (BWM) ... 28

3.3.3 Interpretive Structural Modeling (ISM) ... 30

3.4 Selection of Sample, Data Collection and Evaluation ... 31

Chapter 4: Results and Discussion ... 40

4.1 Key Barriers to Circular Economy in Agricultural Development Projects ... 41

4.2 Inter-relationship among the Key Barriers to Circular Economy in Agricultural Development Projects ... 46

Chapter 5: Recommendations and Conclusion ... 50

5.1 Recommendations ... 51

5.2 Conclusion ... 52
Bibliography ... 54
Appendices ... 60
Appendix I- Modified Delphi Questionnaire ... 60
Appendix II: Profile of the respondents participated in this research ... 63
Appendix III: Example of Best-Worst Method (BWM) Analysis Results for Main Criteria (Categories of Barriers) ... 65
Appendix IV: Sensitivity Analysis of BWM Results ... 72
Appendix V: Analysis Result of Interpretive Structural Modelling ... 77

List of Tables

Table 1 Research objectives and research questions. 6
Table 2. R-strategies in circular economy. 18
Table 3 Initial framework of barriers to supply chain management of agricultural development projects developed from literature review. 23
Table 4 Framework of barriers to supply chain management of agricultural development projects developed from modified-Delphi analysis. 32
Table 5 Weights and ranking of the barriers of the circular economy of agricultural development project supply chain. 34
Table 6 Weights and ranking of the top 10 (ten) key barriers of the circular economy of agricultural development projects. 41

List of Figures

Figure 1 Conceptual framework of this research 7
Figure 2 Structure of the literature review 10
Figure 3 Linear economy model and circular economy model. 11
Figure 4 A basic supply chain model 12
Figure 5 Project supply chain building blocks 13
Figure 6 Project supply chain framework 15
Figure 7 Process of project supply chain (the total supply chain) 15
Figure 8 A conceptual model for integrating CE and Agricultural project supply-chain management – CEProSCM framework 20
Figure 9 The research ‘onion 26
Figure 10 Inductive logic of qualitative research 27
Figure 11 Research methodology. 28
Figure 12 Flow chart for establishing the ISM models of the barrier to circular economy in agricultural development project supply chain. 30
Figure 13 Global weight variation of the barriers found in the sensitivity analysis. 37
Figure 14 Ranking variation of the barriers found in the sensitivity analysis 38
Figure 15 The ISM model of the key barriers of the circular economy of agricultural development projects. 47
Figure 16 MICMAC analysis of the key barriers. 48

List of Abbreviations and Acronyms

ADB	: Asian Development Bank
ADP	: Annual Development Program
AHP	: Analytical Hierarchy Process
BWM	: Best Worst Method
CE	: Circular Economy
CIPS	: Chattered Institute of Procurement and Supply, UK
CPTU	: Central Procurement Technical Unit, Bangladesh
CSCMP	: Council of Supply Chain Professional, USA
DAE	: Department of Agricultural Extension, Bangladesh
DEMATEL	: Decision Making Trial and Evaluation Laboratory
DPP	: Development Project Proforma/Proposal
ECNEC	: National Economic Council, Bangladesh
ERP	: Enterprise Resource Planning
FDM	: Fuzzy Delphi Method
FGD	: Focus Group Discussion
FY	: Financial Year
GDP	: Gross Domestic Product
GoB	: Government of Bangladesh
GRM	: Grievance Redress Mechanism
HOPE	: Head of Procurement Entity
ICT	: Information And Communication Technology
ID	: International Development
IMED	: Implementation Monitoring and Evaluation Division, Bangladesh
ISM	: Interpretive Structural Modelling
KII	: Key Informant Interview
MoA	: Ministry of Agriculture, Bangladesh
MCDM	: Multi-Criteria Decision Making
MICMAC	: MaMatriced'Impacts Croises-Mltipication Applique' and Classment (Cross-impact matrix multiplication applied to classification)
NIS	: National Integrity Strategy
PC	: Planning Commission, Bangladesh
HOPE	: Head of Procurement Entity
PIP	: Program Implementation Plan
PIU	: Project Implementation Unit
PMI	: Project Management Institute, USA
SASC	: Sustainable Agriculture Supply Chain Management
SCM	: Supply Chain Management
ToR	: Terms of Reference
TPP	: Technical Assistance Project Proforma
WB	: World Bank
ZESA	: Zimbabwe Electricity Supply Authority

Chapter 1: Introduction

1.1 Background of the Study

Transitioning to a circular economy is not without the challenges of preserving the natural environment, maintaining sociocultural practices, combating climate change, and moving from a linear to a circular agricultural economy. Further, it is important to reduce the negative environmental footprint of agricultural activities, loss of biodiversity, deforestation, increased greenhouse gas emissions, and overuse of resources such as water, energy, and other chemical fertilizers and pesticides. Therefore, sound economic and regulatory institutions are required to play an important role in creating a circular economic pathway for any sector, such as agriculture, for sustainable development (Medhekar 2024).

Transforming the agriculture sector and motivating the farmers to adopt and implement a circular economy model, along with new recycling technologies and infrastructure required for the agricultural circular economy, is full of barriers or challenges for developing countries (Yang et al., 2022). Agarwal et al. (2023) suggest that public private partnerships (PPPs) between the key stakeholders can help implement the sustainable circular economy business models, along with new recycling technologies and infrastructure in the agriculture sector to ensure food security, improve access to communication technology, modernize agriculture with the use of innovative harvesting technologies, and improve agriculture infrastructure, transportation, cold-transport, and value adding production processes. These efforts can create jobs, increase productivity, and contribute to long-term prosperity, ensuring food security and economic growth (Medhekar 2024).

The circular economy has the potential to achieve numerous sustainable development goals (SDGs) (United Nations. UN-SDG, 2022). The agriculture sector in developing countries, in particular, has to face various challenges and opportunities related to adopting and transitioning to a circular economy model. These challenges include coping with climate change, dealing with the vagaries of the monsoon/rainfall at various stages of production, and experiencing losses along the agricultural food chain life cycle at micro and macro levels. This cycle involves processes from sowing, pre/postharvest, handling, sorting, storing, packaging, transporting, processing, and the retail sector to the final consumer. (Medhekar 2024).

The agricultural sector has a major impact on the environment contributing to the greenhouse impact, climate change, and increased water and fertilizer consumption resulting in pollution. Therefore, a circular economy can be applied to the agriculture sector to reduce the negative impact of agriculture on the environment and also gain economic value by utilizing wasteful resources and increasing food production for the growing population demand (Vilasco-Munoz et al., 2022).

Even though there are different definitions for circular economy from the context of various industries and sectors in the economy, one common theme emerges, which is to reduce, minimize, recycle, and reuse waste by transforming and adding value along the whole supply chain and increasing the utility of the scarce resources, waste, and the value-added product. Transitioning to a circular economy practice by the agriculture sector is still in the infancy stage across the globe, whereby farm waste can be reused, repurposed for recycling to minimize waste, minimizing the use of external inputs in agriculture such as water and chemical fertilizers, and grow drought and pest resistance crops that need less water and external inputs. Implementation of the circular economy principles needs to consider cultural, social, economic, and environmental dimensions for a sustainable circular economy in all sectors of the economy such as agriculture, manufacturing, and services sectors for health, education, transport, and technology. Therefore, more research is required to identify ways to improve the efficiency of resource use, agricultural waste, and agricultural sustainability of crop production by adopting circular economy practices. In this process, it is first essential to understand how the concept of sustainable circular economy could be embedded and implemented in the agricultural systems and how different business models can be examined and tested by the farmers for achieving United Nations SDGs, such as, zero hunger, food security, responsible production and consumption, reduced waste, reuse, value addition, efficient use of scarce economic resources, and promoting economic efficiency in production processes by reducing the negative impact of environmental footprint and climate change for current and future generations (Medhekar 2024).

On the other hand, project procurement and supply-chain management are crucial for delivering a successful project as it is essential to optimize the resources throughout the project phases from project initiation to project closing. And the procurement management being a part of the project supply chain plays a vital role by enhancing the value of the total project supply chain (Basu and Wright, 2017; Morris and Pinto, 2007; PMI, 2017).

Notwithstanding this fact, however, the importance of the project supply chain has not been recognized properly in the context of project management (Basu, 2011; Morris and Pinto, 2007). Due to its inherent complexity, the supply chain encounters several challenges. The complexities along the chain underscore the importance and need for project-based organizations to manage the total supply chain in a more efficient and organized way (Morris and Pinto, 2007).

In the context of developing countries, the development projects pose a particularly complex scenario since the natural, political, and social factors create a range of difficulties in the project environment which include, but not limited to, imperfect project design, unclear project objectives, and delay between project identification and initiation (Cusworth and Franks, 2013; Gasik, 2016; Golini *et al*., 2015). Consequently, the professionals need to retain as much flexibility as possible to cope up with the changes to the overall design while managing and implementing projects; in addition, they have to focus on the long-term effect of the project beyond the project phases and project life cycles to create the lasting and beneficial assets to the development projects (Cusworth and Franks, 2013). If the project's goal is focused only on the department or at the individual corporate level, instead of focusing on the total project supply chain, optimization in value cannot be achieved (Morris and Pinto, 2007). As a result, the projects fail to manage the total project supply chain efficiently, which focus on individual corporate level of the department and optimization in value might not be attained (Morris and Pinto, 2017).

1.2 Research Gap

Given the barriers and challenges related to adopting a circular economy business model, transforming the agriculture sector is in its experimental stage in developing countries. It is important to have more research where farmers are provided subsidies at the institutional level to adopt the circular economy model, and new key performance indicators should be identified and developed for evaluating the transformation of a farm (agriculture, horticulture, aquaculture, or cattle) to a circular economy model. There are numerous case studies and systematic literature reviews on the adoption of sustainable circular economy in the agriculture sector in developed European countries, in particular (Barros et al., 2020), and few in developing countries (Medhekar 2024).

Generally, the public-sector development projects in developing countries are funded by respective governments or the international development partners. These projects consist of different stakeholders and management strategies. This study considers both the funding sources (i.e., government and donor funded projects) to address the research objectives. Although the project procurement and supply-chain issues are crucial to optimizing the value of the projects, the issue remains somewhat neglected and inadequately recognized in the context of project management (Basu, 2011; Khan et al., 2022; Morris and Pinto, 2007). Specifically, there is a real dearth of research work relating to circular economy and agricultural project supply chain management in developing country context. Project procurement and supply chain issues in public sector agriculture projects in the Bangladesh context. In fact, no substantial research work has been identified on circular economy in agricultural development project issues from the initial literature review.

Accordingly, no substantial research has been found on circular economy and agricultural development projects in the developing country context. More specifically, the research gap highlights the following areas of the barriers to the circular economy in the project supply chain of agricultural development projects in a developing country context, which need to be investigated.

It is highly likely that the study findings would contribute to the existing literature of project procurement and supply-chain management in the developing country context. Also, it would be greatly applicable for the respective project professionals and policy makers who are involved in project procurement and supply chain management and future policy formation processes. Thus, the research contributes significantly to the body of knowledge and the industry practice in Bangladesh and beyond.

1.3 Research Objectives

The background study and research gap discussed in the above leads to the following research objectives.

1. To develop a conceptual model for integrating circular economy and supply-chain management of agricultural development projects.
2. To investigate the key barriers to circular economy in supply-chain management of agricultural development projects.
3. To investigate the inter-relationships among the key barriers to circular economy in supply-chain management of agricultural development projects.

1.4 Research Questions

The research objectives translated into the following research questions-

Table 1: Research objectives and research questions.

Research Objectives (RO)	Research Questions (RQ)
1. To develop a conceptual model for integrating circular economy and supply-chain management of agricultural development projects.	1. How can circular economy (CE) principles be systematically integrated into supply-chain management (SCM) processes within agricultural development projects in developing countries? 2. What conceptual model can best represent the integration of CE principles with SCM functions for agricultural development projects?
2. To investigate the key barriers to circular economy and their inter-relationship in supply-chain management of agricultural development projects.	3. What are the key barriers to circular economy in supply-chain management of agricultural development projects?
3. To investigate the inter-relationships among the key barriers to circular economy in supply-chain management of agricultural development projects.	4. What are inter-relationships among key barriers to circular economy and their inter-relationship in supply-chain management of agricultural development projects?

1.5 Scope of the Study: Conceptual Framework of the Research

In Bangladesh, there have lately been growing concerns about the challenges and/or barrier of development project implementation especially relating to project supply chain and procurement (Khan et al., 2022). Such concerns – officially dubbed as 'objections' were raised by several international development partners that support development projects in the country; consequently, since the total public procurement of the country accounts for more than 75 percent of the total Annual Development Program (ADP), the government responded in good spirit by initiating several measures to ensure effective procurement management in its public sector projects (CPTU, 2020; WB, 2020). Moreover, nearly 8-30 percent share of the GDP is represented by public procurement, so the issue has become highly relevant to sustainable development goal (Goal 12.7- "Promote public procurement practices that are sustainable, in accordance with national policies and priorities") of the country (CPTU, 2018; 2017). In the case of Circular

Economy (CE) in agricultural project supply chain management would be phenomenal for not only improving overall performance of the project but also sustainable development of the country.

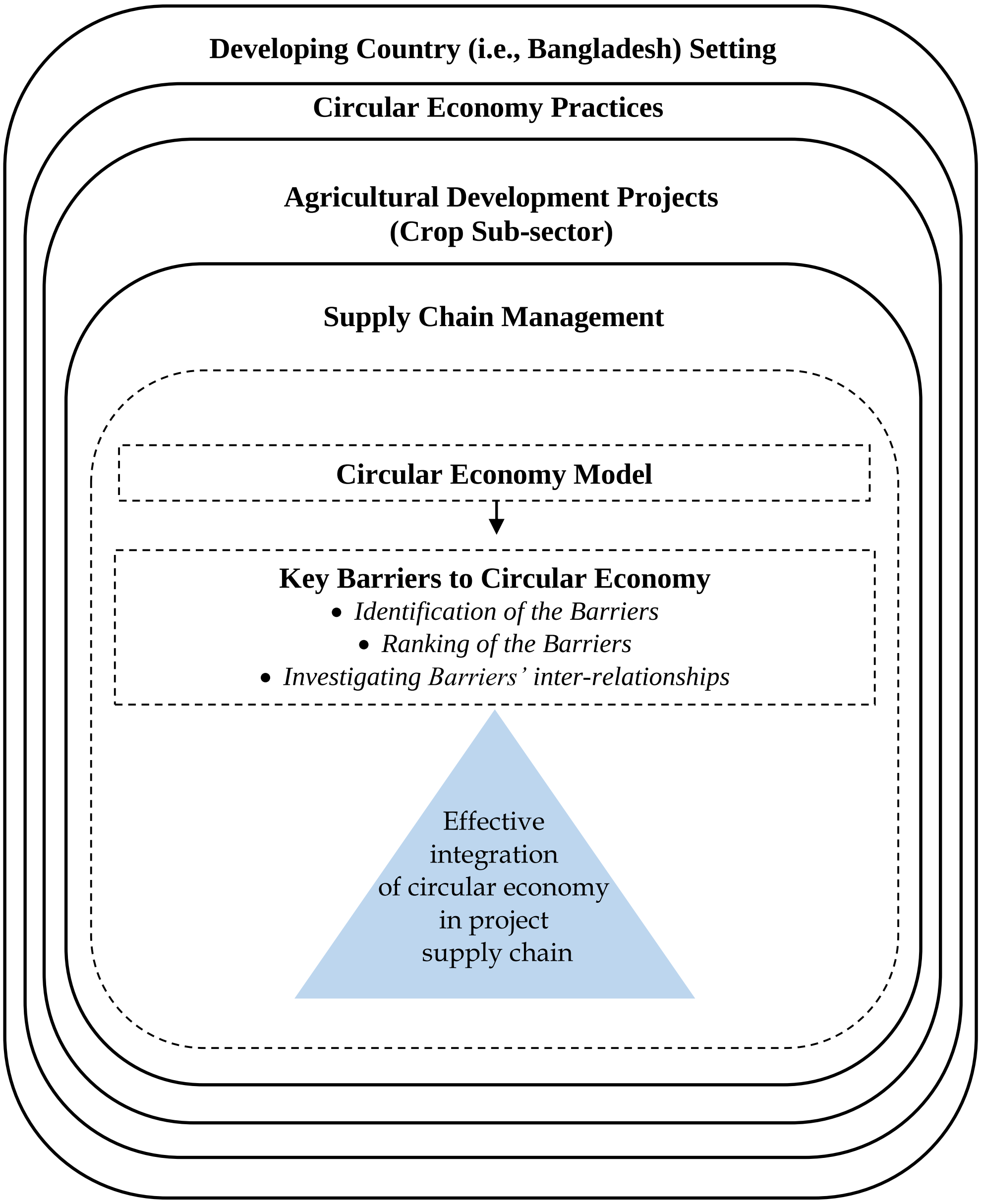


Figure 1: Conceptual framework of this research

The study investigates the public sector agricultural development projects in Bangladesh to address the issue-circular economy in project supply chain management. Since there is no substantial research that has been undertaken on this issue, the study initially develops conceptual model (Figure 8) for integrating CE and agricultural project supply-chain management. Then, it investigates barrier to it as mentioned in Figure 1.

1.6 Limitations of the Study

The study does have a few limitations, which are detailed below.

- The study investigated only agricultural (crop sector) development projects.
- Initially, the study included most of the barriers to circular economy from the literature that were not mostly directly relevant to agricultural projects because there is no substantial research work or literature on agricultural development projects and circular economy, particularly from the perspective of developing countries.
- In terms of methods, the study used a variety of approaches, including modified Delphi, BWM (Best-worst Method), and ISM (Interpretive Structural Modeling), to identify the most significant barriers to circular economy in agricultural development projects in Bangladesh, as well as their interdependence. While these methods require a small number of participants, they may bias the results in some cases.
- The study exclusively examines public sector agricultural development projects and does not consider initiatives from the private sector.

Chapter 2: Literature Review

This chapter represents a review of the relevant literature. The aim of any literature review is to provide the reader with information about the 'state of the art' knowledge and key issues related to the topic; additionally, it provides justification for the research undertaken (Fellows and Liu, 2003). Thus, this chapter focuses on literature that is related to circular economy, supply-chain, supply chain management, and project supply chain management in agricultural development projects along with their circular economy model in a developing country context. The literature review is structured as shown in Figure 2 below.

