Developing Sustainable Circular Supplier Selection Model Using FUZZY DEMATEL Technique

By

Maha Abd El-Hamid Morssi

A thesis presented in fulfillment of the requirements for the degree of

Doctor of Philosophy

Department of Design, Manufacture and Engineering Management
University of Strathclyde
Glasgow, United Kingdom

2023

Supervised by:

Dr. Andy TC Wong

COPYRIGHT STATEMENT

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination, which has led to the award of a degree.

ACKNOWLEDGMENTS

I am really grateful to the members of the Design, Manufacturing, and Engineering Management Department who have all worked so hard to guide and assist me throughout my time in the Ph.D. programme.

My first supervisor, Dr. Andy Wong, deserves special thanks for everything that he did to guide and instruct me as I created this work.

I'd also like to thank all the industrial partners who contributed to this research. My gratitude to Dr. Sahar El Barky for her continuous support and help during my research.

On the personal level, special thanks to my mother for all your standing effort and caring across this journey. Thank you, my sister and her husband, and my brother, for motivating me all the time to pursue this journey. I am deeply indebted to my father-in-law and mother-in-law for their encouragement and their countless acts of kindness that made this achievement possible.

My dear husband, I'm so grateful for everything you've done for me! Thank you for your endless patience, support, and love throughout this journey. It's been such a lovely experience we've shared. Your encouragement helped me reach this big milestone. I can't say "I DID IT", I can proudly say "WE DID IT".

I dedicated this PhD degree to my father, ***ABD EL-HAMID MORSSI,*** *the reason behind this achievement. May God prolong his life.*

PUBLICATIONS

1- **Working paper for international journal.**

Title: Improving Sustainable Circular Supplier Selection Process Using Sustainable Circular Supplier Selection Model: An Action Research Case Study.

Abstract: This research investigates the implementation of sustainable and circular economy principles within the supplier selection process of two large industrial firms. Utilising an action research methodology, the study examines the challenges and opportunities associated with transitioning to a more circular supply chain, particularly focus on the upstream part. An action research framework – "action research cycle" – is proposed and the role of action researcher in improving supplier selection process is discussed. A sustainable circular supplier selection model based on four dimensions: economic, environmental, social, and circular is employed to enhance the firms' capability to identify suppliers that are consistent with sustainable and circular economy plans. The findings reveal that the action research approach effectively facilitates organisational learning and change, leading to significant improvements in supplier selection practices. The study concludes by discussing the implications of the findings for broader adoption of sustainable and circular supplier selection process within the industrial sector.

2- **International Journal:**

Morssi, M., Wong, A. T. C. and El-Barky, S. (2023) 'Development of sustainable and circular criteria in supplier selection', *International Journal of Procurement Management*, 18(4), pp. 505–526. doi: 10.1504/IJPM.2023.134631.

3- **International conference:**

Morssi, M. (2021) 'Sustainable Circular Supplier Selection Criteria : An Empirical Study', in *Proceedings of the International Conference on Industrial Engineering and Operations Management Monterrey, Mexico,* pp. 3808–3820.

ABSTRACT

In the present time, sustainability and the circular economy (CE) have emerged as predominant concepts within the context of contemporary industrialization and the management of supply chains, primarily in response to issues such as global warming, economic ramifications, and increased social awareness. Within this emerging, the adoption of sustainable supply chain management (SSCM) and circular supply chain management (CSCM) practices is imperative for the advancement of Sustainable Development. One notable distinction between CSCM and traditional SSCM is that CSCM, with its focus on restoration and regenerative perspectives, embraces a zero-waste approach that enables the recycle of value not only within the initial supply chains but also throughout diverse supply chains through collaborations with companies operating within the same industry sector or across different sectors.

The literature elucidates that a crucial approach to operationalise SSCM and CSCM revolves around guaranteeing that suppliers effectively integrate sustainable and circular practices. While a considerable number of academics focus on sustainable supplier selection, there is a scarcity of scholarly attention towards circular supplier selection. Accordingly, this research aims to develop, for the first time, a **Sustainable Circular Supplier Selection Model (SCSS Model)** considering economic, environmental, social, and circular dimensions. The proposed model assists firms in supplier assessment within sustainability and CE frameworks, enhancing supply chain efficiency towards sustainability and CE. Additionally, a novel criterion within the circular dimension, namely "Reverse Logistics Agreement," was introduced in this research for the first instance in scholarly literature.

The SCSS Model proposed in this study was developed through a comprehensive review of existing literature and insights gathered from experts in the industry. Prior to formulating the model, a survey questionnaire was employed to assess the importance and practical applicability of 26 criteria incorporated in the proposed SCSS Model, based on the perspectives of experts across diverse sectors. The questionnaire data was analysed through the application of the Relative Importance Index (RII) and Mann-Whitney U-test, whereas validation of its reliability and accuracy was confirmed using Cronbach's alpha. Based on the findings, four criteria were eliminated, with only 22 criteria considered adequately integrated into the proposed SCSS Model.

To establish the interdependence relationships among the criteria of the proposed SCSS Model, the FUZZY-Decision Making Trial and Evaluation Laboratory (FUZZY-DEMATEL) technique,

which is categorized as a Multi Criteria Decision Making (MCDM) method, was employed. A panel of 20 experts was used for a pairwise comparison to conduct FUZZY-DEMATEL, which assessed the impact of the effective criteria. The evaluation of criteria interdependence conducted through the application of the FUZZY-DEMATEL technique aimed to develop a cause-and-effect diagram. In the cause-and-effect diagram, the criteria are divided into four quadrants according to their relation and prominence values. The results showed that the criterion “Environmental Mgt. Systems” has the greatest influence among the sustainable circular supplier selection criteria. Additionally, the results indicate that the criteria GHG emissions ENV5, Air pollution resulting from recycling process, Clean technology for recycling, Occupational Health & Safety, Respecting environmental standards and regulations in the process of recycling, Training Related Carbon, and Green Technology are also having great influence on the other sustainable circular criteria. These criteria are positioned in the first quadrant of the cause-and-effect diagram, thereby they are the core criteria in the process of sustainable circular supplier selection. The research conducted action research study with two industrial companies in the Middle East and North Africa (MENA) region to carry out the proposed SCSS Model and assess its practicality. The action research was centered around a cycle consisting of six primary steps: Data collection, Data feedback, Data analysis, Action Planning, Implementation, and Evaluation.