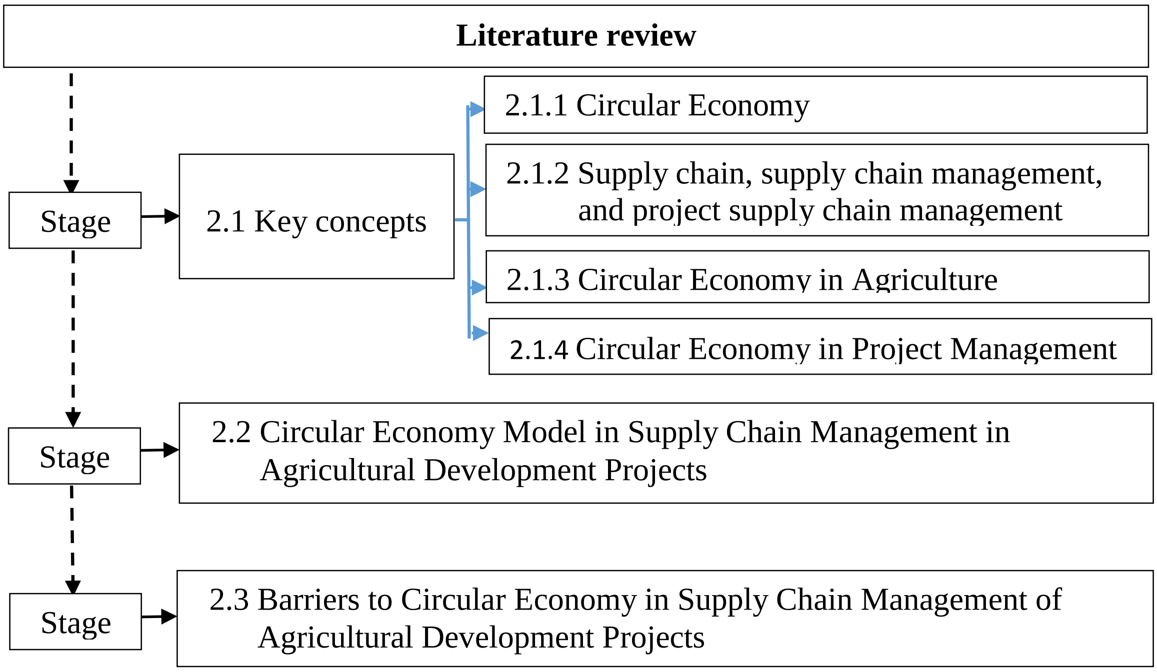


Figure 2: Structure of the literature review

It is structured in four stages: the initial stage is to define key concepts related to circular economy, supply chain, supply chain management, circular economy in agriculture, and project management; the second stage is to explore the literature in the context of the circular economy model in supply-chain management of agricultural development projects; and the third stage is to explore the literature in the context of the key barriers to circular economy in supply chain management of agricultural development projects. Since there is a dearth of literature on such issues, particularly in the context of a developing country's context, the study considered the issues beyond the agriculture sector in both developed and developing countries.

2.1 Key Concepts

2.1.1 Circular Economy

The circular economy (CE) is defined as a method to manage resource circularity, efficiency, and optimization that advocates the use of waste as resources to generate value (Azizuddin et al., 2021). It is possible to achieve Sustainable Development Goals (SDGs) through a circular economy because the model replaces production with sufficiency, reuses what we can, recycle what cannot be reused, repairs what is broken, and remanufactures what cannot be broken (Ahmed el al., 2022). Aside from polluting the environment, this model also results in huge waste and inefficient use of resources. The circular economy involves production, consumption, dispose of wastage to recycle it for further production (Figure 3) and it is governed mainly by Recycling, Reduce and Reuse (3Rs) concept (Manickam and Duraisamy, 2019).

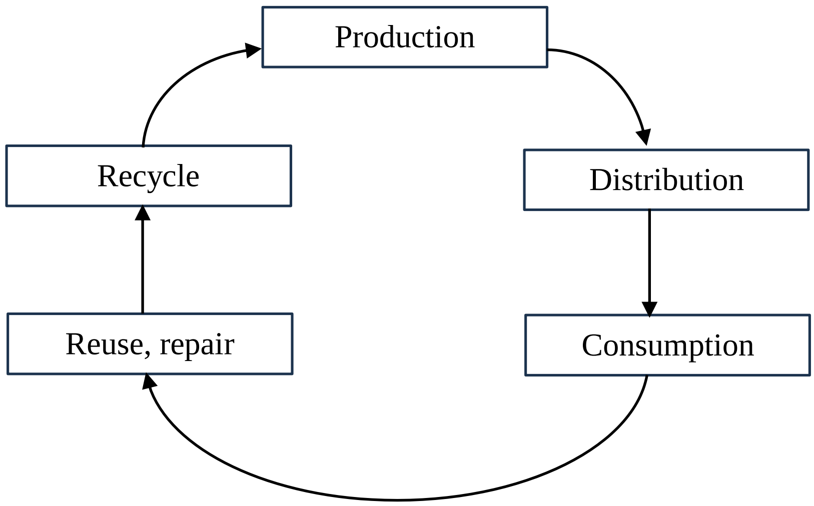


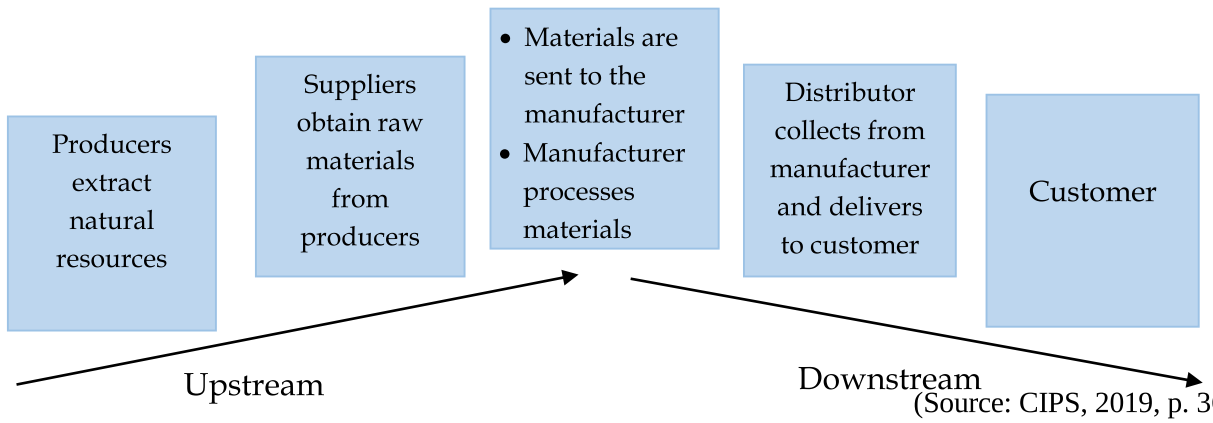
Figure 3: Linear Economy Model and Circular Economy Model.

The four guiding principles of a circular economy, as identified by William (2014), are as follows: (1) efficient material management through zero waste, where things are repaired, disassembled, and reused, and nothing is thrown away. (2) A reduction of waste of toxic substances, given the two types of industrial waste: (a) disposable— which are biodegradable-paper and fabric and (b) durable—which can be reused or dismantled and sorted at the end of life of plastic, metals machinery, and large cruise ship. (3) For a sustainable industrial cycle, where renewable energy must be used and energy efficiency achieved so that businesses are prepared in advance for any exposure to supply shocks. (4) Customers are users, which means that businesses would want the materials returned when customers finish using the things at the end of their life cycle, leading to more sharing, leasing, and renting.

Kirchherr, Reike, & Hekkert (2017) found that the concept, in most cases, is identified as a mixture of reduce, reuse, and recycle strategies. Although various R-strategies are present in academic and other literature, origins cannot be linked to specific authors and articles. These R-strategies (or frameworks) are visioned as a ladder, where strategies higher up on the ladder have a higher level of circularity, minimizing natural resources depletion and waste accumulation (Potting et al., 2017). Numerous authors offered R-strategies beyond the basic 3R (reduce, reuse, and recycle), ranging from 4R to 10R (Reike et al., 2018). The idea behind these frameworks is to group R-strategies according to their degree of circularity, that is, their ability to stay in a closed-loop longer. Potting et al. (2017) argue that "smarter product use and manufacture" is more favorable than "lifetime product extension", followed by "useful application of material", which should be the last resort. The concept of circular economy has been largely promoted by the EU, UN, UNDP, UNEP and OECD. In 2020, European Commission adopted a New Circular Economy Action Plan, with the aim to decrease "pressure on natural resources and creating sustainable growth and jobs". This action plan is defined as one of the fundamental points of the EU larger strategy, which is to be climate neutral by 2050 (European Green Deal, 2019; Obradović et al., 2024).

2.1.2 Supply Chain, Supply Chain Management, and Project Supply Chain Management

Handfield *et al*., (2002) define supply chain as "the supply chain encompasses all organizations and activities associated with the flow and transformation of goods from the raw materials stage, through to the end user, as well as the associated information flows". According to CIPS (2019) "a supply chain involves a network of individuals, organizations, technology, activities and resources to make sure goods or services flow along the chain". Thus, all parts of the supply chain need to work together. The basic objective of the chain is to procure and supply something to the customer or end user; thus the chain has two stages (Figure 4): upstream and downstream.

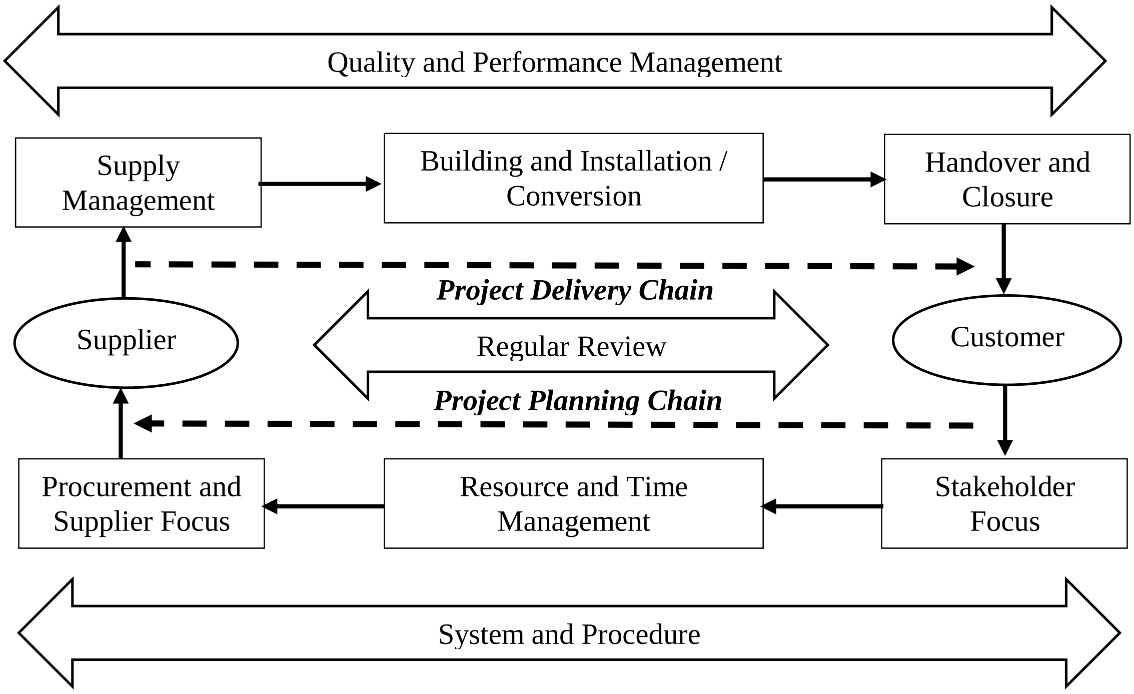


(Source: CIPS, 2019, p. 36)

Figure 4: A basic supply chain model

While the Council of Supply Chain Professional (CSCMP) defines the supply chain management as encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies (CSCMP, 2013). Similarly, CIPS (2019) argues that the management is to reduce the costs, improve value and reduce risks; additionally, it is involved in managing customer relationships as mentioned in Figure 4.

On the other hand, Basu and Wright (2017) studied on total supply chain in a project, and the study states that the supply chain building blocks (Figure 5) consist of nine components, out of which six components are for supply chain configuration (e.g., customer focus and demand management, resource and capacity management, procurement and supplier focus, inventory management, operations management and distribution management), and three components are for supply chain integration (e.g., systems and procedures, sales and operations planning, and performance management). Project supply chain and procurement differs from other types of supply chain management, such as product supply chain management, in that each project has some unique, novel, and unfamiliar characteristics that must be implemented within a specific budget, time frame, and resource allocation (Basu and Wright, 2016; Khan et al., 2022b, 2022c).



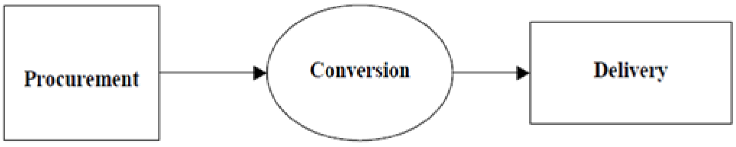
Adapted from Basu and Wrigh, 2017; Morris and Pinto, 2007

Figure 5: Project supply chain building blocks

Generally, project supply chain management is a set of methods used to efficiently and fully integrate all relevant organizations' networks and activities to complete and deliver a product, service, or project while minimizing system-wide costs and exceeding customer service expectations (Khan et al., 2022c; Morris and Pinto, 2007). In addition, project supply, procurement management, and supply chain strategies are interconnected as a result of the approaches to project management (Basu and Wright, 2016; Pari and Persichilli (2019). Many academics have acknowledged SCM's value in enhancing the strategic, tactical, and operational performance of project-based industries (such as construction and shipbuilding) since the 1990s. However, the enormous networks of suppliers and subcontractors in these project-based sectors are generally plagued by high supply chain fragmentation, limited coordination, and frequent disagreements. The project supply chain is made up of two chains (i.e., planning and delivery) with nine components (Basu and Wright, 2016; Khan et al., 2022c). The delivery chain depends on the planning chain and is linked to other elements. The key elements of the project planning chain are stakeholder focus, time and resource management, and procurement and supply chain focus (Figure 5); on the other hand, the delivery chain focuses on supply management, conversion or reproduction, and issues related to project handover and closure. While the other three components (system and procedure, regular review, and quality and performance) are involved throughout the chain, they are directly linked with identifying and addressing project supply chain challenges and risks throughout the project.

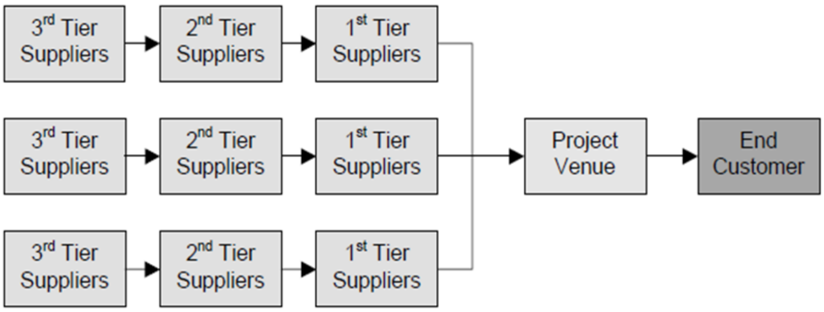
Macbeth *et al.*, (2012) conducted separate research on procurement and supply chain in project issues, and their focus was on how the worldwide project management and supply chain professionals define the procurement and supply chain in project. The study finds that the term used started off as purchasing in 1980s, became procurement in 1990s, and then procurement and supply chain from 2000s. However, the study reveals that the issue of supply and its role in projects is insufficiently recognized and incorporated into best practice guidance and action for and by project managers.

Morris and Pinto (2007) studied on project supply chain framework, and they found that the supply chain management is a set of approaches utilized to integrate the network of all organizations and their related activities efficiently and fully in producing/completing and delivering a product, a service, or a project so that system wide costs are minimized while maintaining or exceeding customer-service-level requirements. Supply chains are often referred to as value chains, as value is added to the product, service, or project as they progress through the various stages of the chain. However, the project supply chain management is considerably more difficult as project supply chains are inherently more complex. Project supply chain framework consists of procurement, conversion and delivery phases as shown in Figure 6. The procurement part could be linear or multi-linear as shown in Figure 7. For example, many projects typically involve a multitude of suppliers and experience considerable variability in supply delivery lead times and resource constraints, as well as frequent changes to the project scope. Such project supply chain complexities underscore the importance and need for project-based organizations to manage their total supply chain in a more formal and organized manner. If the project's goal is focused only on the department or at the individual company level, instead of the total project supply chain, value optimization for the project cannot be achieved.



(Source: Morris and Pinto 2007, p. 236)

Figure 6: Project supply chain framework



(Source: Morris and Pinto 2007, p. 228)

Figure 7: Process of project supply chain (the total supply chain)

Syahruddin and Kalchschmidt (2012) conducted a study on Sustainable Agriculture Supply Chain Management (SASC) based on secondary data. The study argues that SASC is not only the matter of practicing farm cultivation; however, it includes transportation, warehouse, manufacturing, and distribution along with the issues of environment and biodiversity. A better policy on it is required to ensure the practice in a holistic approach.

Yadav and Ray (2015) conducted research on Supply Chain Management (SCM) in Flyover projects, the construction industry, in India. The study investigated the SCM practices within the projects. It is stated that knowledge on SCM is essential to implement a project; therefore, training on SCM for all of the project agents should be an integral part of the construction, and it should be conducted before the start of the project.

2.1.3 Circular Economy in Agriculture

The most comprehensive definition of the circular economy in the agriculture sector is given by Vilasco-Munoz et al. (2021) in their seminal paper as "the set of activities designed to not only ensure economic, environmental, and social sustainability in agriculture through practices that pursue the efficient, effective use of resources in all phases of the value chain but also guarantee the regeneration of and biodiversity in agro-ecosystems and the surrounding ecosystems" (p. 4). They have also provided a list of indicators for narrowing resource loops, closing resource loops, and regenerating indicators' descriptions, strengths, and weaknesses in detail to measure circular economic activity in the agriculture sector. Vilasco-Munoz et al. (2022) conducted a systematic review of the application of the circular economy in agriculture across its life stages and found that this is a new area of research with growing interest in the agricultural circular economy. The most external resource-intensive phases of agriculture are cultivation, preparation of land for sowing, fertilizer application, sowing seeds, planting seedling, and irrigation. Conversely, waste generation occurs during mulching, pruning, training, and harvesting, which need to be managed to minimize waste and add value by adopting circular economy models and practices in the different stages of the agricultural food production cycle (Medhekar 2024).

The agricultural sector is one of the largest contributors to negative externality-related greenhouse emissions and impacts climate change. According to Barros et al. (2020), the agriculture sector could transform to reduce the greenhouse impact and move from a linear economy related to "take-make-use-dispose," to the circular economy of "grow-make use-restore" and use the economic resources efficiently, add value to the agricultural waste, increase environmental benefits, and minimize costs by adopting circular economy practices and principles. Their study has mapped via a systematic literature review "bioenergy boosters" through circular economy practices in the agricultural sector, suggesting the adoption of circular economy practices in agriculture to reduce waste and generate bio-fuel green energy.

Ven der Wiel et al. (2019) define circular economy in the agriculture sector as the production of crops involving three stages of activities: (1) processes, (2) reserves of soil as nutrients, and (3) flow of nutrients, linked with the production of crops for fodder, grasslands, fruits, and vegetables. Production of any crop involves extensive use and consumption of external resources such as water, energy, and fertilizers. The study by Nattassha et al. (2020) examines the implementation of a circular economy in the agri-food supply chain to prevent loss of eco nomic value and use wasteful resources for another production process by adding economic value as a new resource or input for another pro duction process.

For sustainable development, adopting a sustainable circular economy model for production and consumption is the key to reducing waste and securing a sustainable future for farmers, businesses, and households in developing countries. Circular economy is particularly important for reducing, reusing, and recycling to restore and regenerate the environment, thereby fostering sustainable development in the agriculture sector. It also helps reduce waste in horticulture and vegetable production systems (Medhekar 2024).

The study by Vilasco-Munoz et al. (2021) summarizes three key principles of a circular economy for adopting to the agriculture production sector: (1) eliminate waste and pollution, (2) maximize the value of the product and material in use in all stages of the agriculture supply chain, and (3) regenerate the natural agricultural systems by preserving the nature through the use of renewable resources to reduce the impact of greenhouse gases, enhance carbon capture by plants in soil, and increase soil health and fertility, which reduces the need for external inputs like chemical fertilizers and pesticides.

2.1.4 Circular Economy in Project Management

Projects are limited in time, resources and budget. Projects always have a specific goal and have been proven as a very effective mechanism to implement organizational change. Since many international organizations and institutions provide social, political, economic, and environmental change via programs and projects, we can conclude that we live in a project society and that projects are not used only for reaching organizational goals but the goals at the national and international level. CE implementation at the organizational level requires certain conditions that could be provided at the local and national levels. In favor of this conclusion are initiatives of international institutions: OECD, UNDP and European Commission are incorporating circularity and CE targets in strategies and strategic plans of many countries. This further robust legal regulation change creates new opportunities for CE business, influence the education system, favour knowledge and skills improvement, enables companies to implement circularity faster. Therefore, the project management approach should be set up to meet the needs of the CE and support CE implementation at different levels of society (Obradović et al., 2024).

Based on the circular economy and R-strategies, project strategies focuses on three areas: responsible resource utilization and manufacturing (refuse, rethink, and reduce); preserve and prolong the lifetime of a product and its elements (reuse, repair, refurbish, remanufacture, repurpose); and using waste for material and energy recovery (recycle, recover) as mentioned in the following table (Obradović et al., 2024):

Table 2. R-Strategies in circular economy.

R-Strategies	Key features
Responsible product utilization and manufacturing	
Refuse	• Make a product redundant by offering a different product with the same or similar function as an alternative. • Refrain from buying; use less-buy less-prevent waste. • Avoid using virgin materials in the production process.
Rethink	• Make products utilization more intensive through sharing or products with multiple functions. • Recreate ideas, concepts, processes with innova tive models.
Reduce	• Decrease the use of natural resources and raw materials in the production process. • Dematerialize – to deliver the same product or service without using any material.
Preserve and prolong the lifetime of a product and its elements	
Reuse	• Resell or donate discarded product, which still works as new, to another consumer for further usage. • The rejected product needs only minor improvements, such as cleaning or polishing.
Repair	• Restore damaged products to good condition by fixing or replacing broken parts. • Repaired products or materials retain the original functions.
Refurbish	• Restore old products by replacing or repairing many of its components. • Modernize or upgrade products with new and advanced parts.
Remanufacture	• Second-hand or recycled parts from a discarded product are used in a new product. • A new product has the same function as the discarded one. • Old product is disassembled, inspected, and worn or damaged parts are replaced by new or re-machined parts, making them as close as new as possible.
Repurpose	• Make completely new products from discarded products or parts. • The new product has a different function than discarded one.
Using waste for material and energy recovery	
Recycle	• Collect, separate and process waste products and materials and reuse them in new products. • Destruction of the original product during the process.
Recover	• Non-recyclable products and material incineration for energy production. • Complete destruction of products and materials.

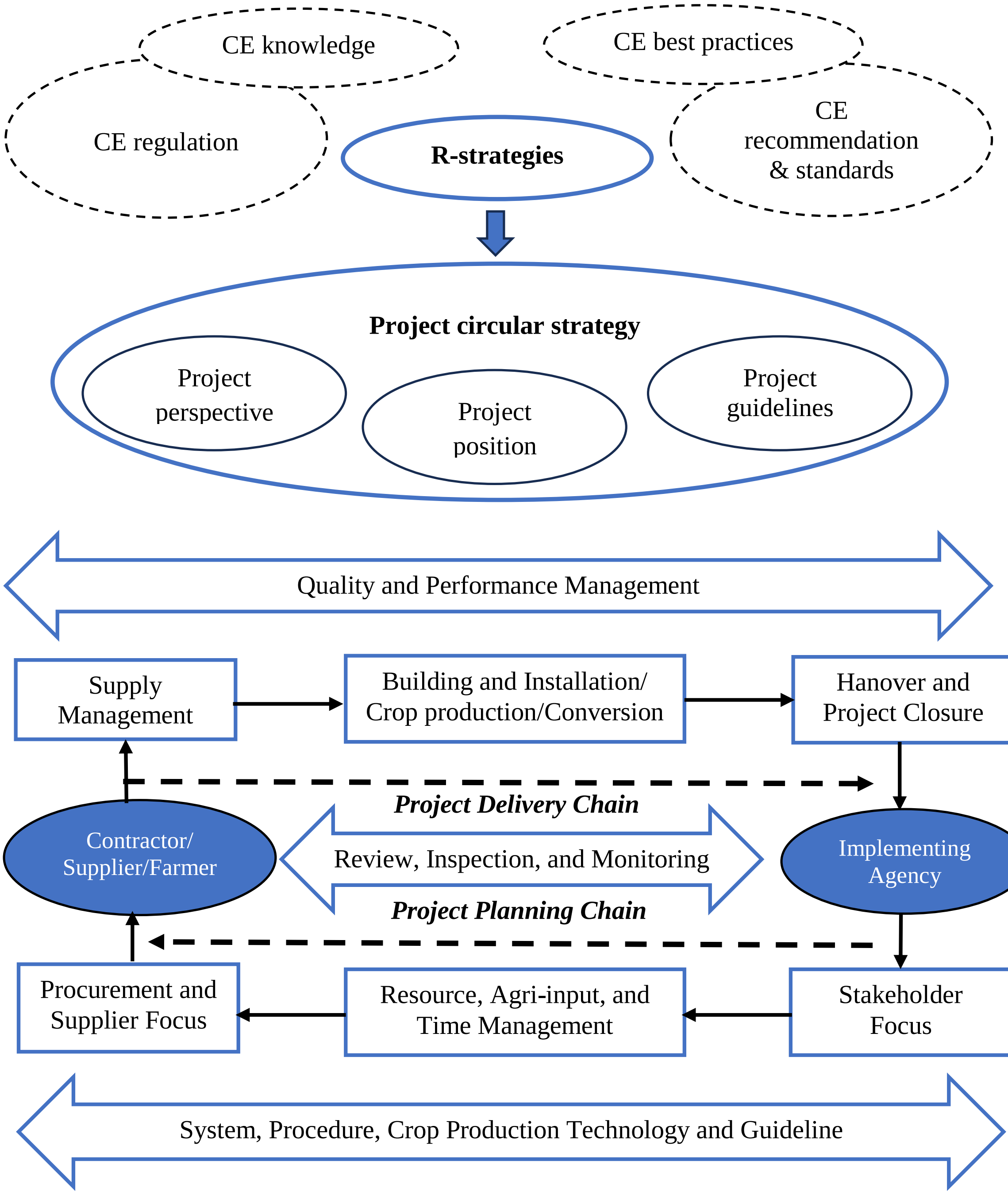
2.2 Circular Economy Model in Supply Chain Management in Agricultural Development Projects

There is limited research on the Circular Economy (CE) model in project management (Obradović et al., 2024), and a notable absence of substantial studies regarding the circular economy model in project supply chains, especially within agricultural development project supply chains. Indeed, empirical research on project supply chain management is scarce in the literature (khan et al., 2022), rendering this study essential for both industry professionals and scholars, as well as future researchers.

In the case of agricultural development project, within the project scopes, it is first essential to understand how the concept of sustainable circular economy could be embedded and implemented in the agricultural supply chain systems and how different business models can be examined and tested by the farmers for achieving United Nations SDGs, such as, zero hunger, food security, responsible production and consumption, reduced waste, reuse, value addition, efficient use of scarce economic resources, and promoting economic efficiency in production processes by reducing the negative impact of environmental footprint and climate change for current and future generations.

Therefore, the study adopted a conceptual model for understanding on integrating circular economy and project supply-chain management in agricultural projects (Figure 8). It presents how R-strategies can be cascaded to the project supply chain level and how an adequate project strategy can be developed referring to the CE concept. This framework provides an insight into how project strategy can be further operationalized in project supply chain via its building blocks: stakeholder focus, resource management, procurement and supplier focus, supply management, conversion, system and procedure, review, quality management, and project closure phase.

Project supply chains, like projects themselves, strive to solve problems, bring about change, and benefit clients and end users. The circular economy along with regulations, knowledge, best practices and recommendation standards make possible and makes a substantial contribution to sustainable development via various R-strategies. The strategies may vary from project to project. Transitioning to a circular economy practice by the agriculture sector is still in the infancy stage across the globe, whereby farm waste can be reused, repurposed for recycling to minimize waste.



Adapted from Basu and Wrigh, 2017; Khan et al., 2022; Obradović et al., 2024

Figure 8: A conceptual model for integrating CE and Agricultural project supply-chain management – CEProSCM framework

Minimizing the use of external inputs in agriculture such as water and chemical fertilizers and grow drought and pest resistance crops that need less water and external inputs. The implementation of circular economic principles must account for cultural, social, economic, and environmental dimensions to achieve a sustainable circular economy, as well as to ensure the successful delivery of project outcomes within defined scopes. It may include responsible resource utilization and manufacturing (refuse, rethink, reduce); extension of product life cycle and lifetime of its elements (reuse, repair, refurbish, remanufacture, repurpose); waste usage and energy recovery (recycle, recover) as shown in Figure 8.

In the context of circular economy (CE) and project perspective, it encompasses business cases, business goals, and strategic concepts that justify and align projects with organizational objectives. The business case serves as a critical foundation for project success by presenting the project's background, environment, opportunities, constraints, problems to be solved, deliverables, and value proposition while justifying the investment of time, effort, and budget and ensuring compliance with organizational strategic goals. Organizations often utilize project portfolio management processes to align projects with strategic goals, mapping and selecting projects based on defined criteria that maximize portfolio value while considering organizational capacities and resources. For large strategic projects, the business case includes cost-benefit analysis and risk impact assessments to support decision-making throughout the project lifecycle. The strategic concept establishes the dominant strategic principles that guide project planning and execution, with CE strategies and R-strategies focusing on three key areas that determine how circular economy principles are integrated into project approach and implementation (Obradović et al., 2024).

On the other hand, project position in circular economy (CE) involves defining the project product, establishing competitive advantage, and setting success criteria while integrating circular strategies throughout the project lifecycle. CE principles such as rethinking, refusing, reducing, reusing, and recycling can be embedded into product design, manufacturing, distribution, and disposal processes to create competitive advantages through strategies like Extended Producer Responsibility and Product Service Systems. Implementing circularity affects all major project management plans including procurement, resource management, cost, quality, scheduling, communication, risk management, and stakeholder engagement. While circular practices may initially increase design or operational costs and potentially cause scheduling delays, they offer long-term savings through resource sharing, second-hand procurement, and life cycle extension. Successful circular project management requires a mindset shift in procurement planning that prioritizes reducing purchases, engaging with circular market suppliers, utilizing take-back programs, and accessing second-hand markets. Effective stakeholder management is crucial in this multi-stakeholder environment, with suppliers, business partners, consumers, government institutions, and regulatory bodies playing key roles in implementing circular standards.

Ultimately, integrating CE into project strategy demands developing monitoring plans with key performance indicators and success criteria that track circular economy targets, ensuring that the project management process aligns with circular philosophy and delivers both immediate project outcomes and long-term sustainable value (Obradović et al., 2024).

While, project guidelines encompass project definition and strategic focus, where project definition includes presenting the project scope, statement of work, and work breakdown structure composed of work packages broken down into specific tasks, while strategic focus establishes behavioral guidelines, values, and mindsets that direct project processes toward organizational performance and competitive advantage. Transitioning to circular economy (CE) principles requires fundamental changes in organizational behavior, mindsets, values, capabilities, and competences, yet faces significant barriers including social and behavioral factors (lack of interest, knowledge, skills, engagement, and inter-functional collaboration), technological challenges, industrial barriers (linear production orientation), strategic barriers (unaligned initiatives), and regulatory barriers (insufficient standards and legal regulations). To effectively integrate CE at the project level, organizations must implement specific actions through project policies and guidelines: accepting and following CE regulations at international, national, and local levels; utilizing standards, best practices, and recommendations; implementing circularity measurement techniques and tools such as life cycle assessment methods (LCA, LCI, LCC, S-LCA), material circularity indicators (MCI), and multi-criteria approaches; defining specific roles and responsibilities for circular project strategy implementation; enabling learning processes, knowledge sharing, and lessons learned capture; providing training for team members; creating communication principles and procedures for stakeholders; and establishing guidelines for monitoring, reporting on project performance against circularity objectives, and preparing circularity progress reports (Obradović et al., 2024).

In the case of project supply chain management, during the project planning phase, the CE approaches need to be addressed in three (03) building blocks: (1) stakeholder focus, (2) resource, agri-input, and time management, and (3) procurement and supplier focus. It also needs to be considered for systems, procedures, production technology, and guidelines. While, during the project delivery phase, another three (3) building blocks—(1) supply management, (2) conversion/crop production/building and installation, and (3) project closure—should also adopt the CE approaches based on project goals and objectives. Throughout the project delivery chain, quality and performance management is also crucial for ensuring the CE approaches. Review, inspection, and monitoring are common for all of the phases of the project supply chain.

2.3 Barriers to Circular Economy in supply chain management of Agricultural Development Projects

Although there is no substantial research on barriers to the circular economy in agricultural development project supply chain management, the study initially developed a circular economy barrier framework (Table 3) from the literature, which includes literature beyond agricultural projects and the developing country context.

Table 3 Initial framework of barriers to supply chain management of agricultural development projects developed from literature review.

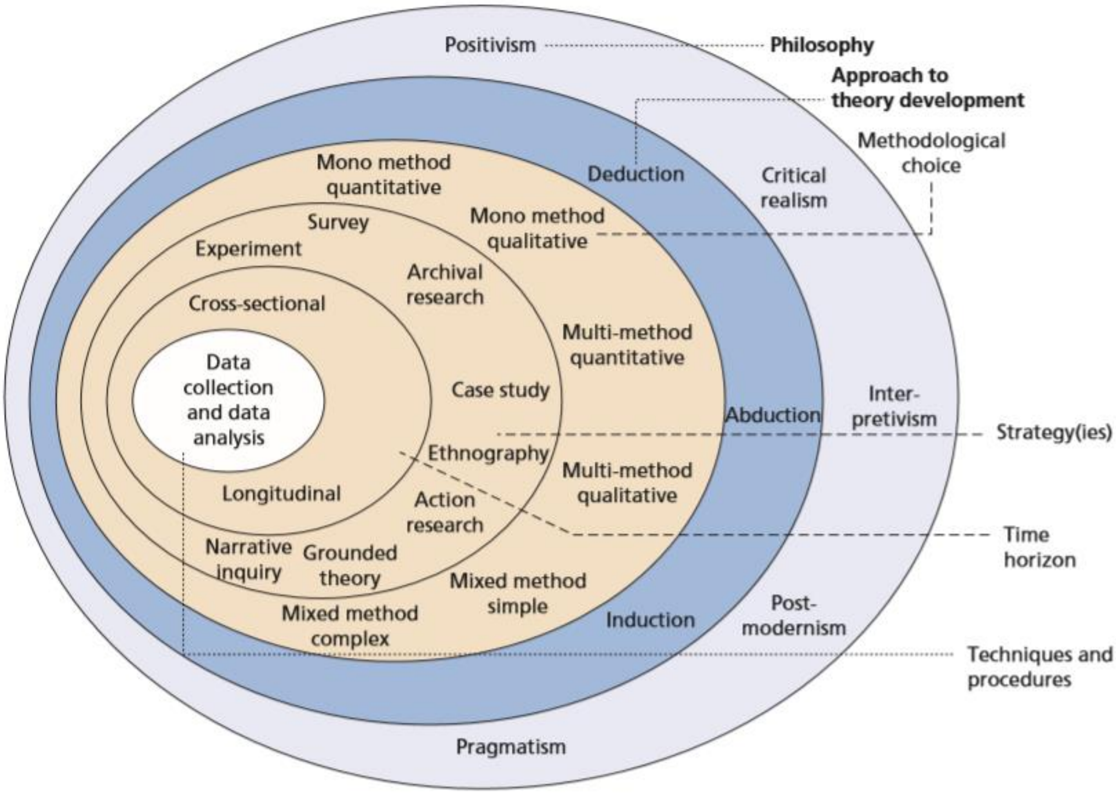
Category	Sub-category	Reference
Organizational (ORG)	Insufficient management support to adopt CSCM applications (ORG1)	Çıkmak and Kesici, 2023; Martinez-Moreno et al., 2024; Mehmood et al., 2021;
	Lack of strategic planning for CSCM adoption (ORG2)	Çıkmak and Kesici, 2023; Mehmood et al., 2021;
	Lack of CE integration across different organizational units and business levels (ORG3)	Çıkmak and Kesici, 2023; Mehmood et al., 2021;
	Lack of performance measurement system regarding CSCM applications (ORG4)	(Çıkmak and Kesici, 2023); Martinez-Moreno et al., 2024
	Insufficient knowledge and awareness among organizational members (employees) about CSCM (ORG5)	(Çıkmak and Kesici, 2023); Martinez-Moreno et al., 2024; Osei-Tutu et al., 2023;;
Regulatory (REG)	Insufficient environmental laws and regulations for CSCM adoption (REG1)	(Çıkmak and Kesici, 2023); Osei-Tutu et al., 2023;
	Lack of financial incentive (i.e., tax) for promoting the CSCM (REG2)	Çıkmak and Kesici, 2023; Mehmood et al., 2021;
	Lack of accurately implementation of ISO management systems (REG3)	Çıkmak and Kesici, 2023; Mehmood et al., 2021;)
	Obligation to comply with the F-gas regulation (REG4)	Çıkmak and Kesici, 2023; Mehmood et al., 2021;
Technological (TECH)	Quality problem of products made from recovered materials (TECH1)	(Çıkmak and Kesici, 2023); Osei-Tutu et al., 2023;;
	Design challenges to durable, reuse and recovery products (TECH2)	Çıkmak and Kesici, 2023; Mehmood et al., 2021;
	Technological challenges in reducing gas uses (The HFC phase -down) (TECH3)	Çıkmak and Kesici, 2023; Mehmood et al., 2021;
Economic and Financial (ECOFIN)	Lack of financial benefits in short-term (ECOFIN1)	(Çıkmak and Kesici, 2023); Osei-Tutu et al., 2023; Martinez-Moreno et al., 2024;
	CSCM processes require high costs (ECOFIN2)	(Çıkmak and Kesici, 2023); ;Martinez-Moreno et al., 2024; Osei-Tutu et al., 2023;
	Competitive market limiting CSCM adoption (ECOFIN3)	Çıkmak and Kesici, 2023; Mehmood et al., 2021;
	Client readiness to pay for extra (ECOFIN4)	Çıkmak and Kesici, 2023; Mehmood et al., 2021;
	Additional construction cost for reclaimed and recycle materials (ECOFIN5)	Çıkmak and Kesici, 2023; Mehmood et al., 2021;