The novelty of this research is developing, for the first time, a SCSS Model using FUZZY-DEMATEL considering four dimensions: Economic, Environment, Social, and Circular. This research will be of interest to supply chain managers, procurement managers, and industrial companies. Also, researchers who are working in the field of supply chain management and industrial engineering management. The proposed model will aid practitioners in enhancing the performance of their companies' sustainable and circular supply chains, thereby contributing to the achievement of Sustainable Development Goals (SDGs), specifically SDG 8 (Decent Work and Economic Growth) and SDG 12 (Responsible Consumption and Production). Regarding SDG 8, the SCSS Model incorporates sustainable principles that target ethical labor practices and the assurance of safe working conditions by suppliers, thereby fostering decent work. Furthermore, since the CE principles promote repair, reuse, and remanufacturing, they lead to the creation of potential job opportunities. Furthermore, when suppliers prioritise resource efficiency and waste reduction, it can contribute to operational enhancements, leading to reduced costs, increased productivity, and ultimately improved economic competitiveness. Concerning SDG 12, the integration of CE principles within the SCSS Model prompts suppliers to engage in resource efficiency, material recycling and waste reduction, thereby mitigating the environmental consequences and fostering responsible consumption and production. Furthermore, CE principles encourage suppliers to develop their products with a focus on increased longevity, thereby prolonging the product lifecycle and fostering sustainable consumption actions. Furthermore, selecting suppliers based on their environmental practices in accordance with the sustainable criteria of the SCSS Model helps in decreasing pollution, reducing energy consumption, and minimizing water usage. This, in turn, contributes to sustainable production, leading to responsible production and consumption.

TABLE OF CONTENTS

7 CONCLUSION

List of Appendix

List of Figures

List of Tables

CHAPTER 1
INTRODUCTION

1.1 Research Background

In the foreseeable future, the ongoing level of utilisation of natural resources globally is expected to present obstacles for the environmental and economic sustainability (Farooque *et al*., 2022). Additionally, in excess of 8.5 million tonnes of harmful chemicals and 30,000 million tonnes of CO2 emissions are annually emitted (Kannan *et al.*, 2020). According to these challenges, striving to achieve both sustainability and circular economy (CE) practices is widely regarded as crucial in the passage towards a more sustainable society (Walker *et al.*, 2022).Thus, the concepts of sustainability and the CE have recently experienced an increase in prominence among researchers, theorists, scholars, and practitioners. Although these concepts are considered necessary to solve many of the existing global environmental and social challenges (e.g., climate change, environment preservation and social fairness), it appears there is no constancy relating to their contents (Nikolaou *et al.*, 2021).

The creation of sustainability concept can be drawn back to 1987 in the Brundtland Report, where Sustainable Development (SD) was defined as "*the development of that meets the needs of the present without compromising the ability to future generations to meet their own needs*". The United Nations SDGs (UN SDGs), often known as the 2030 Agenda, were implemented in 2015 to address various global sustainability challenges. The UN SDGs have the objective of eliminating poverty in its various manifestations, addressing inequality both within and between nations, safeguarding the environment, promoting long-term, comprehensive and sustainable economic progress, and nurturing social inclusivity (Pisano *et al.*, 2015). Businesses are being urged by the UN SD Agenda 2030 to align their operations and plans with the organisation's sustainability objectives to create and realise a sustainable future through cooperation. Ban Ki-moon, Secretary General of the United Nations challenged business, stating that: *"Companies can contribute through their core activities, and we ask companies everywhere to assess their impact, set ambitious goals and communicate transparently about the results*" (UN 2017).

On the other hand, CE emphasises the reintegration of waste by-products into production systems through the transformation of traditional business manufacturing paradigms from a linear model to a circular framework (García *et al*, 2019). CE is viewed as a strategic method to resource management, and is increasingly being recognised for its potential to facilitate SD (Zhang *et al.*, 2023). According to the Ellen MacArthur Foundation (2019), the CE is a comprehensive framework that operates on three fundamental design principles: (1) the elimination of waste and pollution; (2) the circulation of products and materials at their maximum value; and (3) the regeneration of resources (A. Zhang *et al.*, 2023). CE achieves material circularity through the utilisation of two distinct cycles: a restorative cycle for technical materials and a regenerative cycle for biological materials (Farooque *et al.*, 2019). Consequently, organisations have the potential to exert a substantial influence in facilitating the shift toward sustainability by actively engaging in the CE (Heras-Saizarbitoria *et al.*, 2023).

The adoption and implementation of CE necessitates that organisations engage in a comprehensive re-evaluation and restructuring of their supply chains, encompassing many aspects such as sourcing, operations, logistics, as well as returns and disposal processes. Approaching supply chain management from a CE standpoint can generate advantages across multiple levels (Theeraworawit *et al*., 2022). At the macro level, countries can anticipate faster progress in achieving SDGs (SDGs) regarding resource security, carbon reduction and landfill utilisation at a larger scale (Ghisellini *et al*., 2016). At the meso-level, countries can mitigate resource scarcity and price volatility, minimise harmful emissions and enhance community support by implementing green operations and fostering supply chain coordination (Genovese *et al.*, 2017; Zeng *et al*., 2017). At the micro level, implementing CE philosophies allows enterprises to establish their legitimacy in international marketplaces, enhance their brand image, generate additional sources of income and mitigate business risks arising from inventory and supply deficiencies (Lüdeke-Freund *et al*., 2019).

It is crucial to understand the difference between the “Environmental”, as a sustainability dimension, and “Circular” perspectives for achieving SD goals. Both perspectives have similar objectives but employ distinct approaches (Montag and Pettau, 2022). The CE focuses on extending the lifecycle and value of products, components, and materials through practices such as reuse and recycling, while environmental sustainability aims to minimise damage to the earth's ecosystem by decreasing waste and negative outputs such as CO2 emissions (Lieder and Rashid, 2016; Blum *et al*., 2020).

In the era of sustainability and CE, practices towards sustainable supply chain management (SSCM) and circular supply chain management (CSCM) are essential for promoting SD. In this context, the concepts of SSCM and CSCM have traditionally been discussed as distinct topics within academic literature. There is an increasing interest in exploring the potential overlap between these two paradigms, since it may uncover beneficial synergies (Hussain and Malik, 2020). SSCM can be defined as the management of material, information and capital flows, as well as cooperation among companies along the supply chain, while taking into account all three dimensions of SD, namely economic, environmental and social, as determined by customer and stakeholder requirements (Seuring and Müller, 2008). While CSCM is defined by Farooque *et al.* (2019) as "*the integration of circular thinking into the management of the supply chain and its surrounding industrial and natural ecosystems*".

A significant contrast, comparing CSCM to traditional SSCM, is that CSCM adopts a zero-waste perspective and facilitates the retrieval of value not just within the initial supply chains but also across various supply chains by partnering with companies in the same industry sector and/or different sectors (Farooque *et al.*, 2022).

SSCM aims to reduce environmental and social effects across the whole supply chain by prioritising responsible sourcing and ethical practices; its primary objective is to achieve long-term sustainability through the reduction of waste and emissions, as well as the advocacy for ethical practices (Abualigah *et al.*, 2023a; Kumar *et al.*, 2023). On the other hand, CSCM seeks to establish a self-contained system in which items are specifically designed for reuse, remanufacturing or recycling to minimise waste and enhance the efficient use of resources (A. Zhang *et al.*, 2023). CSCM especially focuses on implementing a closed-loop strategy for product life cycles (Farooque *et al.*, 2019).