	Immature recycling market operation (ECOFIN6)	Çıkmak and Kesici, 2023; Mehmood et al., 2021
Consumer and Society (CS)	Lack of awareness about the advantages of reuse and renovation (CS1)	(Çıkmak and Kesici, 2023); Martinez-Moreno et al., 2024; Mehmood et al., 2021;Osei-Tutu et al., 2023;
	Skepticism about the quality and safety of remanufactured, recycled and refurbished products (CS2)	(Çıkmak and Kesici, 2023); Mehmood et al., 2021; Osei-Tutu et al., 2023;
	The challenge of making customers eager to engage in circular initiatives (CS3)	(Çıkmak and Kesici, 2023; Mehmood et al., 2021;
	Resistance to change of old generation (CS4)	(Osei-Tutu et al., 2023; Mehmood et al., 2021;
Operational (OP)	Lack of sufficient coordination and collaboration among SC partners to adopt CSCM implement (OP1)	(Çıkmak and Kesici, 2023); Mehmood et al., 2021; Osei-Tutu et al., 2023;
	Lack of support from municipalities to adopt CSCM applications Expert opinion (OP2)	(Çıkmak and Kesici, 2023; Mehmood et al., 2021;
	Inadequacy of authorized organizations to fulfill collection targets (OP3)	(Çıkmak and Kesici, 2023; Mehmood et al., 2021;
Environmental (ENV)	Lack of environmental protection in waste management (ENV1)	(Osei-Tutu et al., 2023; Mehmood et al., 2021;
	Lack of incentives on environmental assessment methods (ENV2)	Osei-Tutu et al., 2023; Mehmood et al., 2021;
	Environmental impact: emission from transport, use of virgin feedstock (ENV3)	(Osei-Tutu et al., 2023; Mehmood et al., 2021;

Chapter 3: Research Methodology

3.1 Research Philosophy and Approach

This study adopted two philosophies to design the research methodology: interpretivism and pragmatism (Figure 9). Since the objectives are to investigate the key barrier to circular economy in supply chain management in agricultural development project, the researcher had to investigate the literature and rely on the participants' (industry experts) views and their interpretations based on their own backgrounds and experiences. Therefore, the philosophy of this research is linked with interpretivism (Creswell, 2003; Mackenzie and Knipe, 2006; Saunders *et al*., 2009). Additionally, the study is value-bound research, and interpretation is the key to research contribution. While the key focus of this research is on the barriers to circular economy in supply chain management in agricultural development projects-crop sector projects- in Bangladesh. Thus, the study is understandably linked with interpretivism and pragmatism philosophy based on research assumptions, research objectives, and research questions.



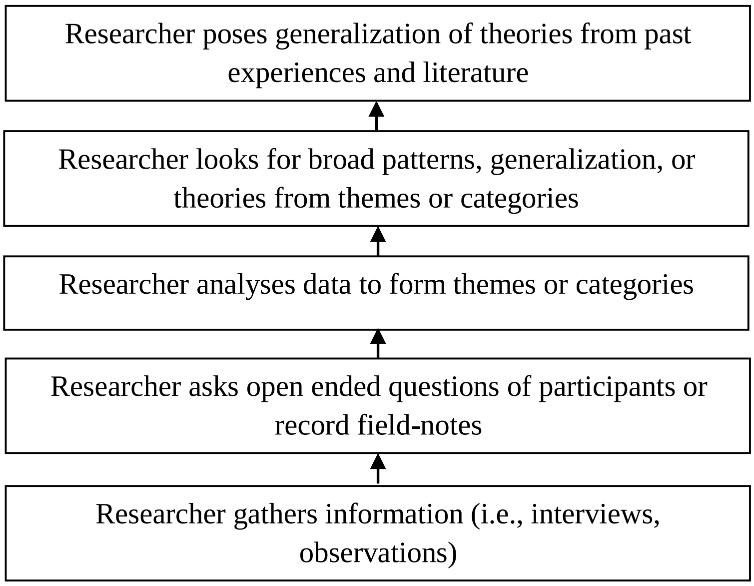
(Source: Saunders *et al*., 2016, p. 124)

Figure 9: The research 'onion

On the other hand, based on research philosophy and research questions, the inductive approach (Figure 9) has been used for the research since the researcher investigates something that cannot necessarily be found in previous research (Saunders *et al*., 2016). Similarly, Sekaran (2006) states that the approach can be applied when nothing much is known about the issue at hand or no empirical evidence is there to support similar problems solved in the past. For this particular research there is not much study done in the past in the same context, with the same group of people and the existing theories are not applied with them either.

3.2 Methodological Choice and Strategy

The qualitative method is more open-ended and exploratory when the researcher does not know exactly which independent variables to examine, and the method is more concerned with data that is not responsive to numerical measurement (Berg, 2007; Lancaster, 2005). Therefore, the pattern and logic of this qualitative research will follow the pattern and logic presented in Figure 10.

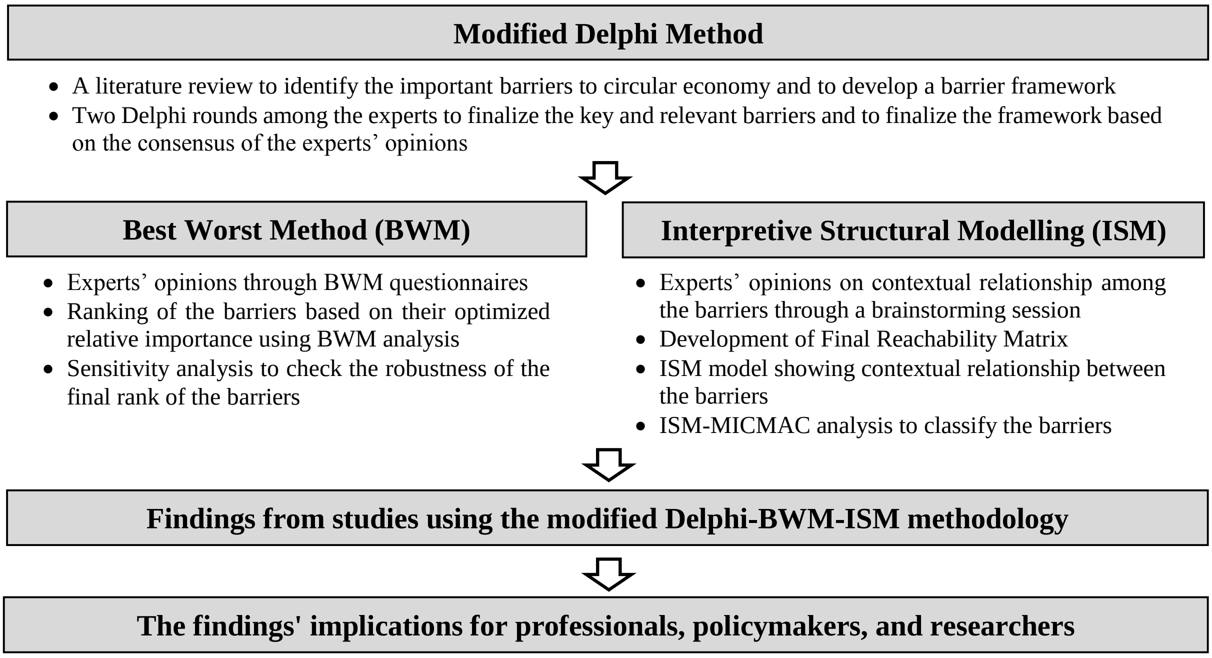


Source: Creswell 2009, p. 57.

Figure 10 Inductive logic of qualitative research

3.3 Analytical Tools

Based on the research methodological choices and research strategies mentioned above, this study adopts three multi-criteria decision-making methods to analyse and evaluate the barriers to circular economy in supply chain management of agricultural development projects (Figure 11): modified Delphi, Best Worst Method (BWM), and Interpretive Structural Modelling (ISM)-Cross-impact matrix multiplication applied to classification (MICMAC). Given the effectiveness of multi-criteria decision-making (MCDM) approaches in resolving complex problems with a large number of variables (Khan et al., 2022b; Yadav et al., 2019), and given that the approach chosen is dependent on the nature of the problem and the output required by the researchers (Yadav and Desai, 2017), the use of the modified Delphi-BWM-ISM approach was justified in this study.



(adapted from Khan et al., 2022)

Figure 11 Research methodology.

Note: BWM- Best Worst Method, ISM- Interpretive Structural Modeling, MICMAC cross-impact matrix multiplication applied to classification.

3.3.1 Modified Delphi Method

The modified Delphi method is used in the first phase of the study to determine the barriers and barrier framework. The method used a short-closed question questionnaire, which helped such research work go more smoothly, saved time, and let the participating experts to focus on the research problem without the speculations that an open questionnaire entails (Khan et al., 2022b; Khan et al., 2022; Khan et al., 2022a). It does not necessitate a big sample size, and it also increases the rate of questionnaire recovery and aids experts in reaching a consensus (Ameyaw et al., 2016; Golini et al., 2015; Hsu et al., 2020; Khan et al., 2022).

3.3.2 Best Worst Method (BWM)

While the BWM is used in the second phase to evaluate and rank the barriers because it has been shown to be a useful technique for making decisions about practical difficulties and determining criteria weight coefficients (Khan et al., 2022b; Moktadir et al., 2019; Rezaei, 2015; Rezaei et al., 2016). The method employs an integer scale of 1-9 to reduce comparison complexity, and this method outperforms other MCDMs (e.g., AHP) since it resolves inconsistency difficulties (Moktadir et al., 2019; Rezaei, 2015; Rezaei et al., 2016; Yadav et al., 2018). As a result, many studies have used the BWM to analyze supply chain challenges (Khan et al., 2022b; Khan et al., 2022; Khan et al., 2022a; Rezaei et al., 2016).

The literature finds the method outperforming other MCDMs (i.e., AHP), not because it uses a 1-9 integer scale, which reduces the complexity of the comparison, but because it solves the inconsistency issues. Therefore, the tool has found great use in analyzing supply chain issues (Khan et al., 2022b; Khan et al., 2022b; Liang et al., 2020; Luthra et al., 2015; Mohaghar et al., 2017; Rezaei, 2015; Sahebi et al., 2017). To collect the data from the experts (e), the method follows five steps (Gupta et al., 2017; Moktadir et al., 2019; Rezaei, 2015):

Step 1: Identification of the decision-making criteria (i.e., barriers of circular economy);

Step 2: Selection of the best (*B*) criteria (i.e., most important) and the worst (*W*) criteria (i.e., least important) for both main and sub-criteria;

Step 3: Identification of the best (*B*) criteria over the other criteria using a 1–9 point rating scale determined by the experts (*e*) through a pairwise comparison. The resulting best-to-others (BO) vector for the e*th* respondent of identified criteria can be formulated as follows: $Y_{Bj}^{e} = (y_{B1}^{e}, y_{B2}^{e}, \ldots, y_{Bn}^{e})$. In this matrix, the notation y_{Bj}^{e} represents the importance of the best criterion *B* compared to criterion *j*. Therefore, the value of y_{BB}^{e} is equal to 1.

Step 4: Identification of the order preference of all other criteria over the worst (*W*) criteria using the 1–9 point rating scale and ascertaining the optimal weighting of the decision-making criteria using the best (*B*) criteria. In this case, the vector can be written as follows: $Y_{jW}^{e} = (y_{1W}^{e}, y_{2W}^{e}, \ldots, y_{nW}^{e})$. Where, the notation y_{jW}^{e} represents importance of criterion *j* over the worst (least important) criterion *W*, and the value of y_{WW}^{e} would be 1.

Step 5: Finally, the optimized criteria weighting is determined such that the maximum absolute difference for all *j* is minimized for the following set: $\{\left|w_B^e - a_{Bj}^e w_j^e\right|, \left|w_j^e - a_{jw}^e w_w^e\right|\}$. The problem is converted and formulated as follows:

min. $\{\left|w_B^e - a_{Bj}^e w_j^e\right|, \left|w_j^e - a_{jw}^e w_w^e\right|\}$, subject to,

$$\sum_j w_j^e = 1 \qquad (1)$$

$w_j^e \geq 0$ for all *j*.

Equation (1) can be formulated as a problem of linear programming, and can be written as follows:

min. ξ^L

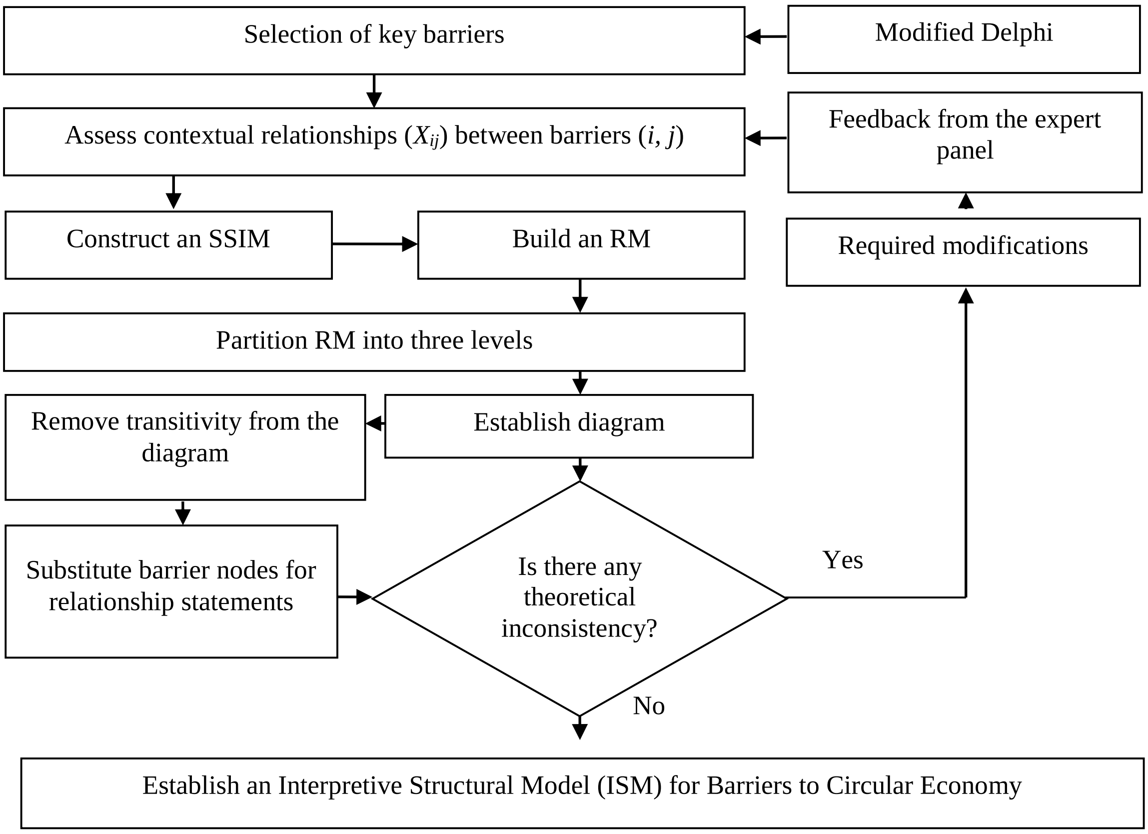
Subject to, $\left|w_B^e - a_{Bj}^e w_j^e\right| \leq \xi^L$ for all *j*

$$\left|w_j^e - a_{jw}^e w_w^e\right| \leq \xi^L \text{ for all } j \qquad (2)$$

$\sum_j w_j^e = 1$

$w_j \geq 0$ for all j

The optimal weights $(w_1^*, w_2^*, \ldots, w_n^{e*})$ are computed while minimizing the value of ξ^{L^*}. The value of ξ^{L^*} justifies the obtained consistency results; the value closer to zero is an indication of a more consistent result. In addition, the level of reliability can be cross-checked with the consistency ratio (CR) threshold levels (Liang et al., 2020; Mangla et al., 2014).



(Adapted from Ahmad and Qahmash, 2021; Khan et al., 2022)

Figure 12 Flow chart for establishing the ISM models of the barrier to circular economy in agricultural development project supply chain.

3.3.3 Interpretive Structural Modeling (ISM)

In the last phase, the study applied the Interpretive Structural Modeling (ISM) method and conducted the MICMAC (Matrice d'Impacts Croisés Multipli cation Appliquée á un Classement (cross-impact matrix multiplication applied to classification)) analysis to portrait the existing contextual relationships among the barriers (Ahmad and Qahmash, 2021; Khan et al., 2022). The ISM is useful to analyze the interrelationships among the attributes and structure them into a systemic model (Mangla et al., 2014) and this method has also been widely applied in different fields of supply-chain management: agriculture project supply chain management, sustainable supply chain management, green supply chain management, humanitarian supply chain management; reverse logistics, supplier selection, etc. are the most applied fields of this method

(Gopal and Thakkar, 2016; Luthra et al., 2015; Moktadir et al., 2019; Raut et al., 2017; Sivaprakasam et al., 2015; Kumar et al., 2014).

This method follows eight steps (John and Ramesh, 2016; Luthra et al., 2015; Mahajan et al., 2013; Moktadir et al., 2019; Sharma et al., 2019): attribute identification (i.e., barriers); contextual relationship development; structural self-interaction matrix (SSIM) formation; development of the reachability matrix; partitioning of different levels using the final reachability matrix; formation of a digraph; formation of the ISM model; and testing of the ISM model for any theoretical inconsistency (Figure 12). While based on the driving and dependence power of the attributes found in ISM finding, the MICMAC analysis classifies the attributes (i.e., barriers) into four clusters: independent enablers, linkage enablers, autonomous, and dependent enablers (Duperrin and Godet, 1973; Mahajan et al., 2013; Sivaprakasam et al., 2015).

3.4 Selection of Sample, Data Collection and Evaluation

In this study, fifteen experts were selected based on their expertise in planning, implementing, and evaluating agricultural crop sector development projects funded by the government and donors in Bangladesh, a developing country in South Asia, using deliberate and snowball methods (Khan et al., 2022).