While both methods share common sustainability goals, SSCM emphasises the integration of sustainable practices within the traditional linear supply chain framework, following the take-make-dispose linear economy model. This approach fails to tackle the issue of valuable materials being lost in landfills, resource scarcity and excessive consumption (Theeraworawit *et al.*, 2022). In contrast, CSCM shifts away from linear model towards a circular supply chain model that extends product lifecycles and manages waste more effectively based on regenerative and restoration design (Roy *et al.*, 2022; Burke *et al.*, 2023).

The concept of CSCM integrates multiple dimensions that improve the circularity of the supply chain, such as a closed-loop supply chain (CLSC), remanufacturing, recycling, reverse logistics (RL), industrial symbiosis and other strategies aimed at achieving a zero-waste objective; therefore, it exceeds the objectives of SSCM (A. Zhang *et al.*, 2023). Thus, CSCM will expand the scope of SSCM by minimising the reliance on new materials, therefore promoting the circulation of resources within the supply chain system (Genovese *et al.*, 2017; Zhang *et al.*, 2023). Hence, the CSCM surpasses the SSCM by enhancing resource utilisation, reducing waste and aligning with long-term environmental and economic goals (Farooque *et al.*, 2019).

In conclusion, SSCM covers a broad spectrum of strategies aimed at enhancing the ecological and social accountability of the entire supply chain. On the other hand, CSCM emphasises the extension of resource utilisation lifecycles via strategies such as product design, reusability and recycling, ultimately seeking to optimise resource efficiency and minimise waste generation by promoting the creation of easily repairable, disassemble and re-manufacturable products.

At the business level, the integration of sustainability and CE practices aims to primarily reduce environmental impact, improve social welfare and foster economic growth in a more sustainable manner (Toni, 2023). In this context, some companies are considered as industry leaders in the incorporation of sustainability and CE principles throughout their comprehensive business framework, spanning from supply chain management to product design and end-of-life plans. For instance, Patagonia, Inc. is widely acknowledged as a prominent entity in SSCM within the garment industry and has recently begun pursuing a regenerative approach towards CE. Patagonia exemplifies a prominent instance of a corporation that places emphasis on both sustainable supply chain and the implementation of CE principles. Patagonia's dedication to sustainability is evident in its supply chain, which comprises an “Input-Throughput-Output” system that aims to progress a fully sustainable and circular business model. During the "Input" phase of the system, Patagonia prioritises sustainable and renewable materials, collaborates with suppliers that follow ethical sourcing practices and focuses on key initiatives, such as utilising organic cotton and recycled materials. At the "Throughput" phase, where the manufacturing process is taken into account, Patagonia incorporates sustainable manufacturing processes. These include a focus on minimising waste, optimising energy consumption through renewable sources and adhering strictly to ethical manufacturing and fair labor practices. Finally, in the "Output" phase, Patagonia prioritises closing the loop by recycling and storing for future solutions. They also focus on extending the product lifecycle through lifetime warranty, repair services, reselling and upcycling. By applying these tactics, Patagonia can greatly decrease its impact on the environment and establish a closed-loop model in which materials are consistently reused in the production of new items. This approach not only helps the environment but also enhances the company's reputation as a pioneer in sustainability and circular initiatives (Shourkaei *et al.*, 2024). Moreover, Hyla Mobile, another industry leader in sustainability practices and CE, engaged in repurposing and reutilising mobile devices and/or their components, with an approximate record of bestowing a 'second life' upon 50 million devices. This process has led to an economic gain of $4 billion for the initial owners and a diversion of 6500 tonnes of electronic waste from being disposed in landfills (Velenturf and Purnell, 2021).

It is widely recognised that the assessment of the supply chain performance plays a crucial role in the ongoing enhancement of organisational procedures (Lima and Carpinetti, 2016). One of the key aspects in supply chain performance evaluation involves the identification of appropriate performance criteria (Markaki and Askounis, 2021). Properly specified supply chain performance measures enable the strategic distribution of processes among multiple companies and give companies the chance to improve their success by providing competitive advantage through differentiated services and low costs (Narayanan and Ishfaq, 2022). In light of the existing literature on supply chain performance measurement methods, the Supply Chain Operations Reference (SCOR) model has emerged as a highly credible approach to evaluating performance over an extended period of time (Hervani *et al.*, 2022). The SCOR model was developed by the Supply Chain Council to facilitate the evaluation and management of supply chain performance. In the scope of sustainability and environmental resource management, the SCOR model has been utilised to assess the environmental efficacy of supply chain process capabilities within organizations (Hervani *et al.*, 2022). Furthermore, as the CE reaches a pivotal role in supply chain processes, it becomes essential to also incorporate the conventional SCOR model into the CE context (Ozbiltekin-Pala *et al.*, 2023). The deficiency of crucial circular processes and metrics within the SCOR model may weaken its effectiveness as a managerial instrument for enterprises embracing circular supply chain methodologies, like recycling and refurbishing (van Engelenhoven *et al.*, 2023). Montag and Pettau (2022) utilised SCOR processes fitted for circularity and sustainability supply chain; they presented a holistic set of performance metrics to evaluate the supply chain’s economic, environmental, social and circular performance. Moreover, they distinguished between circular and environmental performance perspectives, shedding light on the intricate link between circularity and sustainability.

In these contexts, modifications to the SCOR model processes- Plan, Source, Make, Deliver and Return-are being adopted to better support sustainable and circular supply chains’ processes (Montag and Pettau, 2022; Sudusinghe and Seuring, 2022; Ozbiltekin-Pala *et al*., 2023; van Engelenhoven *et al*., 2023). Accordingly, the evaluation of the traditional “Source” phase measurements of the SCOR model has been adopted for enhancing sustainability and circularity supply chain performance, such as supplier collaboration, use of recyclable products, sourcing of environmental friendly inputs and sourcing of compatible inputs for circularity with minimised resource extraction (Ozbiltekin-Pala *et al*., 2023). In this context, it is essential to integrate the assessment of a supplier's performance for improvement with the overall evaluation of the supply chain's performance (Khan *et al.*, 2023). Hence, the evaluation of a chosen supplier who adopts sustainability and CE principles is a demanding task that fulfils the criteria for incorporating sustainable and circular considerations into the conventional supplier selection (Liu *et al.*, 2022). Supplier selection within the context of sustainable and CE entails the assessment of suppliers according to criteria that promote sustainability and circularity within supply chains (Echefaj *et al*., 2023).

In the present context, a new approach to supplier selection is by means of sustainable circular supplier selection (SCSS) (Kannan *et al.*, 2020). As stated above, since that there is a difference between “environmental” dimension of sustainability and “circular” perspective for achieving SDGs, it is necessary to select suppliers based on different criteria related to the three pillars of sustainability (economic, environmental and social) in addition to circular dimension to achieve holistic view for SD. With the aid of sustainable-circular suppliers, organisations have the ability to effectively augment environmental conservation by optimising resource circulation, all the while achieving sustainability (environmental, economic and social) in their supply chain operations (Ali *et al.*, 2023).

In the era of CE, there is a growing emphasis on circulating products, components and materials through recovery channels like reuse and recycling. In the present situation, the implementation of RL has become imperative for organisations; therefore, business managers are encouraged to consider RL in their supply chains as the “recycling” of products can offer them substantial financial benefits (El Boudali *et al.*, 2022; Fernando *et al.*, 2023). The efficient and successful operation of RL processes greatly depends on the optimal configuration of the supply chain network (Kalverkamp and Young, 2019).

To select the appropriate supplier, it is necessary to take into account and appraise various criteria about the attributes of the supplier (Khan *et al.*, 2018). Consequently, the act of selecting a supplier is regarded as a problem of making decisions based on multiple criteria, commonly referred to as multicriteria decision-making (MCDM) (Memari *et al.*, 2019). In previous literature, several MCDM methods have been employed for selecting sustainable and circular suppliers. These methods include, but are not limited to, Fuzzy-TOPSIS (Govindan *et al.*, 2013; Yu *et al.*, 2019); Fuzzy-AHP (Gold and Awasthi, 2015); Fuzzy-AHP AND Fuzzy-TOPSIS (Fallahpour *et al.*, 2017); DEA (Bai and Sarkis, 2014); Fuzzy-AHP-VIKOR approach (Awasthi *et al.*, 2018); and FBWM (Hendiani *et al.*, 2020). However, the amount of research conducted on the application of MCDM methods, specifically in the context of selecting suppliers merging sustainability and circular perspectives, is limited (Govindan *et al.*, 2020; Kannan *et al.*, 2020a; Alavi *et al*., 2021).

The Middle East and North Africa (MENA) region, similar to numerous other regions worldwide, is currently encountering a multifaceted "multiple crisis" marked by the intersection of various factors, such as climate change, biodiversity decline, soil erosion, increasing social and economic inequalities, depletion of fossil fuel resources, rising forced displacement and challenged governance systems (Göll *et al.*, 2019). Consequently, this study places emphasis on this region with the aim of enhancing its SDGs.

The Middle East and North Africa (MENA) region is enormously exposed to the risk of climate change impacts due to factors including water scarcity, the concentration of economic activity in coastal areas and a reliance on agriculture that is climate sensitive. This region is made up of Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Malta, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates, West Bank, Gaza and Yemen. According to the Word Bank, MENA region has the third largest growth in carbon emissions globally, increasing the danger of climate change despite having relatively low total greenhouse gas emissions compared to other areas (https://www.worldbank.org). The MENA region accounts for approximately 57% of the global oil reserves and 41% of its natural gas reserves, thereby possessing abundant oil and gas reservoirs. The region experiences ecological degradation, perilous environmental conditions, a deterioration in environmental quality, an upsurge in ecological degradation, alterations in species distribution and a reduction in biodiversity, all attributed to the impacts of global warming and the unsustainable utilisation of natural resources (Namdar *et al.,* 2021). According to these challenges, the region's countries and cities must reevaluate their economies to align with sustainable and CE principles for maximum benefits (Mir *et al*., 2021).

Consequently, MENA region countries have taken positive steps in tackling fundamental environmental problems and enhancing sustainability in their separate nations; furthermore, they have generated a variety of exceptional prospects for fostering circular resource management, which could have a catalytic impact on economic recovery (ACTED, 2022).

1.2 Research Problem

Sustainable and circular supply chains are increasingly receiving attention as businesses aim to minimise their environmental footprint and shift towards a CE. Suppliers are pivotal in the management of sustainable and circular supply chains, as they have the ability to diminish the environmental consequences of supply chains by adopting environmentally friendly measures like minimising harmful emissions, waste reduction, ethical raw material and integrating sustainable practices. Furthermore, they have the capability to enhance resource efficiency through the optimisation of their production processes, incorporation of recycled materials and participation in CE programs like take-back initiatives. Therefore, selecting suppliers according to sustainable and circular criteria has a great impact on SSCM and CSCM.

Several scholars have addressed the problem of sustainable supplier selection in the current body of literature, while only a few supplier selection models have taken into consideration the concept of the CE, such as Govindan *et al.* (2020), Kannan *et al.* (2020), Kusi-Sarpong *et al.* (2021), Ecer and Torkayesh (2022), Liu *et al*. (2022), Perçin (2022) and Wang (2022). Upon thorough examination of these prior studies, certain deficiencies were identified that still require attention in the existing body of literature. For example, there exists a notable gap concerning the formulation of a supplier selection model that encompasses economic, environmental, social, and circular dimensions, that incorporates an approach considering the interdependencies among the criteria of each dimension. Such consideration is crucial for enabling decision-makers to comprehend the impact of these criteria in assigning more precise weights to each criterion throughout the supplier selection procedure (Kannan *et al.*, 2020).

RL plays a key function in closing the loop of the product and utilisation of resources within a CE perspective. The management of RL primarily consists of three key elements: products, suppliers and raw materials (Zhang *et al.*, 2020). Yet, the limited literature on supplier selection models for sustainability and CE lacks a selection and evaluation criterion for assessing the supplier's collaboration, capabilities and infrastructure to guarantee effective product returns and material recovery to promote efficient RL. Through integrating this criterion into supplier selection models towards sustainability and CE, organisations will be able to assess suppliers' capability to maintain principles of the CE, reduce waste and enhance the efficiency of resource utilisation.

Besides, the researcher conducted in-depth semi-structured interviews in a real-life context with seven experts from five different industrial companies. The findings of the interviews showed that the companies had already sustainable practices and CE initiatives. However, a significant lack was identified in terms of establishing the criteria for choosing suppliers in the contexts of sustainability and CE.

Based on the existing gap in literature and the semi-structured interviews conducted, the researcher found a significant necessity to develop a Sustainable Circular Supplier Selection (SSCS) model. This model should be structured based on four primary dimensions, namely Economic, Environmental, Social and Circular, utilising MCDM technique to assess the interdependency relationships among the various criteria. Furthermore, the model must incorporate a specific criterion that supports the principles of CE, which involves assessing the contractual arrangements related to the suppliers' expertise and abilities in effectively managing RL operations to guarantee the accomplishment of product circularity. The following section outlines the aim and objectives of the study.