Fifteen of the participants attended the modified Delphi rounds and the ISM brainstorming session, while eight attended the BWM (Appendix II). Initially, a barrier framework having twenty-eight barriers and seven barrier categories (Table 3) was formulated from the literature review and applied in the Delphi rounds to get feedback from 15 industry experts who had a minimum of five years of professional experience in managing supply chain of donor-funded agricultural development projects. Finally, the fifty most important barriers with seven major barrier categories (Table 4) have been identified by applying the modified Delphi method. While the content analysis method was applied to analyze the data, based on the majority (> 50%) consensus of the experts, twenty-eight barriers and seven barrier categories were identified through the Delphi rounds (Khan et al., 2022b; Khan et al., 2022a; Loughlin and Moore, 1979; PMI, 2017).

Table 4 Framework of barriers to supply chain management of agricultural development projects developed from modified-Delphi analysis.

Category	Sub-category
Organizational (ORG)	Insufficient management support to adopt CSCM applications (ORG1)
	Lack of strategic planning for CSCM adoption (ORG2)
	Lack of CE integration across different organizational units and business levels (ORG3)
	Absence of performance measurement system regarding CSCM applications (ORG4)
	Insufficient knowledge and awareness among organizational members (employees) about CSCM (ORG5)
	Short-term, project-based implementation approaches instead of system-wide CE strategies (ORG6)
Regulatory (REG)	Insufficient environmental laws and regulations for CSCM adoption (REG1)
	Lack of financial incentive (i.e., tax) for promoting the CSCM (REG2)
	Insufficient government programs encouraging key stakeholders' participation in CE supply chains (REG3)
	Bureaucratic complexities in licensing, compliance, and approval processes (REG4)
	Lack of standards for secondary agricultural materials (e.g., compost, biofertilizer, packaging recovery) (REG5)
	Fragmented institutional responsibilities (REG6)
	Weak enforcement of waste management, food safety, and environmental regulations (REG7)
Technological (TECH)	Design challenges to durable, reuse and recovery products (TECH1)
	Technological challenges in reducing greenhouse gas (TECH2)
	Low R&D capacity for circular products and process innovation in agriculture (TECH3)
	Poor cold-chain and storage infrastructure to reduce post-harvest losses (TECH4)
	Limited availability of affordable digital tools for supply chain traceability and monitoring (TECH5)
	Weak technology transfer and collaboration between research institutions and supply chain actors (TECH6)
	Lack of standardization in quality control for recovered agricultural inputs (TECH7)
Economic and Financial (ECOFIN)	Client readiness to pay extra (ECOFIN1)
	Additional construction cost for reclaimed and recycled materials (ECOFIN2)
	High initial investment required for circular supply chain technologies and infrastructure (ECOFIN3)
	Limited access to green financing, microcredit, or investment for CE practices (ECOFIN4)
	Lack of economic incentives for adopting circular logistics, packaging recovery, or composting (ECOFIN5)

	Low profit margins in agricultural value chains discourage long-term CE investments (ECOFIN6)
	Market dominance of linear supply chains and conventional farming practices (ECOFIN7)
	Insufficient financial support for smallholder farmers and SMEs to transition to CE (ECOFIN8)
	Immature recycling market operation (ECOFIN9)
Consumer and Society (CS)	Lack of awareness about the advantages of reuse and renovation (CS1)
	Resistance to change of old agricultural practices (CS2)
	Low consumer awareness and demand for circular or sustainable agricultural products (CS3)
	Limited communication and marketing of CE benefits to consumers and local communities (CS4)
	Lack of stakeholder engagement (e.g., farmers, cooperatives, consumers) in CE design (CS5)
	Social norms discouraging use of recycled or recovered agricultural inputs (CS6)
Operational and Supply Chain (OPSC)	Lack of sufficient coordination and collaboration among SC partners to adopt CSCM implement (OPSC1)
	Fragmented supply chains with weak coordination among producers, processors, and retailers (OPSC2)
	Lack of structured collection, sorting, and redistribution systems for agricultural by-products (OPSC3)
	Insufficient logistics infrastructure to support reverse flows and resource recovery (OPSC4)
	Weak collaboration between private and public sector actors in CE supply chains (OPSC5)
	Lack of standardized procurement practices encouraging reuse and recycling (OPSC6)
	Poor data sharing and supply chain visibility (OPSC7)
	Absence of integrated platforms for connecting CE stakeholders across the chain (OPSC8)
Environmental (ENV)	Inefficient waste management and lack of circular practices in rural supply chains (ENV1)
	High greenhouse gas emissions from transportation and post-harvest losses (ENV2)
	Limited incentives for environmental risk reduction in supply chains (ENV3)
	Insufficient adoption of Life Cycle Assessment (LCA) and other CE tools (ENV4)
	Application of agri-inputs undermining circular resource flow (ENV5)
	Uncontrolled disposal of agricultural residues contributing to environmental degradation (ENV6)
	Climate vulnerability increasing operational risks for CE implementation (ENV7)

Table 5 Weights and ranking of the barriers of the circular economy of agricultural development project supply chain.

Barriers Category	Weights	Barrier sub-category	Local Weights	Global Weights	Rank
Organizational (ORG)	0.231	Insufficient management support to adopt CSCM applications (ORG1)	0.1379	0.0319	11
		Lack of strategic planning for CSCM adoption (ORG2)	0.2104	0.0486	3
		Lack of CE integration across different organizational units and business levels (ORG3)	0.0379	0.0088	38
		Absence of performance measurement system regarding CSCM applications (ORG4)	0.1394	0.0322	10
		Insufficient knowledge and awareness among organizational members (employees) about CSCM (ORG5)	0.1910	0.0441	4
		Short-term, project-based implementation approaches instead of system-wide CE strategies (ORG6)	0.2834	0.0655	1
Regulatory (REG)	0.2157	Insufficient environmental laws and regulations for CSCM adoption (REG1)	0.2892	0.0624	2
		Lack of financial incentive (i.e., tax) for promoting the CSCM (REG2)	0.0363	0.0078	42
		Insufficient government programs encouraging key stakeholders' participation in CE supply chains (REG3)	0.1686	0.0364	7
		Bureaucratic complexities in licensing, compliance, and approval processes (REG4)	0.0886	0.0191	22
		Lack of standards for secondary agricultural materials (e.g., compost, biofertilizer, packaging recovery) (REG5)	0.1339	0.0289	12
		Fragmented institutional responsibilities (REG6)	0.1261	0.0272	14
		Weak enforcement of waste management, food safety, and environmental regulations (REG7)	0.1572	0.0339	9
Technological (TECH)	0.1351	Design challenges to durable, reuse and recovery products (TECH1)	0.0988	0.0133	30
		Technological challenges in reducing greenhouse gas (TECH2)	0.0380	0.0051	43
		Low R&D capacity for circular products and process innovation in agriculture (TECH3)	0.1642	0.0222	18
		Poor cold-chain and storage infrastructure to reduce post-harvest losses (TECH4)	0.2835	0.0383	5

		Limited availability of affordable digital tools for supply chain traceability and monitoring (TECH5)	0.1583	0.0214	19
		Weak technology transfer and collaboration between research institutions and supply chain actors (TECH6)	0.1751	0.0237	17
		Lack of standardization in quality control for recovered agricultural inputs (TECH7)	0.0822	0.0111	35
Economic and Financial (ECOFIN)	0.1736	Client readiness to pay extra (ECOFIN1)	0.0936	0.0162	25
		Additional construction cost for reclaimed and recycle materials (ECOFIN2)	0.0676	0.0117	31
		High initial investment required for circular supply chain technologies and infrastructure (ECOFIN3)	0.0976	0.0169	23
		Limited access to green financing, microcredit, or investment for CE practices (ECOFIN4)	0.1545	0.0268	15
		Lack of economic incentives for adopting circular logistics, packaging recovery, or composting (ECOFIN5)	0.2203	0.0382	6
		Low profit margins in agricultural value chains discourage long-term CE investments (ECOFIN6)	0.1189	0.0206	20
		Market dominance of linear supply chains and conventional farming practices (ECOFIN7)	0.1515	0.0263	16
		Insufficient financial support for smallholder farmers and SMEs to transition to CE (ECOFIN8)	0.0676	0.0117	31
		Immature recycling market operation (ECOFIN9)	0.0285	0.0049	44
Consumer and Society (CS)	0.0737	Lack of awareness about the advantages of reuse and renovation (CS1)	0.1873	0.0138	29
		Resistance to change of old agricultural practices (CS2)	0.3786	0.0279	13
		Low consumer awareness and demand for circular or sustainable agricultural products (CS3)	0.1164	0.0086	39
		Limited communication and marketing of CE benefits to consumers and local communities (CS4)	0.1551	0.0114	33
		Lack of stakeholder engagement (e.g., farmers, cooperatives, consumers) in CE design (CS5)	0.1073	0.0079	41

		Social norms discouraging use of recycled or recovered agricultural inputs (CS6)	0.0552	0.0041	47
Operational and Supply Chain (OPSC)	0.1314	Lack of sufficient coordination and collaboration among SC partners to adopt CSCM implement (OPSC1)	0.1238	0.0163	24
		Fragmented supply chains with weak coordination among producers, processors, and retailers (OPSC2)	0.2622	0.0345	8
		Lack of structured collection, sorting, and redistribution systems for agricultural by-products (OPSC3)	0.0865	0.0114	34
		Insufficient logistics infrastructure to support reverse flows and resource recovery (OPSC4)	0.1188	0.0156	26
		Weak collaboration between private and public sector actors in CE supply chains (OPSC5)	0.0313	0.0041	46
		Lack of standardized procurement practices encouraging reuse and recycling (OPSC6)	0.1477	0.0194	21
		Poor data sharing and supply chain visibility (OPSC7)	0.1148	0.0151	27
		Absence of integrated platforms for connecting CE stakeholders across the chain (OPSC8)	0.1148	0.0151	27
Environmental (ENV)	0.0394	Inefficient waste management and lack of circular practices in rural supply chains (ENV1)	0.0772	0.0030	48
		High greenhouse gas emissions from transportation and post-harvest losses (ENV2)	0.0336	0.0013	50
		Limited incentives for environmental risk reduction in supply chains (ENV3)	0.1225	0.0048	45
		Insufficient adoption of Life Cycle Assessment (LCA) and other CE tools (ENV4)	0.2708	0.0107	36
		Application of agri-inputs undermining circular resource flow (ENV5)	0.2064	0.0081	40
		Uncontrolled disposal of agricultural residues contributing to environmental degradation (ENV6)	0.2290	0.0090	37
		Climate vulnerability increasing operational risks for CE implementation (ENV7)	0.0605	0.0024	49

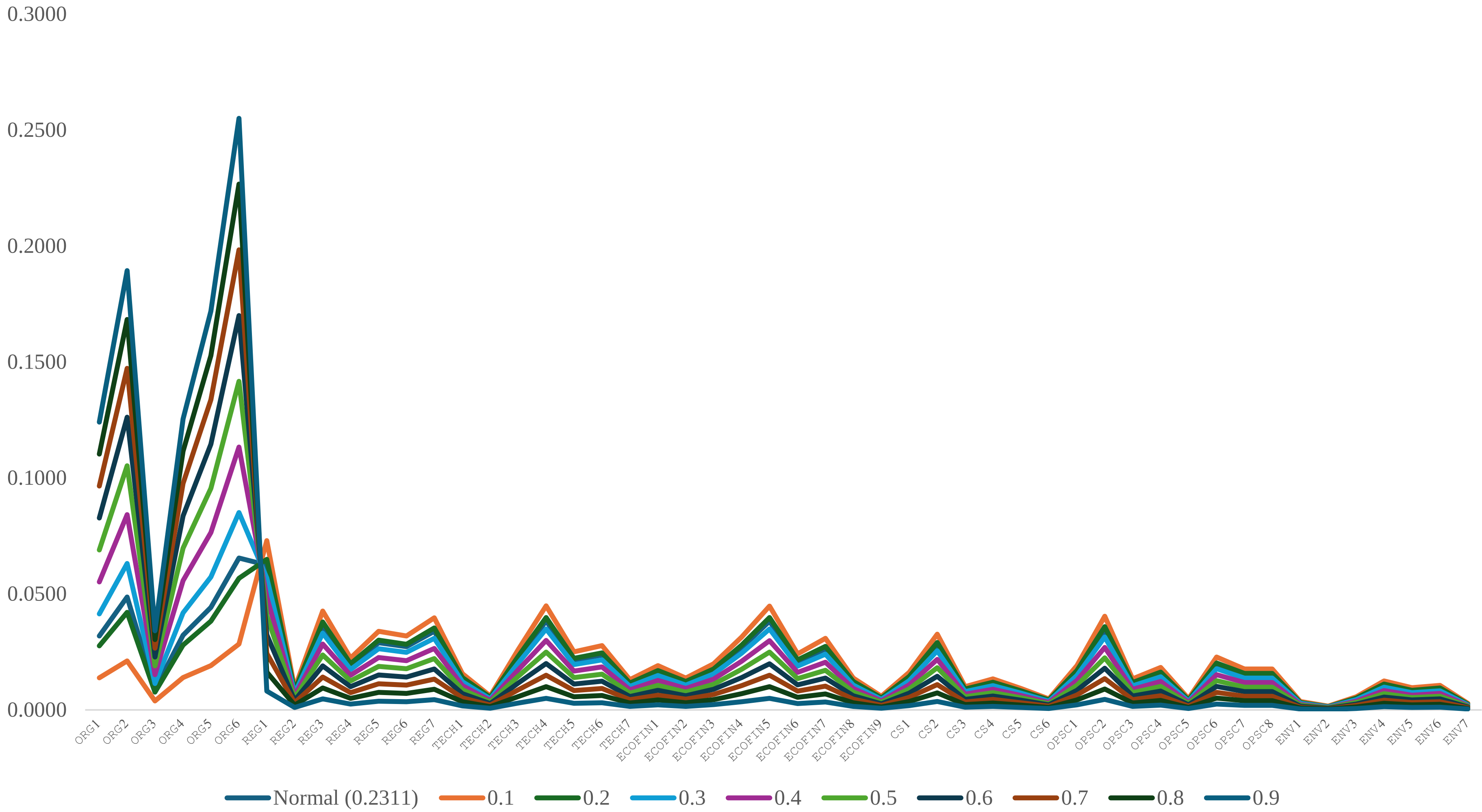


Figure 13: Global weight variation of the barriers found in the sensitivity analysis.

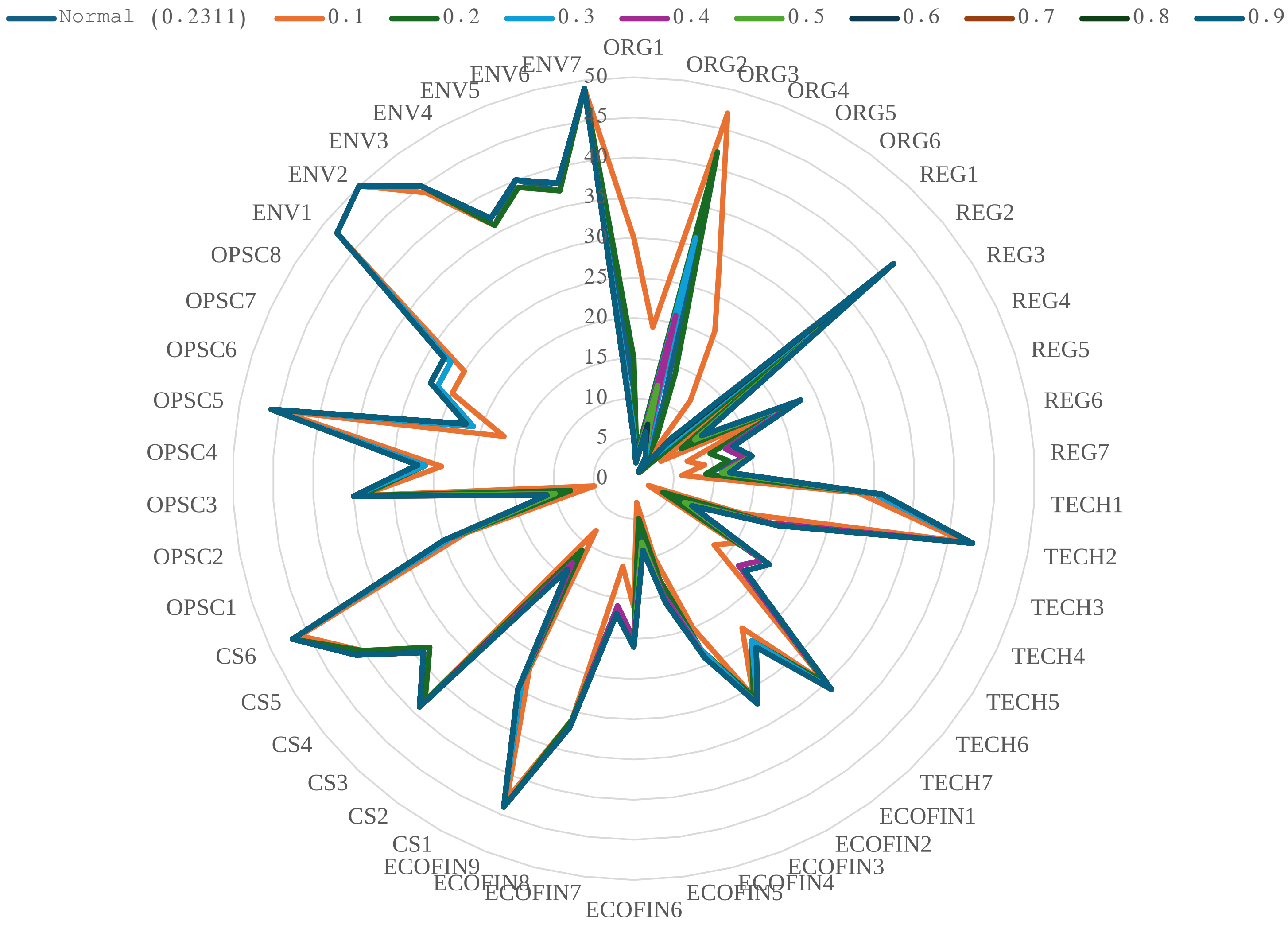


Figure 14: Ranking variation of the barriers found in the sensitivity analysis

The study finally identified ten most important barriers to circular economy in supply chain management of agricultural development projects (Table 6). After receiving the initial framework (Table 3), eight industry professionals (Appendix II) with more than ten years of experience working in managing supply chain of agricultural development projects participated in an online survey using structured BWM questionnaires (Appendix I). The deliberate and snowball methods were employed to choose the experts. Following the BWM steps listed above, the data was then gathered and examined (Figure 12). Due to the fact that the consistency ratio (CR) of the experts' opinions was below the threshold level, they were deemed reliable and acceptable (Liang et al., 2020). Their overall weights and rankings were determined after weighing the individual barrier criteria and barrier (Table 5). A sensitivity analysis was carried out to evaluate the barriers' robustness (Figure 13, Figure 14, Appendix III, and Appendix IV).