1.3 Research Aim and Objectives

This study aims to develop an **SCSS Model** that integrates sustainable and CE principles through the utilisation of FUZZY- Decision making trial and evaluation laboratory (FUZZY-DEMATEL) MCDM technique for evaluating the interdependency relationship among the model's criteria. The model is structured on four primary dimensions and their corresponding criteria, specifically Economic, Environmental, Social and Circular dimensions. Measuring the interdependency relationships among criteria serves to figure out the cause-and-effect connection between them. Additionally, a new criterion is integrated into the "Circular" dimension of the model, known as "Reverse Logistics Agreement," which assesses the contractual agreements regarding suppliers' expertise and abilities in managing RL operations to ensure product circularity. **Table 1.1** highlights the four main research objectives and the associated research questions which will be achieved in order to support the research aim.

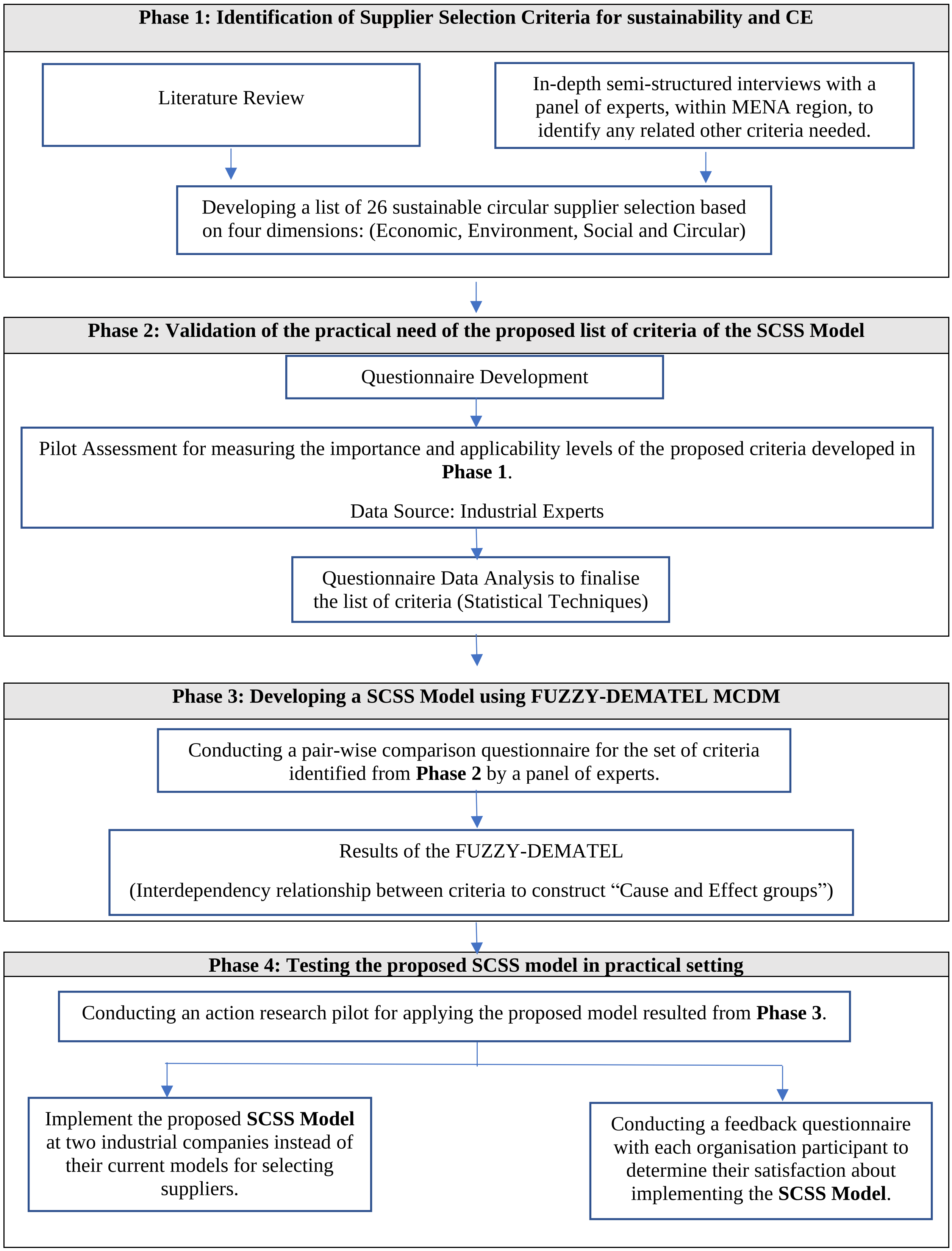
Table 1.1 The research objectives of the study:

Research Objective (RO)	**Research Question (RQ)**
(RO1)	**(RQ1.1)**
To develop a list of supplier selection criteria for sustainability and CE with four dimensions (Economic, Environmental, Social, Circular), with a particular focus on the application in the MENA region.	What are the economic, environmental, social and circular criteria that are essential for selecting suppliers towards sustainability and CE in the current body of literature?
	(RQ1.2)
	What are the economic, environmental, social and circular criteria that are essential for selecting suppliers towards sustainability and CE according to the MENA region circumstances.
(RO2)	**(RQ2)**
To find out the importance and applicability levels of criteria for supplier selection that refers to sustainability and CE, particularly within the context of the MENA region's specific circumstances.	What is the importance level of the proposed criteria and to what extent are they applicable for practical /industrial practices within the MENA region?
(RO3)	**(RQ3)**
To develop a **SCSS Model** using the FUZZY-DEMATEL technique to measure the interdependence relationship between the proposed criteria.	What is the influence of individual criteria on the interconnected criteria that affect the process of making decisions regarding the selection of suppliers?
(RO4)	**(RQ4)**
To test the proposed **SCSS Model** within a practical setting through the implementation of an action research pilot.	How efficiently could the suggested **SCSS Model** enhance the process of supplier selection within the contexts of sustainability and CE in practice?

1.4 Research Methodology

To develop a **SCSS Model** and achieve the research objectives, the researcher utilised four distinct methodological phases as illustrated in **Figure 1.1**. According to Haleem *et al.* (2021), the employment of a multi-phased research methodology significantly aids in the fulfilment of specified research objectives.

Figure 1.1 Research methodology of the research process:



Phase 1, known as the "Identification of Supplier Selection Criteria for sustainability and CE", aimed to achieve **RO1**. During this phase, the researcher compiled a list of 24 supplier selection criteria concerning sustainability and CE based on existing literature. Additionally, **in-depth semi-structured interviews** were conducted with a panel of experts from the MENA region. The goal of the interviews was to assess the level of familiarity that the organisations in the MENA region have with sustainability and CE concepts in their supply chain management. Furthermore, the interviews aimed to uncover the primary motivations for incorporating sustainability and CE concepts in supplier selection and to identify any recommended criteria for selecting suppliers that align with sustainability and CE principles. The output of this phase was to conduct a list of 26 supplier selection criteria based on four dimensions, namely, Economic, Environmental, Social and Circular based on existing literature and industrial experts' suggestions.