For ISM data collection (Figure 12), ten industry experts (Appendix II) with 5 to 20 years of experience managing agricultural development projects participated in a brainstorming session. The respondents were chosen using the method of purposive sampling. In addition, one academic expert with a decade of experience and a specialty in supply-chain challenges was involved in confirming the ISM analysis. Respondents were initially requested to comment on the contextual relationship among the barriers, allowing researchers to develop an SSIM with the Barriers (Appendix V). The data collection and analysis processes adhered to the ISM-described steps for constructing the final reachability matrix (Appendix V), level partitions (Appendix V), and the ISM model (Figure 15). On the basis of the driving and dependence power of the barriers, as determined by the final reachability matrix, the MICMAC analysis was conducted to determine the four clusters (Figure 16).

Chapter 4: Results and Discussion

This chapter represents the key results of the analysis as mentioned in chapter three, and it also describes the findings with the following points.

4.1 Key Barriers to Circular Economy in Agricultural Development Projects

Following the methodology (literature review and modified Delphi), initially the study identified seven (07) categories of barriers (Organizational-ORG, Regulatory-REG, Technological-TECH, Economic and Financial-ECOFIN, Consumer and Societal-CS, Operational and Supply Chain-OPSC, and Environmental-ENV) along with fifty (50) barriers.

Table 6 Weights and ranking of the top 10 (ten) key barriers of the circular economy of agricultural development projects.

Barriers	Local Weight	Global Weight	Rank
Short-term, project-based implementation approaches instead of system-wide CE strategies (ORG6)	0.2834	0.1417	1
Lack of strategic planning for CSCM adoption (ORG2)	0.2104	0.1052	2
Insufficient knowledge and awareness among organizational members (employees) about CSCM (ORG5)	0.1910	0.0955	3
Absence of performance measurement system regarding CSCM applications (ORG4)	0.1394	0.0697	4
Insufficient management support to adopt CSCM applications (ORG1)	0.1379	0.0690	5
Insufficient environmental laws and regulations for CSCM adoption (REG1)	0.2892	0.0406	6
Poor cold-chain and storage infrastructure to reduce post-harvest losses (TECH4)	0.2835	0.0249	7
Lack of economic incentives for adopting circular logistics, packaging recovery, or composting (ECOFIN5)	0.2203	0.0249	8
Insufficient government programs encouraging key stakeholders' participation in CE supply chains (REG3)	0.1686	0.0236	9
Fragmented supply chains with weak coordination among producers, processors, and retailers (OPSC2)	0.2622	0.0224	10

Then, using the BWM method, the study identified the top-ranked ten (10) key barriers to the circular economy of the agricultural development project supply chain as mentioned in Table 6. The barrier— 'Short-term, project-based implementation approaches instead of system-wide CE strategies (ORG6)' ranked first position with the global weight 0.1417. While the barriers 'Lack of strategic planning for CSCM adoption (ORG2)' and 'Insufficient knowledge and awareness among organizational members (employees) about CSCM (ORG5)' have been found in second and third positions with the global weights of 0.1052 and 0.0955, respectively. Other barriers found in later positions consecutively—'Absence of performance measurement system regarding CSCM applications (ORG4)' -4th position with a weight of 0.0697; 'Insufficient management support to adopt CSCM applications (ORG1)' - 5th position with a weight of 0.097; 'Insufficient environmental laws and regulations for CSCM adoption (REG1)' -6th position with a weight of 0.0460; 'Poor cold-chain and storage infrastructure to reduce post-harvest losses (TECH4)' - 7th position with a weight of 0.0249; 'Lack of economic incentives for adopting circular logistics, packaging recovery, or composting (ECOFIN5)'—8th position with a weight of 0.0249; 'Insufficient government programs encouraging key stakeholders' participation in CE supply chains (REG3)'—9th position with a weight of 0.0236; and 'Fragmented supply chains with weak coordination among producers, processors, and retailers (OPSC2)'—10th position with a weight of 0.0224, respectively.

Based on the above finding, major barriers to circular economy in agricultural development projects in the supply chain of the developing countries belong to the "Organizational-ORG" category. Most importantly, the first five top-ranked barriers belong to this category: 'Short-term, project-based implementation approaches instead of system-wide CE strategies (ORG6)'; 'Lack of strategic planning for CSCM adoption (ORG2)'; 'Insufficient knowledge and awareness among organizational members (employees) about CSCM (ORG5)'; 'Absence of performance measurement system regarding CSCM applications (ORG4)'; and 'Insufficient management support to adopt CSCM applications (ORG1)', respectively.

So, among the various constraints hindering CSCM adoption, organizational barriers play a foundational and often decisive role. Agricultural development projects are typically implemented by public agencies, non-governmental organizations, donor-funded programs, cooperatives, and agribusinesses, all of which operate within organizational structures that significantly influence decision-making, resource allocation, and innovation capacity. Organizational readiness, leadership commitment, strategic orientation, knowledge capacity, and performance evaluation mechanisms collectively determine whether circular principles can be successfully embedded into supply chain practices. The top five barriers have been described below-

Short-Term, Project-Based Implementation Approaches Instead of System-Wide CE Strategies (ORG6)

One of the most pervasive organizational barriers to CSCM adoption in agricultural development projects is the reliance on short-term, project-based implementation approaches. Agricultural development initiatives are frequently designed around limited funding cycles, donor priorities, and predefined timelines, which prioritize rapid outputs over long-term systemic transformation. As a result, circular economic interventions are often treated as temporary pilot activities rather than as integral components of organizational strategy.

This short-term orientation undermines the core logic of the circular economy, which requires long-term planning, sustained investment, and continuous learning. Circular supply chains depend on durable infrastructure such as composting facilities, reverse logistics systems, cold-chain networks, and digital traceability platform investments that cannot yield meaningful returns within short project durations. Consequently, organizations hesitate to commit resources to CSCM initiatives whose benefits extend beyond the project lifecycle.

Moreover, project-based approaches tend to emphasize isolated interventions, such as small-scale waste recycling or input reuse schemes, without addressing broader supply chain redesign. These fragmented efforts fail to generate systemic circularity and often collapse once external funding ends. In agricultural development contexts, where supply chains involve multiple actors across production, processing, distribution, and consumption stages, the absence of system-wide CE strategies prevents the alignment of incentives, roles, and responsibilities necessary for circular integration.

Ultimately, the dominance of short-term project logic reflects organizational cultures that prioritize compliance and reporting over sustainability transformation. Without shifting toward long-term, system-oriented planning frameworks, agricultural development organizations remain structurally ill-equipped to implement CSCM effectively.

Lack of Strategic Planning for CSCM Adoption (ORG2)

Closely linked to project-based implementation is the lack of strategic planning for CSCM adoption. Strategic planning provides a roadmap for embedding circular economy principles into organizational missions, operational processes, and supply chain partnerships. However, many organizations involved in agricultural development lack explicit CSCM strategies, resulting in ad hoc and reactive implementation.

In the absence of strategic planning, CSCM initiatives are often driven by external pressures—such as donor requirements, policy trends, or environmental crises—rather than internal commitment. This reactive approach limits coherence and consistency across projects and departments. For example, while one unit may promote organic waste composting, another may continue to support linear input procurement practices, creating internal contradictions that weaken overall circular performance.

The lack of strategic planning also hampers cross-functional integration, which is essential for CSCM. Circular supply chains require coordination between procurement, production, logistics, marketing, and waste management functions. Without a strategic framework that aligns these units around shared CE objectives, organizational silos persist, preventing effective resource circulation across the supply chain.

Furthermore, strategic planning is critical for managing trade-offs between short-term costs and long-term benefits. CSCM often entails higher initial investments but delivers environmental, social, and economic gains over time. Organizations lacking strategic foresight are unlikely to justify such investments, especially in resource-constrained agricultural development settings. Thus, the absence of strategic planning not only limits CSCM adoption but also signals a deeper organizational incapacity to integrate sustainability into core decision-making processes.

Insufficient Knowledge and Awareness among Organizational Members about CSCM (ORG5):

Even when organizations express interest in circular economy principles, insufficient knowledge and awareness among employees frequently obstruct effective implementation. CSCM is a complex, interdisciplinary concept that requires understanding of systems thinking, life-cycle assessment, sustainable logistics, and circular design principles. In many agricultural development organizations, such knowledge remains limited or unevenly distributed.

Field-level staff, project managers, and supply chain coordinators often lack formal training in CSCM concepts. Their professional experience is typically rooted in conventional agricultural development models focused on yield maximization and cost efficiency, rather than resource circularity. This knowledge gap leads to misinterpretation of CSCM as merely waste management or recycling, rather than a holistic supply chain transformation approach.

Insufficient awareness also contributes to resistance to change within organizations. Employees may perceive CSCM practices as additional burdens that increase workload or operational complexity. Without adequate understanding of the long-term benefits of circular supply chains, staff are unlikely to support or champion CSCM initiatives.

Moreover, the lack of internal knowledge limits organizational learning and innovation. Agricultural development projects operate in diverse ecological and socio-economic contexts, requiring localized adaptation of circular practices. When organizational members lack CSCM expertise, opportunities for experimentation, problem-solving, and continuous improvement are significantly reduced. Addressing this barrier requires systematic capacity-building initiatives, including training programs, knowledge-sharing platforms, and experiential learning opportunities. Without investing in human capital, organizational commitment to CSCM remains superficial and unsustainable.

Absence of Performance Measurement Systems Regarding CSCM Applications (ORG4): Another critical organizational barrier is the absence of performance measurement systems tailored to CSCM applications. Performance measurement plays a central role in guiding organizational behavior, allocating resources, and evaluating success. However, most agricultural development organizations rely on traditional performance indicators that prioritize output quantity, budget utilization, and short-term efficiency. Such metrics fail to capture the multidimensional value of circular supply chains, including waste reduction, resource recovery, emissions mitigation, and long-term resilience. In the absence of CSCM-specific indicators, circular initiatives remain invisible within organizational performance frameworks, reducing incentives for adoption and improvement.

The lack of performance measures also limits accountability. Without clear indicators, organizations cannot assess whether CSCM interventions are achieving their intended outcomes or identify areas requiring adjustment. This measurement gap undermines learning and discourages evidence-based decision-making.

Furthermore, donor-funded agricultural development projects often emphasize compliance with predefined indicators that overlook circular economic outcomes. Organizations consequently prioritize activities that align with reporting requirements rather than those that enhance circularity. This misalignment reinforces linear supply chain practices and marginalizes CSCM efforts. Establishing robust performance measurement systems that integrate environmental, economic, and social dimensions of circular supply chains is therefore essential. Without such systems, CSCM cannot be institutionalized within organizational structures.

Insufficient Management Support to Adopt CSCM Applications (ORG1):
At the core of organizational barriers lies insufficient management support for CSCM adoption. Leadership commitment is widely recognized as a critical success factor for organizational change, particularly when implementing complex and transformative approaches such as circular economy models.

In many agricultural development organizations, senior management remains hesitant to prioritize CSCM due to perceived risks, costs, and uncertainty. Circular initiatives may be viewed as experimental or peripheral, rather than as strategic investments. Without clear endorsement from leadership, CSCM lacks legitimacy and struggles to compete with established linear practices.

Insufficient management support also manifests in limited resource allocation. CSCM requires financial investment, dedicated personnel, and institutional support. When management fails to allocate adequate resources, circular initiatives remain underfunded and vulnerable to discontinuation. Moreover, leadership plays a key role in shaping organizational culture. Without strong managerial advocacy, employees receive mixed signals regarding the importance of CSCM. This ambiguity weakens motivation and reduces collective commitment to circular transformation.

In agricultural development projects, where organizations operate under high uncertainty and resource constraints, proactive leadership is particularly crucial. The absence of such leadership reinforces organizational inertia and perpetuates linear supply chain models.

4.2 Inter-relationship among the Key Barriers to Circular Economy in Agricultural Development Projects

For agricultural development projects, it is crucial not only to identify their barriers but also to find out their interrelationships since their scopes are fixed. It would be wise to address the barriers based on their importance and interdependency (Khan et al., 2022). Therefore, the study investigates the interrelationship and their dependency level through Interpretive Structural Modeling (ISM) and MICMAC analysis, respectively.

Following the methodology, the study develops an Interpretive Structural Model (ISM) (Figures 15) of the barriers to the circular economy of the agricultural development project supply chain.

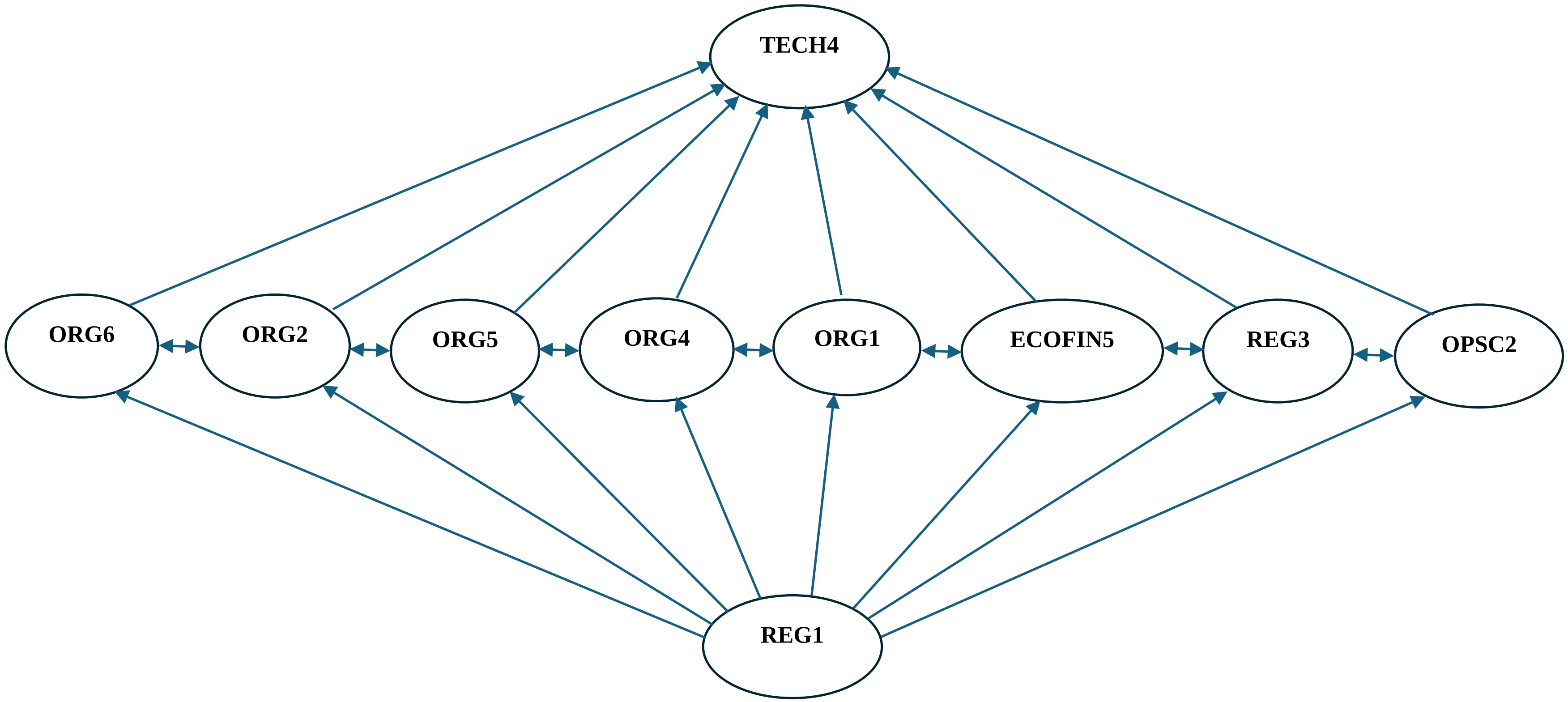


Figure 15 The ISM model of the key barriers of the circular economy of agricultural development projects.

(Note: ***ORG1:*** *Insufficient management support to adopt CSCM applications;* ***ORG2:*** *Lack of strategic planning for CSCM adoption;* ***ORG4:*** *Absence of performance measurement system regarding CSCM applications;* ***ORG5:*** *Insufficient knowledge and awareness among organizational members (employees) about CSCM;* ***ORG6:*** *Short-term, project-based implementation approaches instead of system-wide CE strategies;* ***REG1:*** *Insufficient environmental laws and regulations for CSCM adoption;* ***REG3:*** *Insufficient government programs encouraging key stakeholders' participation in CE supply chains;* ***TECH4:*** *Poor cold-chain and storage infrastructure to reduce post-harvest losses;* ***ECOFIN5:*** *Lack of economic incentives for adopting circular logistics, packaging recovery, or composting;* ***OPSC2:*** *Fragmented supply chains with weak coordination among producers, processors, and retailers)*

According to the ISM model (Figure 15) of the key barriers of the circular economy of agricultural development projects, the position of the 7th ranked barrier—'Poor cold-chain and storage infrastructure to reduce post-harvest losses (TECH4)'—is in level I. Which indicates that it has direct or indirect relationships with all other barriers. So, if any project team wants to address it, they should address the other barriers that are linked to it. On the other hand, the 'Insufficient environmental laws and regulations for CSCM adoption (REG1)' barrier stands in level III, which indicates that it affects all other barriers while none of the barriers affects it. Thus, during the project planning, the project owner needs to address the environmental laws and regulations for CSCM adoption. While, as per the model, other barriers stay between the two levels, and they are interconnected, as mentioned in Figure 15.

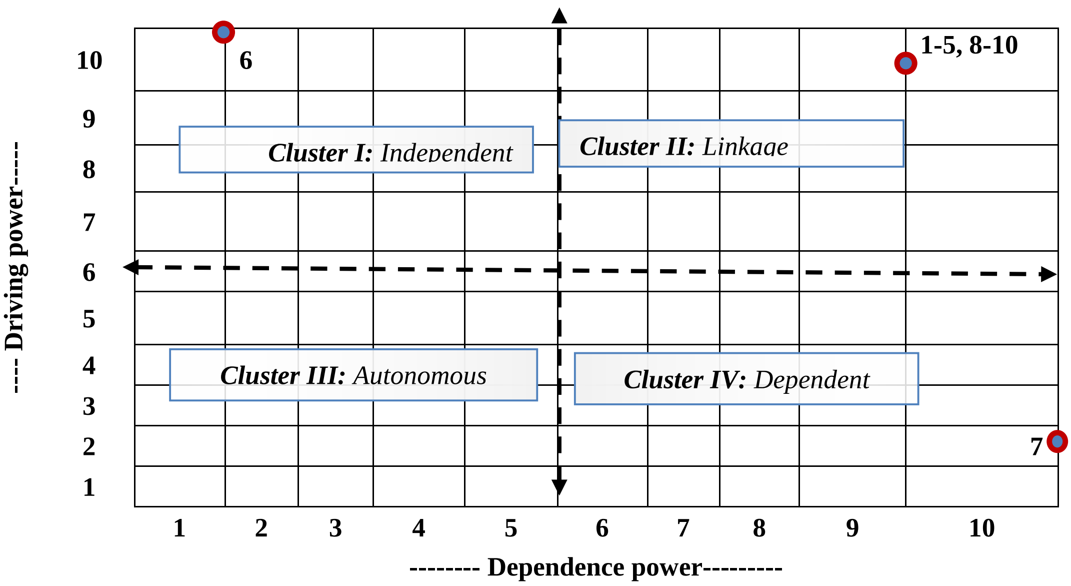


Figure 16 MICMAC analysis of the key barriers.

*(Note: **ORG6 (1):** Short-term, project-based implementation approaches instead of system-wide CE strategies; **ORG2 (2):** Lack of strategic planning for CSCM adoption; **ORG5 (3):** Insufficient knowledge and awareness among organizational members (employees) about CSCM; **ORG4 (4):** Absence of performance measurement system regarding CSCM applications; **ORG1 (5):** Insufficient management support to adopt CSCM applications; **REG1 (6):** Insufficient environmental laws and regulations for CSCM adoption; **TECH4 (7):** Poor cold-chain and storage infrastructure to reduce post-harvest losses; **COFIN5 (8):** Lack of economic incentives for adopting circular logistics, packaging recovery, or composting; **REG3 (9):** Insufficient government programs encouraging key stakeholders' participation in CE supply chains; **EOPSC2 (10):** Fragmented supply chains with weak coordination among producers, processors, and retailers)*

According to the MICMAC analysis (Figure 16), the barrier 'Insufficient environmental laws and regulations for CSCM adoption (REG1)' is identified as independent, whereas the barrier 'Poor cold-chain and storage infrastructure to reduce post-harvest losses (TECH4)' is classified as dependent. Conversely, all other barriers have been identified as interrelated barriers, indicating their instability and their impact on one another.

Chapter 5: Recommendations and Conclusion

5.1 Recommendations

Considering the research experience and limitations, the following recommendations are proposed for future researchers conducting similar studies with enhanced precision.

- The study included study applied different types of methods: the study applied modified Delphi, BWM, and ISM methods, while in some cases, these techniques might show bias, which may lead to unbalanced results since they are mostly dependent on the feedback of the expert panel, Thus, researchers in the future need to be very careful about selecting appropriate respondents and a large enough sample.

- Other MCDM tools, such as fuzzy-BWM, fuzzy-ISM, or TISM, could be used instead of BWM to conduct research in different dimensions.

- To make the study more interesting, an additional analysis (i.e., correlation or Kendall Tau) could be conducted to identify possible interdependence among the ranks identified by BWM analysis.

- Even though the purpose of the study was to determine the barriers to circular economy faced by the agricultural (crop sector) development project professionals, including the perspectives of other stakeholders (i.e., project beneficiaries, vendors, etc.) from agricultural organizations would have added a valuable new dimension to the study, which was not done. Future researchers conducting this type of investigation may consider these issues.

- However, considering the pros and cons of the applied methods found in the literature, the researchers believe that the integration of the Delphi, BWM, and ISM-MICMAC models provides useful insights, and such an approach might also be recommended in other services or industry domains to conduct similar research.

5.2 Conclusion

Studying the barriers to the circular economy in the supply chain management of agricultural development projects is essential, as agriculture functions through intricate, resource-demanding supply chains that experience inefficiencies, waste production, and greenhouse gas emissions at various stages, including input utilization, cultivation, harvesting, and post-harvest processing. Despite the significant potential of circular economy principles to convert linear supply chains into regenerative systems that reduce waste, close resource loops, and enhance the value of agricultural by-products, current research shows that adoption is still limited and fragmented.

Initially, the study identified seven categories of barriers to the circular economy of agricultural project supply chains: organizational, regulatory, technological, economic and financial, consumer and societal, operational and supply chain, and environmental. Under these categories it identified fifty (50) barriers that affect the implementation of the circular economy in the agricultural development project supply chain. Based on their importance, the study identified the top ten most significant barriers, which include short-term, project-based implementation approaches instead of system-wide circular economy strategies; lack of strategic planning for CSCM adoption; insufficient knowledge and awareness among organizational members (employees) about CSCM; absence of a performance measurement system regarding CSCM applications; insufficient management support to adopt CSCM applications; insufficient environmental laws and regulations for CSCM adoption; poor cold-chain and storage infrastructure to reduce post-harvest losses; lack of economic incentives for adopting circular logistics, packaging recovery, or composting; insufficient government programs encouraging key stakeholders' participation in CE supply chains; and the supply chains are fragmented due to the lack of coordination among producers, processors, and retailers.

Furthermore, it is essential not only to identify barriers to circular economy adoption but also to understand their interrelationships and relative dependencies. Using Interpretive Structural Modeling (ISM) and MICMAC analysis, the research systematically examines how these barriers influence one another within the agricultural project supply chain. The ISM results reveal that poor cold-chain and storage infrastructure to reduce post-harvest losses is a highly dependent barrier, directly or indirectly linked to all other barriers, and therefore cannot be effectively addressed in isolation. In contrast, insufficient environmental laws and regulations for circular supply chain management adoption emerge as a key driving barrier, influencing all others while remaining unaffected itself, underscoring the importance of addressing regulatory issues at the project planning stage. The MICMAC analysis further supports these findings by classifying regulatory barriers as independent, infrastructure-related barriers as dependent, and the remaining barriers as interrelated, reflecting the complex and interconnected nature of challenges to circular economy implementation in agricultural development project supply chains.

In conclusion, significant obstacles to the circular economy in agricultural development projects within the supply chains of developing countries fall under the organizational category: short-term, project-based implementation approaches instead of system-wide CE strategies; lack of strategic planning for CSCM adoption; insufficient knowledge and awareness among organizational members (employees) about CSCM; absence of performance measurement system regarding CSCM applications; and insufficient management support to adopt CSCM applications (ORG1), and so on. Without overcoming these organizational barriers, efforts to promote circular supply chains in agricultural development will remain fragmented and unsustainable. Conversely, strengthening organizational foundations can enable agricultural development projects to harness the full potential of the circular economy, contributing to resilient food systems, environmental sustainability, and inclusive development

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Appendices

Appendix I- Modified Delphi Questionnaire

Research Title: Identification of key barriers to circular economy and their inter-relationship in supply-chain management of agricultural development projects.

The questionnaire is prepared to collect information for MBA thesis at Sonargaon University, Dhaka, Bangladesh on **"**Circular Economy in the Supply Chain Management of Agricultural Development Projects: Evidence from a Developing Country".

Respondent/participant serial no:

Participant's Name & Address:

Gender: Male ( ) Female ( ) **Age:** ( ) years

Please provide the following information based on your job responsibilities and previous working experiences in project procurement management activities in public sector agriculture projects in Bangladesh. According to the invitation letter, your information will be kept restricted and will be used only for research purposes.

Q1. What is your designation and experience/role?

………………………………………………………………………………………………

Q2. Are the listed barriers being relevant/critical to Circular Economy in the Supply Chain Management of Agricultural Development Projects?

Instruction 1: Please answer **"Yes"** if you think the mentioned barrier is relevant and provide a short description of the challenges based on your experience. If you find that the challenge is not relevant, mark it as **"NO".**

Instruction 2: Based on your professional experience, you are allowed to **add/delete** any challenges (main categories or sub-challenges) along with their descriptions mentioned in the following list and the attachment (challenge description found in the literature).

Q3. Are the listed project supply chain challenges relevant/critical to the GoB funded public sector agriculture projects in Bangladesh?

Instruction 1: Please answer **"Yes"** if you think the mentioned barrier is relevant and provide a short description of the barrier based on your experience. If you find that the barrier is not relevant, mark it as **"NO".**

Instruction 2: Based on your professional experience, you are allowed to **add/delete** any barriers (main categories or sub-categories) in the following list and the attachment.

Category	Sub-category	Response (Yes/No)	Challenge description
Organizational (ORG)	Insufficient management support to adopt CSCM applications (ORG1)		
	Lack of strategic planning for CSCM adoption (ORG2)		

	Lack of CE integration across different organizational units and business levels (ORG3)		
	Lack of performance measurement system regarding CSCM applications (ORG4)		
	Insufficient knowledge and awareness among organizational members (employees) about CSCM (ORG5)		
Regulatory (REG)	Insufficient environmental laws and regulations for CSCM adoption (REG1)		
	Lack of financial incentive (i.e., tax) for promoting the CSCM (REG2)		
	Lack of accurately implementation of ISO management systems (REG3)		
	Obligation to comply with the F-gas regulation (REG4)		
Technological (TECH)	Quality problem of products made from recovered materials (TECH1)		
	Design challenges to durable, reuse and recovery products (TECH2)		
	Technological challenges in reducing gas uses (The HFC phase -down) (TECH3)		
Economic and Financial (ECOFIN)	Lack of financial benefits in short-term (ECOFIN1)		
	CSCM processes require high costs (ECOFIN2)		
	Competitive market limiting CSCM adoption (ECOFIN3)		
	Client readiness to pay for extra (ECOFIN4)		
	Additional construction cost for reclaimed and recycle materials (ECOFIN5)		
	Immature recycling market operation (ECOFIN6)		
Consumer and Society (CS)	Lack of awareness about the advantages of reuse and renovation (CS1)		
	Skepticism about the quality and safety of remanufactured,		

	recycled and refurbished products (CS2)		
	The challenge of making customers eager to engage in circular initiatives (CS3)		
	Resistance to change of old generation (CS4)		
Operational (OP)	Lack of sufficient coordination and collaboration among SC partners to adopt CSCM implement (OP1)		
	Lack of support from municipalities to adopt CSCM applications Expert opinion (OP2)		
	Inadequacy of authorized organizations to fulfill collection targets (OP3)		
Environmental (ENV)	Lack of environmental protection in waste management (ENV1)		
	Lack of incentives on environmental assessment methods (ENV2)		
	Environmental impact: emission from transport, use of virgin feedstock (ENV3)		

Q4. Concluding question: Please list any other experts you would recommend to participate in this survey.

____.

Appendix II: Profile of the respondents participated in this research

Table a. Respondents participated in the modified Delphi round

Sl. No	Position (level)	Years of experience in Agricultural Development project
01	Executive	7 years
02	Assistant Project Manager	7 Years
03	Assistant Project Manager	7 Years
04	Executive	8 years
05	Assistant Project Manager	8 Years
06	Executive	10 Years
07	Project Manager	5 Years
08	Executive	8 Years
09	Programme Manager	9 Years
10	Executive	4 Years
11	Project Manager	5 Years
12	Executive	5 Years
13	Executive	5 Years
14	Assistant Project Manager	10 Years
15	Executive	6 years

(b)

Table b. Respondents participated in the BWM interview

Sl. No	Position (level)	Years of experience in Agricultural Development project
01	Executive	7 years
02	Assistant Project Manager	7 Years
03	Assistant Project Manager	7 Years
04	Executive	8 years
05	Assistant Project Manager	8 Years
06	Executive	8 Years
07	Programme Manager	9 Years
08	Assistant Project Manager	10 Years

(c)

Table c.

Respondents participated in the ISM brainstorming session

Sl. No	Position (level)	Years of experience in Agricultural Development project
01	Executive	7 years
02	Assistant Project Manager	7 Years
03	Assistant Project Manager	7 Years
04	Executive	8 years
05	Assistant Project Manager	8 Years
06	Executive	8 Years
07	Programme Manager	9 Years
08	Assistant Project Manager	10 Years
09	Procurement Consultant	20 years
10	Procurement Consultant	20 years

Appendix III: Example of Best-Worst Method (BWM) Analysis Results for Main Criteria (Categories of Barriers)

This document contains the results of the BWM analysis for 8 respondents (experts).

Aggregated Weights

Criterion	Weight
ORG	**0.2311 (23.11%)**
REG	**0.2157 (21.57%)**
TECH	**0.1351 (13.51%)**
ECOFIN	**0.1736 (17.36%)**
CS	**0.0737 (7.37%)**
OPSC	**0.1314 (13.14%)**
ENV	**0.0394 (3.94%)**

Expert 1 Results:

Best Criterion: REG

Worst Criterion: ENV

ξ (Optimal): 0.6834

Consistency Index: 3.73

Consistency Ratio: 0.1832

Consistency Level: Good (0.1 ≤ CR < 0.2)

Expert 1 Weights

Criterion	Weight
ORG	**0.0705 (7.05%)**
REG	**0.3143 (31.43%)**
TECH	**0.1357 (13.57%)**
ECOFIN	**0.2325 (23.25%)**
CS	**0.0705 (7.05%)**
OPSC	**0.1357 (13.57%)**
ENV	**0.0409 (4.09%)**

Expert 1 Consistency Check

Criterion	a_Bj	a_jW	a_Bj * a_jW	Consistent?
C1	**5**	**2**	**10**	**No**
C2	**1**	**7**	**7**	**Yes**
C3	**3**	**4**	**12**	**No**
C4	**2**	**5**	**10**	**No**
C5	**5**	**2**	**10**	**No**
C6	**3**	**3**	**9**	**No**
C7	**7**	**1**	**7**	**Yes**

Expert 2 Results:

Best Criterion: ORG

Worst Criterion: ENV

ξ (Optimal): 4.1459

Consistency Index: 4.47

Consistency Ratio: 0.9275

Consistency Level: Poor (CR ≥ 0.3)

Expert 2 Weights

Criterion	Weight
ORG	0.1776 (17.76%)
REG	0.0958 (9.58%)
TECH	0.2022 (20.22%)
ECOFIN	0.1199 (11.99%)
CS	0.1776 (17.76%)
OPSC	0.2022 (20.22%)
ENV	0.0249 (2.49%)

Expert 2 Consistency Check

Criterion	a_Bj	a_jW	a_Bj * a_jW	Consistent?
C1	1	3	3	No
C2	6	8	48	No
C3	4	4	16	No
C4	3	6	18	No
C5	5	3	15	No
C6	4	4	16	No
C7	8	1	8	Yes

Expert 3 Results:

Best Criterion: ORG

Worst Criterion: ENV

ξ (Optimal): 2.7251

Consistency Index: 4.47

Consistency Ratio: 0.6096

Consistency Level: Poor (CR ≥ 0.3)

Expert 3 Weights

Criterion	Weight
ORG	0.3043 (30.43%)
REG	0.2387 (23.87%)
TECH	0.1029 (10.29%)
ECOFIN	0.1482 (14.82%)
CS	0.0577 (5.77%)
OPSC	0.1029 (10.29%)
ENV	0.0452 (4.52%)

Expert 3 Consistency Check

Criterion	a_Bj	a_jW	a_Bj * a_jW	Consistent?
C1	1	4	4	No
C2	4	8	32	No
C3	3	5	15	No
C4	2	6	12	No
C5	4	4	16	No
C6	3	5	15	No
C7	8	1	8	Yes

Expert 4 Results:

Best Criterion: ORG

Worst Criterion: ENV

ξ (Optimal): 1.0000

Consistency Index: 3.73

Consistency Ratio: 0.2681

Consistency Level: Moderate (0.2 ≤ CR < 0.3)

Expert 4 Weights

Criterion	Weight
ORG	0.2264 (22.64%)
REG	0.2264 (22.64%)
TECH	0.1132 (11.32%)
ECOFIN	0.2264 (22.64%)
CS	0.0566 (5.66%)
OPSC	0.1132 (11.32%)
ENV	0.0377 (3.77%)

Expert 4 Consistency Check

Criterion	a_Bj	a_jW	a_Bj * a_jW	Consistent?
C1	1	5	5	No
C2	2	7	14	No
C3	3	4	12	No
C4	2	5	10	No
C5	5	2	10	No
C6	3	4	12	No
C7	7	1	7	Yes

Expert 5 Results:

Best Criterion: ORG

Worst Criterion: ENV

ξ (Optimal): 1.2984

Consistency Index: 3.73

Consistency Ratio: 0.3481

Consistency Level: Poor (CR ≥ 0.3)

Expert 5 Weights

Criterion	Weight
ORG	0.2032 (20.32%)
REG	0.2677 (26.77%)
TECH	0.1194 (11.94%)
ECOFIN	0.2032 (20.32%)
CS	0.0549 (5.49%)
OPSC	0.1194 (11.94%)
ENV	0.0323 (3.23%)

Expert 5 Consistency Check

Criterion	a_Bj	a_jW	a_Bj * a_jW	Consistent?
C1	1	5	5	No
C2	2	7	14	No
C3	3	5	15	No
C4	2	5	10	No
C5	5	3	15	No
C6	3	4	12	No
C7	7	1	7	Yes

Expert 6 Results:

Best Criterion: ORG

Worst Criterion: ENV

ξ (Optimal): 2.6834

Consistency Index: 3.73

Consistency Ratio: 0.7194

Consistency Level: Poor (CR ≥ 0.3)

Expert 6 Weights

Criterion	Weight
ORG	0.1701 (17.01%)
REG	0.1292 (12.92%)
TECH	0.2000 (20.00%)
ECOFIN	0.2300 (23.00%)
CS	0.0707 (7.07%)
OPSC	0.1701 (17.01%)
ENV	0.0299 (2.99%)

Expert 6 Consistency Check

Criterion	a_Bj	a_jW	a_Bj * a_jW	Consistent?
C1	1	3	3	No
C2	4	7	28	No
C3	3	4	12	No
C4	2	5	10	No
C5	5	2	10	No
C6	3	3	9	No
C7	7	1	7	Yes

Expert 7 Results:

Best Criterion: ORG

Worst Criterion: ENV

ξ (Optimal): 2.4689

Consistency Index: 4.47

Consistency Ratio: 0.5523

Consistency Level: Poor (CR ≥ 0.3)

Expert 7 Weights

Criterion	Weight
ORG	0.3587 (35.87%)
REG	0.2343 (23.43%)
TECH	0.1074 (10.74%)
ECOFIN	0.1074 (10.74%)
CS	0.0424 (4.24%)
OPSC	0.1074 (10.74%)
ENV	0.0424 (4.24%)

Expert 7 Consistency Check

Criterion	a_Bj	a_jW	a_Bj * a_jW	Consistent?
C1	1	6	6	No
C2	4	8	32	No
C3	3	5	15	No
C4	3	5	15	No
C5	6	3	18	No
C6	3	5	15	No
C7	8	1	8	Yes

Expert 8 Results:

Best Criterion: ORG

Worst Criterion: ENV

ξ (Optimal): 3.4586

Consistency Index: 3.73

Consistency Ratio: 0.9272

Consistency Level: Poor (CR ≥ 0.3)

Expert 8 Weights

Criterion	Weight
ORG	0.3383 (33.83%)
REG	0.2195 (21.95%)
TECH	0.0999 (9.99%)
ECOFIN	0.1213 (12.13%)
CS	0.0591 (5.91%)
OPSC	0.0999 (9.99%)
ENV	0.0620 (6.20%)

Expert 8 Consistency Check

Criterion	a_Bj	a_jW	a_Bj * a_jW	Consistent?
C1	1	2	2	No
C2	5	7	35	No
C3	3	4	12	No
C4	2	4	8	No
C5	5	2	10	No
C6	3	3	9	No
C7	7	1	7	Yes

Appendix IV: Sensitivity Analysis of BWM Results

Table a. Average weights of the main categories of the barriers obtained from BWM, and Weights during sensitivity analysis.