Phase 2, known as the "Validation of the practical need of the proposed list of criteria of the **SCSS Model**", was focused on achieving **RO2**. Throughout this phase, the researcher inquired into determining the importance and applicability of the 26 criteria by conducting a **survey** involving 52 experts in supply chain management from the MENA region, aiming to assess the importance and usability of each criterion in promoting sustainability and CE in practical scenarios. The output of this phase was derived from the survey findings, validating a specific set of 22 criteria that had been collectively approved by the experts involved in the survey. These criteria were approved based on their importance and applicability in practical scenarios.

Phase 3, known as "Developing a **SCSS Model** using FUZZY-DEMATEL MCDM", was focused on achieving **RO3**. During this phase, the interdependency relationships among the criteria within the proposed **SCSS Model** were examined to determine the extent to which each criterion influences others. This examination was conducted using the MCDM technique, known as FUZZY-DEMATEL, which determined both the level of prominence and influence of each criterion in order to establish the causal relationships between them. In order to execute the FUZZY-DEMATEL method, a **pairwise comparison questionnaire** was carried out by a panel consisting of 20 experts. The outcome of this phase was the identification of the causal criteria and effect criteria, resulting in a total of 10 causal criteria and 12 effect criteria. The methodological details of this phase will be explained in Chapter 3 of the study.

Phase 4, known as "Testing the proposed **SCSS Model** in practical setting", was focused on **RO4**. During this phase, the efficacy of the suggested **SCSS Model** was assessed through an **action research** pilot conducted in two specific case companies. This phase generated empirical data illustrating how the deficiency in the current supplier selection process could be rectified by implementing the proposed **SCSS Model**, ultimately advancing sustainability and CE principles within industrial settings. Using action research was considered especially suitable as the objective of this phase was to comprehensively examine the existing practices in the supplier selection process of the organisations under examination in order to develop a feasible solution, namely the proposed **SCSS Model**, to improve sustainability and CE practices. Coughlan and Coghlan (2002) action research cycle framework was utilised due to its focused approach towards addressing action research within the field of management studies. The methodological details of this phase will be explained in Chapter 3 of the study.

1.5 Research Contribution:

1.5.1 Contribution to knowledge:

Although previous studies have contributed a lot to the current body of knowledge in sustainable supplier selection, the consideration of CE has been overlooked. This study bridges this knowledge gap by developing, for the first time, a **SCSS Model** that examines both sustainability and CE. To be specific, the proposed model can consider factors in four important dimensions: economic, environmental, social and circular. In other words, this study expands the conceptual comprehension of SSCM and CSCM by incorporating CE principles, introducing a novel perspective to the current body of knowledge through the development of the **SCSS Model**. Another contribution is that the **SCSS Model** uncovers the interdependency between the criteria, using the FUZZY-DEMATEL technique which finds reliable weights for the criteria and categorises them into "cause-and-effect" groups. The final theoretical contribution to the current supplier selection literature is the development of a new supplier selection criterion under the circular dimension, i.e. "Reverse Logistics Agreement". Our analysis results suggest that this criterion can enhance the process of selecting suppliers in terms of sustainability and CE.

1.5.2 Contribution to practice:

In terms of the study's industrial contribution, the proposed **SCSS Model** will assist decision-makers to select and prioritise their suppliers with respect to sustainability and CE contexts. Accordingly, their supply chain's performance towards sustainability and CE would be improved.

The new criterion introduced in this study within the circular dimension of the **SCSS Model**, known as the "Reverse Logistics Agreement," offers decision-makers an opportunity to enhance the supplier selection process for sustainability and CE contexts. Specifically, the **SCSS Model**, which was developed based on the FUZZY-DEMATEL technique to identify interrelationships between criteria, not only assists decision makers in identifying the most impactful criteria of supplier selection process but also tackles the uncertainties linked to the criteria. Hence, this study offers decision-makers a thorough compilation of the most crucial and relevant SCSS criteria, aiming to enhance their decision-making process in supplier selection for sustainability and CE. The **SCSS Model**, as it was developed considering factors of diverse sectors, could be potentially applied across a range of industrial sectors.

1.5.3 Contribution to SDGs:

The provision of decent work and economic growth (SDG 8) and responsible consumption and production (SDG 12) are two SDGs that are aided by the findings of this study. Regarding SDG 8, the SCSS Model incorporates sustainable principles that target ethical labor practices and the assurance of safe working conditions by suppliers, thereby fostering decent work. Since the CE principles promote repair, reuse and remanufacturing, they lead to the creation of potential job opportunities. Furthermore, when suppliers are motivated to prioritise resource efficiency and waste reduction, it can contribute to operational enhancements, leading to reduced costs, increased productivity and, ultimately, improved economic competitiveness.

Concerning SDG 12, the integration of CE principles within the **SCSS Model** prompts suppliers to engage in resource efficiency, material recycling and waste reduction, thereby mitigating the environmental consequences and fostering responsible consumption and production. CE principles encourage suppliers to develop their products with a focus on increased longevity, thereby prolonging the product lifecycle and fostering sustainable consumption actions. Likewise, selecting suppliers based on their environmental practices in accordance with the sustainable criteria of the **SCSS Model** helps in decreasing pollution, reducing energy consumption and minimising water usage. This, in turn, contributes to sustainable production, leading to responsible production and consumption.

1.6 Research Structure

The research consists of seven chapters as follows:

- ***Chapter 1: Introduction***

An introductory chapter that discusses the background of the study, it includes the research problem, the need for the research output, the research gap, the research aims and objectives, the contribution to knowledge and practice, and the thesis outline.

- ***Chapter 2: Literature Review***

It includes a review of the existing literature on SSCM and CE, supplier selection approaches towards sustainable CSCM and knowledge gaps from reviewing the literature.

- ***Chapter 3: Research Methodology***

This chapter explains the research design and methodology in depth. This comprises the researcher's philosophical perspective, which influences the choice of an appropriate research approach, strategy, and techniques to achieve the aims and objectives of the study. The validity and reliability of the chosen research methodologies are also discussed. An overview of the research process is given.

- ***Chapter 4: Identification of supplier selection criteria.***

This chapter introduces the in-depth semi-structured interviews that were conducted to investigate the current supplier selection processes to ensure the need for the proposed approach, followed by a pilot assessment to measure both the importance and applicability of all the proposed criteria in four dimensions (economic, social, environmental, and circular).

- ***Chapter 5: Development of a model of sustainable and circular supplier selection.***

This chapter demonstrates the process of developing and measuring the interdependency relationships among the proposed criteria. It is divided into three sections. **Section 1** defines the MCDM technique that has been used in the study to measure the interdependencies between the criteria for selecting suppliers, which is called FUZZY-DEMATEL. **Section 2** explains how the researcher built the structure for using the **FUZZY-DEMATEL** technique by showing its methodology steps and its results. **Section 3** concludes the practical implications of using the FUZZY-DEMATEL technique for proposing an approach for sustainable circular supplier selection.

- ***Chapter 6: Testing of the proposed model.***

This chapter presents the utilisation of the primary objective of the research, focusing on the method for sustainable circular supplier selection employing the FUZZY-DEMATEL methodology. The utilisation is carried out via action research involving two distinct companies in various industries to evaluate the execution of the suggested method from a practical standpoint.

- ***Chapter 7: Conclusion***

This chapter concludes the study, introduces some recommendations according to the study results, and presents some future work in the research area.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction:

This chapter investigates the importance of Supplier Selection Process (SSP) in the context of Sustainable Supply Chain Management (SSCM) and Circular Supply Chain Management (CSCM). The examination conducted will assist the researcher in pinpointing the research gap by extensively exploring the concept of sustainability, then delving into the relationship between sustainability and Circular Economy (CE), followed by a review of past research on SSP concerning sustainability and CE. The literature review was conducted using an ideological approach; nonetheless, the researcher tried to incorporate a chronological approach in each segment to present previous research.

A thorough examination of literature keywords and search methodologies was carried out in Scopus and Web of Science (WoS), utilising terms that are either explicitly or implicitly associated with the SSCM and CSCM, such as ‘Sustainability’, ‘Sustainable Dimensions’, ‘Sustainable Development’, ‘Supplier Selection’, ‘Circular Economy’, ‘Sustainable procurement’, ‘Sustainable Circular Supplier Selection’ and ‘Circular Supplier Selection’. The search focused on the combination of "title-abstract-keywords".

2.2 Sustainable Supply Chain Management (SSCM):

Over the last decade, sustainability concept has gained attention due to the increase of socio-environmental problems, including climate change, air pollution and pollution-related health conditions (Khan *et al.*, 2020). Hence, most organisations have been under great pressure to address sustainability concerns in their business due to the increasing awareness of the environment and sustainability, stringent government directions and increasing community knowledge (Gaziulusoy and Brezet, 2015; Govindan *et al.*, 2016). In addition, global competition has further urged organisations to raise their level of commitment towards sustainability practices (Hassini *et al.*, 2012; Singh and Trivedi, 2016). Meanwhile, this contemporary era of globally challenging environment, integrating the concept of sustainability in the core business functions of supply chains, enables firms to achieve “competitive position” in the market (Zulfiquar and Kant, 2017; Khan *et al.*, 2021). Hence, an important aspect of promoting sustainability within organisations and a topic of current research interest is SSCM (Cristini *et al.*, 2021). Hence, there has been a growing interest in SSCM among researchers, academia and managers. Additionally, SSCM practices are becoming a popular business trend for promoting sustainable development (SD) in the industry (Köksal *et al.*, 2017).

SSCM has been defined in a number of different ways. On the basis of "supply chain management (SCM) definition, the definition of SSCM given by Seuring and Müller (2008) is widely accepted as: "SSCM is the management of material, information and capital flows as well as cooperation among companies along the supply chain while integrating goals from all three dimensions of SD, i.e., economic, environmental and social, which are derived from customer and stakeholder requirements". The following section outlines the drivers and barriers that organisations encounter when integrating SSCM into their business processes.

2.2.1 Drivers of implementing Sustainable Supply Chain Management (SSCM):

SSCM drivers can be viewed as key factors in the implementation process, providing incentives for companies to embrace SSCM practices (Zimon *et al.*, 2019). SSCM drivers can be described as "motivators that encourage or compel organisations to adopt sustainability practices across the entire supply chain" (Saeed and Kersten, 2019). Numerous scholars have outlined the drivers (or motivators) behind the adoption of SSCM within organisations. These motivators have been distinguished and categorised into two main groups: internal and external as shown in **Table 2.1**. Internal drivers occur within a company and are primarily managed by the company itself, whereas external drivers are factors that exist outside an organisation and are essentially beyond its influence.

Table 2.1: Internal and External Drivers of SSCM:

Driver (Internal)	**References**
Top Management Commitment	(Kulatunga *et al*., 2013; Tay *et al.*, 2015; Ansari and Kant, 2017; Bhanot *et al*., 2017; Emamisaleh and Rahmani, 2017; Saeed and Kersten, 2019; Narimissa *et al*., 2020; Sajjad *et al.*, 2020)
Logistics optimization	(Nikolaou, Evangelinos and Allan, 2013; Vijayan *et al.*, 2014; Boix *et al.*, 2015; Tay *et al.*, 2015; Dubey *et al.*, 2017)
Cost reduction	(Saeed and Kersten, 2019; Sajjad *et al.*, 2020; Abualigah *et al.*, 2023).
Operational efficiency	(Kumar *et al.*, 2019; Pattnaik and Pattnaik, 2019; Zimon *et al*., 2020; Alaei *et al.*, 2023).

Risk Management	(Tay *et al.*, 2015; Freise and Seuring, 2015; Karmaker *et al.*, 2021; Alaei *et al.*, 2023).
Sales increase	(Saeed and Kersten, 2019; Ashraf *et al.*, 2020; Eide *et al.*, 2020; Alaei *et al.*, 2023).
Long-term orientation	(Sajjad et al., 2020; Emamisaleh and Taimouri, 2021; Alaei et al., 2023).
Driver (External)	**References**
Customer pressure	(Giunipero et al., 2012; Alzawawi, 2013; Tay et al., 2015; Bhanot et al., 2017; Zulfiquar and Kant, 2017; Saeed and Kersten, 2019; Narimissa *et al.*, 2020).
Competitors	(Giunipero *et al.*, 2012; Alzawawi, 2013; Tay *et al.*, 2015; Bhanot, Rao and Deshmukh, 2017; Emamisaleh and Rahmani, 2017; Saeed and Kersten, 2019).
Government Regulations	(Giunipero *et al.*, 2012; Alzawawi, 2013; Bhanot *et al.*, 2017; Emamisaleh and Rahmani, 2017; Zulfiquar and Kant, 2017; Saeed and Kersten, 2019; Marculetiu *et al.*, 2023).
ISO Certifications	(Giunipero *et al.*, 2012; Alzawawi, 2013; Tay *et al.*, 2015; Saeed and Kersten, 2019).
Influence of NGOs	(Tay *et al.*, 2015; Sajjad *et al.*, 2015; Saeed and Kersten, 2019;)
Investors' pressure	(Tay *et al.*, 2015; Bhanot, Rao and Deshmukh, 2017; Saeed and Kersten, 2019)

As stated above, the relevant literature categorises drivers into internal and external groups. On the internal group, various drivers are identified to contribute to the transition toward SSCM. Regarding the internal drivers, one of the most agreed drivers is "top management commitment" (Alaei *et al.*, 2023). When top management is dedicated and guided by moral and ethical considerations, they exhibit a heightened motivation for establishing the implementation of SSCM (Sajjad *et al.* , 2020).