Main categories of barriers	**Values of preference weights for main categories of the barriers**									
	Normal (0.2311)	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
Organizational (ORG)	**0.2311**	0.1000	0.2000	0.3000	0.4000	0.5000	0.6000	0.7000	0.8000	0.9000
Regulatory (REG)	0.2157	0.2525	0.2244	0.1964	0.1683	0.1403	0.1122	0.0842	0.0561	0.0281
Technological (TECH)	0.1351	0.1581	0.1406	0.1230	0.1054	0.0879	0.0703	0.0527	0.0351	0.0176
Economic and Financial (ECOFIN)	0.1736	0.2032	0.1806	0.1580	0.1355	0.1129	0.0903	0.0677	0.0452	0.0226
Consumer and Society (CS)	0.0737	0.0863	0.0767	0.0671	0.0575	0.0479	0.0383	0.0288	0.0192	0.0096
Operational and Supply Chain (OPSC)	0.1314	0.1538	0.1367	0.1196	0.1025	0.0854	0.0684	0.0513	0.0342	0.0171
Environmental (ENV)	0.0394	0.0461	0.0410	0.0359	0.0307	0.0256	0.0205	0.0154	0.0102	0.0051
Total:	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Table b. Average weights of the sub-categories of the barriers obtained from BWM, and Weights during sensitivity analysis.
(Global weights for sub-categories of barriers according to sensitivity analysis when the weight of Organization (ORG) is varied from 0.1 to 0.9)

Barriers	**Values of preference weights for sub-categories of the barriers**									
	Normal (0.2311)	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
ORG1	0.0319	0.0138	0.0276	0.0414	0.0552	0.0690	0.0827	0.0965	0.1103	0.1241
ORG2	0.0486	0.0210	0.0421	0.0631	0.0842	0.1052	0.1262	0.1473	0.1683	0.1894
ORG3	0.0088	0.0038	0.0076	0.0114	0.0152	0.0190	0.0227	0.0265	0.0303	0.0341
ORG4	0.0322	0.0139	0.0279	0.0418	0.0558	0.0697	0.0836	0.0976	0.1115	0.1255
ORG5	0.0441	0.0191	0.0382	0.0573	0.0764	0.0955	0.1146	0.1337	0.1528	0.1719
ORG6	0.0655	0.0283	0.0567	0.0850	0.1134	0.1417	0.1700	0.1984	0.2267	0.2551
REG1	0.0624	0.0730	0.0649	0.0568	0.0487	0.0406	0.0325	0.0243	0.0162	0.0081
REG2	0.0078	0.0092	0.0081	0.0071	0.0061	0.0051	0.0041	0.0031	0.0020	0.0010
REG3	0.0364	0.0426	0.0378	0.0331	0.0284	0.0236	0.0189	0.0142	0.0095	0.0047

REG4	0.0191	0.0224	0.0199	0.0174	0.0149	0.0124	0.0099	0.0075	0.0050	0.0025
REG5	0.0289	0.0338	0.0301	0.0263	0.0225	0.0188	0.0150	0.0113	0.0075	0.0038
REG6	0.0272	0.0318	0.0283	0.0248	0.0212	0.0177	0.0141	0.0106	0.0071	0.0035
REG7	0.0339	0.0397	0.0353	0.0309	0.0265	0.0220	0.0176	0.0132	0.0088	0.0044
TECH1	0.0133	0.0156	0.0139	0.0122	0.0104	0.0087	0.0069	0.0052	0.0035	0.0017
TECH2	0.0051	0.0060	0.0053	0.0047	0.0040	0.0033	0.0027	0.0020	0.0013	0.0007
TECH3	0.0222	0.0260	0.0231	0.0202	0.0173	0.0144	0.0115	0.0087	0.0058	0.0029
TECH4	0.0383	0.0448	0.0399	0.0349	0.0299	0.0249	0.0199	0.0149	0.0100	0.0050
TECH5	0.0214	0.0250	0.0223	0.0195	0.0167	0.0139	0.0111	0.0083	0.0056	0.0028
TECH6	0.0237	0.0277	0.0246	0.0215	0.0185	0.0154	0.0123	0.0092	0.0062	0.0031
TECH7	0.0111	0.0130	0.0116	0.0101	0.0087	0.0072	0.0058	0.0043	0.0029	0.0014
ECOFIN1	0.0162	0.0190	0.0169	0.0148	0.0127	0.0106	0.0085	0.0063	0.0042	0.0021
ECOFIN2	0.0117	0.0137	0.0122	0.0107	0.0092	0.0076	0.0061	0.0046	0.0031	0.0015
ECOFIN3	0.0169	0.0198	0.0176	0.0154	0.0132	0.0110	0.0088	0.0066	0.0044	0.0022
ECOFIN4	0.0268	0.0314	0.0279	0.0244	0.0209	0.0174	0.0140	0.0105	0.0070	0.0035
ECOFIN5	0.0382	0.0448	0.0398	0.0348	0.0298	0.0249	0.0199	0.0149	0.0099	0.0050
ECOFIN6	0.0206	0.0242	0.0215	0.0188	0.0161	0.0134	0.0107	0.0081	0.0054	0.0027
ECOFIN7	0.0263	0.0308	0.0274	0.0239	0.0205	0.0171	0.0137	0.0103	0.0068	0.0034
ECOFIN8	0.0117	0.0137	0.0122	0.0107	0.0092	0.0076	0.0061	0.0046	0.0031	0.0015
ECOFIN9	0.0049	0.0058	0.0051	0.0045	0.0039	0.0032	0.0026	0.0019	0.0013	0.0006
CS1	0.0138	0.0162	0.0144	0.0126	0.0108	0.0090	0.0072	0.0054	0.0036	0.0018
CS2	0.0279	0.0327	0.0290	0.0254	0.0218	0.0181	0.0145	0.0109	0.0073	0.0036
CS3	0.0086	0.0100	0.0089	0.0078	0.0067	0.0056	0.0045	0.0033	0.0022	0.0011
CS4	0.0114	0.0134	0.0119	0.0104	0.0089	0.0074	0.0059	0.0045	0.0030	0.0015
CS5	0.0079	0.0093	0.0082	0.0072	0.0062	0.0051	0.0041	0.0031	0.0021	0.0010
CS6	0.0041	0.0048	0.0042	0.0037	0.0032	0.0026	0.0021	0.0016	0.0011	0.0005
OPSC1	0.0163	0.0190	0.0169	0.0148	0.0127	0.0106	0.0085	0.0063	0.0042	0.0021
OPSC2	0.0345	0.0403	0.0358	0.0314	0.0269	0.0224	0.0179	0.0134	0.0090	0.0045
OPSC3	0.0114	0.0133	0.0118	0.0103	0.0089	0.0074	0.0059	0.0044	0.0030	0.0015
OPSC4	0.0156	0.0183	0.0162	0.0142	0.0122	0.0102	0.0081	0.0061	0.0041	0.0020
OPSC5	0.0041	0.0048	0.0043	0.0037	0.0032	0.0027	0.0021	0.0016	0.0011	0.0005

OPSC6	0.0194	0.0227	0.0202	0.0177	0.0151	0.0126	0.0101	0.0076	0.0050	0.0025
OPSC7	0.0151	0.0177	0.0157	0.0137	0.0118	0.0098	0.0078	0.0059	0.0039	0.0020
OPSC8	0.0151	0.0177	0.0157	0.0137	0.0118	0.0098	0.0078	0.0059	0.0039	0.0020
ENV1	0.0030	0.0036	0.0032	0.0028	0.0024	0.0020	0.0016	0.0012	0.0008	0.0004
ENV2	0.0013	0.0015	0.0014	0.0012	0.0010	0.0009	0.0007	0.0005	0.0003	0.0002
ENV3	0.0048	0.0056	0.0050	0.0044	0.0038	0.0031	0.0025	0.0019	0.0013	0.0006
ENV4	0.0107	0.0125	0.0111	0.0097	0.0083	0.0069	0.0056	0.0042	0.0028	0.0014
ENV5	0.0081	0.0095	0.0085	0.0074	0.0063	0.0053	0.0042	0.0032	0.0021	0.0011
ENV6	0.0090	0.0106	0.0094	0.0082	0.0070	0.0059	0.0047	0.0035	0.0023	0.0012
ENV7	0.0024	0.0028	0.0025	0.0022	0.0019	0.0016	0.0012	0.0009	0.0006	0.0003

Table c. Ranking of the sub-categories of the barriers obtained from BWM, and sensitivity analysis.

Barriers	**Ranking**									
	Normal (0.2311)	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
ORG1	11	30	15	6	5	5	5	5	5	5
ORG2	3	19	3	2	2	2	2	2	2	2
ORG3	38	47	42	31	21	12	7	6	6	6
ORG4	10	29	14	5	4	4	4	4	4	4
ORG5	4	21	6	3	3	3	3	3	3	3
ORG6	1	12	2	1	1	1	1	1	1	1
REG1	2	1	1	4	6	6	6	7	7	7
REG2	42	41	41	42	42	42	42	42	42	42
REG3	7	4	7	9	9	9	10	10	10	10
REG4	22	18	22	22	23	23	23	23	23	23
REG5	12	7	10	12	12	13	13	13	13	13
REG6	14	9	12	14	14	15	15	15	15	15
REG7	9	6	9	11	11	11	12	12	12	12

TECH1	30	28	30	30	31	31	31	31	31	31
TECH2	43	42	43	43	43	43	43	43	43	43
TECH3	18	14	18	18	18	19	19	19	19	19
TECH4	5	2	4	7	7	7	8	8	8	8
TECH5	19	15	19	19	19	20	20	20	20	20
TECH6	17	13	17	17	17	18	18	18	18	18
TECH7	35	35	35	36	36	36	36	36	36	36
ECOFIN1	25	23	25	25	26	26	26	26	26	26
ECOFIN2	31	31	31	32	32	32	32	32	32	32
ECOFIN3	23	20	23	23	24	24	24	24	24	24
ECOFIN4	15	10	13	15	15	16	16	16	16	16
ECOFIN5	6	3	5	8	8	8	9	9	9	9
ECOFIN6	20	16	20	20	20	21	21	21	21	21
ECOFIN7	16	11	16	16	16	17	17	17	17	17
ECOFIN8	31	31	31	32	32	32	32	32	32	32
ECOFIN9	44	43	44	44	44	44	44	44	44	44
CS1	29	27	29	29	30	30	30	30	30	30
CS2	13	8	11	13	13	14	14	14	14	14
CS3	39	38	38	39	39	39	39	39	39	39
CS4	33	33	33	34	34	34	34	34	34	34
CS5	41	40	40	41	41	41	41	41	41	41
CS6	47	46	47	47	47	47	47	47	47	47
OPSC1	24	22	24	24	25	25	25	25	25	25
OPSC2	8	5	8	10	10	10	11	11	11	11
OPSC3	34	34	34	35	35	35	35	35	35	35
OPSC4	26	24	26	26	27	27	27	27	27	27
OPSC5	46	45	46	46	46	46	46	46	46	46
OPSC6	21	17	21	21	22	22	22	22	22	22
OPSC7	27	25	27	27	28	28	28	28	28	28
OPSC8	27	25	27	27	28	28	28	28	28	28
ENV1	48	48	48	48	48	48	48	48	48	48

ENV2	50	50	50	50	50	50	50	50	50	50
ENV3	45	44	45	45	45	45	45	45	45	45
ENV4	36	36	36	37	37	37	37	37	37	37
ENV5	40	39	39	40	40	40	40	40	40	40
ENV6	37	37	37	38	38	38	38	38	38	38
ENV7	49	49	49	49	49	49	49	49	49	49

Appendix V: Analysis Result of Interpretive Structural Modelling

Table a. Structured Self Interaction Matrix of the key barriers.

Variables	1	2	3	4	5	6	7	8	9	10
ORG6		A	A	V	X	A	V	A	X	V
ORG2			A	V	X	A	V	X	V	V
ORG5				V	V	A	V	A	V	V
ORG4					A	A	V	A	O	V
ORG1						A	V	A	A	A
REG1							V	V	V	O
TECH4								A	A	A
ECOFIN5									V	V
REG3										V
OPSC2										

Symbols to define relationships:

V → row variable influences corresponding column variable
A → row variable is influenced by corresponding column variable
X → row and correspnding column variable infulence each other
O → row and correspnding column variable have no relationship

Table b. Final Reachability Matrix with Transitivity Links of the key barriers.

Variables	1	2	3	4	5	6	7	8	9	10	Driving Power
ORG6	1	0	0	1	1	0	1	0	1	1	6
ORG2	1	1	0	1	1	0	1	1	1	1	8
ORG5	1	1	1	1	1	0	1	0	1	1	8
ORG4	0	0	0	1	0	0	1	0	0	1	3
ORG1	1	1	0	1	1	0	1	0	0	0	5
REG1	1	1	1	1	1	1	1	1	1	0	9
TECH4	0	0	0	0	0	0	1	0	0	0	1
ECOFIN5	1	1	1	1	1	0	1	1	1	1	9
REG3	1	0	0	0	1	0	1	0	1	1	5
OPSC2	0	0	0	0	1	0	1	0	0	1	3
Dependence Power	7	5	3	7	8	1	10	3	6	7	

Final Reachability Matrix(FRM)

Variables	1	2	3	4	5	6	7	8	9	10	Driving Power
ORG6	1	1*	1*	1	1	0	1	1*	1	1	9
ORG2	1	1	1*	1	1	0	1	1	1	1	9
ORG5	1	1	1	1	1	0	1	1*	1	1	9
ORG4	1*	1*	1*	1	1*	0	1	1*	1*	1	9
ORG1	1	1	1*	1	1	0	1	1*	1*	1*	9
REG1	1	1	1	1	1	1	1	1	1	1*	10
TECH4	0	0	0	0	0	0	1	0	0	0	1
ECOFIN5	1	1	1	1	1	0	1	1	1	1	9
REG3	1	1*	1*	1*	1	0	1	1*	1	1	9
OPSC2	1*	1*	1*	1*	1	0	1	1*	1*	1	9
Dependence Power	9	9	9	9	9	1	10	9	9	9	

1*= Transitive comparison

Table c. Level Partitioning (LP), Level Partitioning Iterations, and Conical Matrix (CM) the Key Barriers found after analysis.

Sl No.	Code
1	ORG6
2	ORG2
3	ORG5
4	ORG4
5	ORG1
6	REG1
7	TECH4
8	ECOFIN5
9	REG3
10	OPSC2

Level Partitioning(LP)

Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
1	1, 2, 3, 4, 5, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	2
2	1, 2, 3, 4, 5, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	2
3	1, 2, 3, 4, 5, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	2
4	1, 2, 3, 4, 5, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	2
5	1, 2, 3, 4, 5, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	2
6	6,	6,	6,	3
7	7,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	7,	1
8	1, 2, 3, 4, 5, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	2
9	1, 2, 3, 4, 5, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	2
10	1, 2, 3, 4, 5, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	2

Level Partitioning Iterations

Elements(Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi)∩A(Ni)	Level
1	1, 2, 3, 4, 5, 7, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	
2	1, 2, 3, 4, 5, 7, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	
3	1, 2, 3, 4, 5, 7, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	
4	1, 2, 3, 4, 5, 7, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	
5	1, 2, 3, 4, 5, 7, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	
6	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	6,	6,	
7	7,	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	7,	1
8	1, 2, 3, 4, 5, 7, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	
9	1, 2, 3, 4, 5, 7, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	
10	1, 2, 3, 4, 5, 7, 8, 9, 10,	1, 2, 3, 4, 5, 6, 8, 9, 10,	1, 2, 3, 4, 5, 8, 9, 10,	
1 2 3				

Conical Matrix(CM)

Variables	7	1	2	3	4	5	8	9	10	6	Driving Power	Level
7	1	0	0	0	0	0	0	0	0	0	1	1
1	1	1	1*	1*	1	1	1*	1	1	0	9	2
2	1	1	1	1*	1	1	1	1	1	0	9	2
3	1	1	1	1	1	1	1*	1	1	0	9	2
4	1	1*	1*	1*	1	1*	1*	1*	1	0	9	2
5	1	1	1	1*	1	1	1*	1*	1*	0	9	2
8	1	1	1	1	1	1	1	1	1	0	9	2
9	1	1	1*	1*	1*	1	1*	1	1	0	9	2
10	1	1*	1*	1*	1*	1	1*	1*	1	0	9	2
6	1	1	1	1	1	1	1	1	1*	1	10	3
Dependence Power	10	9	9	9	9	9	9	9	9	1		
Level	1	2	2	2	2	2	2	2	2	3		

Sl No.	Code
1	ORG6
2	ORG2
3	ORG5
4	ORG4
5	ORG1
6	REG1
7	TECH4
8	ECOFIN5
9	REG3
10	OPSC2

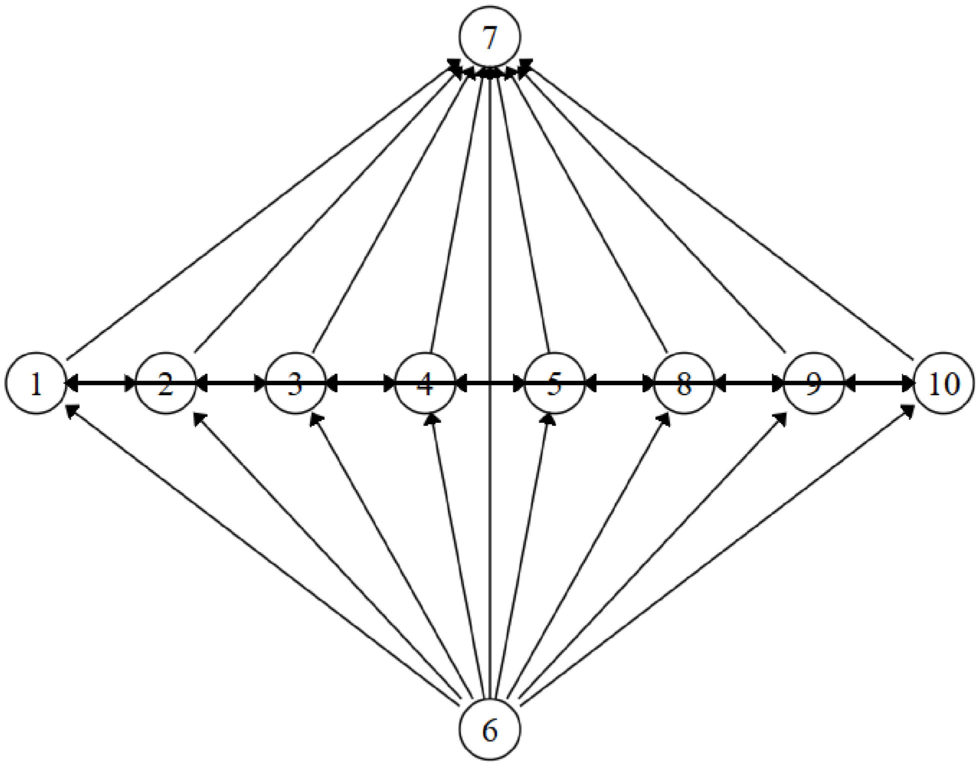

Figure 1. Digraph of the Key Barriers