Engaging with sustainability-related challenges and implementing sustainable practices allows organisations to reduce costs through the conservation of energy, water and raw materials (Walker *et al.*, 2008). Consequently, companies augment their profitability and enhance their sustainability metrics (Schrettle *et al.*, 2014). The implementation of sustainability practices leads to a reduction in costs, enhancements in customer satisfaction and organizational reputation, as well as an increase in profits, thereby yielding superior economic and operational performance, which in turn incentivises organisations to adopt sustainability initiatives (Saeed and Kersten, 2019). Therefore, "Cost reduction" serves as an additional driver for adopting SSCM, as it primarily aligns with the strategic goals of organisations aiming to achieve a competitive edge (Sajjad *et al.*, 2020). The primary aim of optimised SSCM is to diminish the overall logistics costs associated with the supply chain while concurrently enhancing the social and environmental advantages (Abualigah *et al.*, 2023). Therefore, "Logistics Optimisation" is another driver for adopting SSCM, as logistics optimisation refers to enhancing the speed, route, load and type of transportation; the utilisation of alternative fuels in place of fossil fuels; reverse logistics; and logistics collaboration, among other factors, which will greatly enhance the profitability margin and aid in controlling greenhouse gas emissions for the business organisation (Dubey *et al.*, 2017). As an additional motivational factor for the adoption of SSCM, operational efficiency or productivity serves as a key driver primarily associated with the economic and social dimensions of SSCM (Kumar *et al.*, 2019; Pattnaik and Pattnaik, 2019; Zimon *et al.*, 2020; Alaei *et al.*, 2023).

Some studies have shown that sustainability enhances the ability of supply chains to reduce their risks, and at times, it is regarded as a practice for managing risks (Giannakis and Papadopoulos, 2016; Gouda and Saranga, 2018). Consequently, "risk management" constitutes a significant driver for implementing SSCM (Freise and Seuring, 2015; Karmaker *et al.*, 2021; Alaei *et al.*, 2023).

As a crucial factor in the economic dimension of SSCM, "sales increase" serves as a key motivator for sustainability (Alaei *et al.*, 2023). Various studies highlight the influence of sustainability on the expansion of sales; consequently, it will encourage organisations to adopt SSCM (Saeed and Kersten, 2019; Ashraf *et al.*, 2020; Eide *et al*., 2020).

A "long-term orientation" is a crucial driver for the implementation of SSCM. Long-term orientation refers to a corporate stewardship inclination focused on fostering enduring relationships with society, which encompasses customers, employees, suppliers, and the community, in order to minimise risks or enhance corporate resources (Sajjad *et al*., 2020; Emamisaleh and Taimouri, 2021; Alaei *et al*., 2023).

Regarding the external drivers, "customer pressure" is recognised as a significant driver, as the increasing demand from consumers for sustainability efforts has introduced new challenges for organisations striving to move towards a sustainable future (Narimissa *et al*., 2020 and Saeed and Kersten, 2019). Competitors also can be another external driver for implementing SSCM, as the sustainability practices implemented by competitors exert increased pressure on organisations (learning) to adopt sustainability initiatives, thereby striving to attain a comparable level of sustainability-related performance as their competitors, with an emphasis on long-term economic sustainability (Hsu *et al.*, 2013; Saeed and Kersten, 2019). Corporations are compelled to adhere to formal regulatory pressures imposed by governmental entities to implement sustainable practices (Wu *et al.*, 2022). Accordingly, “Government pressure” is considered as one of the drivers/motivators for organisations to adopt SSCM (Marculetiu *et al.*, 2023). Certified organisations tend to embrace sustainability initiatives more readily; for instance, companies certified with ISO 14001 exhibit a heightened awareness of their environmental sustainability performance (Zimon *et al*., 2020). Thus, "ISO certifications" are regarded as a driver for the implementation of SSCM. One of the primary motivators for businesses to address environmental and social risks is the influences and encouragements from stakeholders, especially non-governmental organisations (NGOs) (Sajjad *et al*., 2015).

2.2.2 Barriers for implementing Sustainable Supply Chain Management (SSCM):

Alongside the many drivers of the development of SSCM, there are barriers (Oelze, 2017). Several studies have identified the barriers, as outlined in **Table 2.2**, that could potentially hinder the adoption of SSCM.

Table 2.2: Barriers for implementing SSCM:

Barriers	References
Higher costs of sustainability and economic condition	(Seuring and Müller, 2008; Giunipero, Hooker and Denslow, 2012; Al Zaabi, Al Dhaheri and Diabat, 2013)
Insufficient communication and sharing information in the supply chain.	(Seuring and Müller, 2008; Al Zaabi, Al Dhaheri and Diabat, 2013)
Low “eco-literacy”	(Schaper, 2002; Revell and Blackburn, 2007; Herren, Hadley and Klein, 2010)
Lack of sustainable supplier	(Sajjad, Eweje and Tappin, 2015; Sajjad, Eweje and Tappin, 2020; Moktadir *et al.*, 2018)
Lack of understanding about environmental management/sustainability	(Schaper, 2002; Revell and Blackburn, 2007; Herren, Hadley and Klein, 2010; Vijfvinkel, Bouman and Hessels, 2011; Al Zaabi, Al Dhaheri and Diabat, 2013)
Lack of sustainability standards and appropriate regulations	(Al Zaabi, Al Dhaheri and Diabat, 2013)(Giunipero, Hooker and Denslow, 2012)

Misalignment of short-term and long-term strategic goals	(Giunipero, Hooker and Denslow, 2012)
Lack of effective evaluation measures about sustainability	
Lack of qualified staff, training and education about sustainability	(Al Zaabi, Al Dhaheri and Diabat, 2013)(Bohdanowicz, Zientara and Novotna, 2006)(Dong and Wilkinson, 2007)
Complex in design to reduce consumption of resources and energy	(Al Zaabi, Al Dhaheri and Diabat, 2013)
Inadequate facility for adoptions of reverse logistic practices	
Inadequate industrial self-regulation	(Al Zaabi, Al Dhaheri and Diabat, 2013)
Lack of top management commitment to initiate sustainability efforts	(Preuss, 2009; Giunipero, Hooker and Denslow, 2012; Al Zaabi, Al Dhaheri and Diabat, 2013)
Lack of motivation towards employees (incentives)	(Bowen *et al.*, 2001; Carter and Rogers, 2008; Preuss, 2009)
lack of tools and resources	(Revell, 2011)
Coordination effort and complexity	(Seuring and Müller, 2008)

In the current literature, it is evident that the drivers and barriers of implementing SSCM have received considerable attention. It is crucial to note that the primary internal driver is "Top Management Commitments," while the main external driver is "Collaboration with suppliers." This underscores the necessity of active participation from both internal and external stakeholders for the effective implementation of SSCM. As for the barriers, many researchers highlighted the issue of "Lack of understanding about environmental management/sustainability." This also suggests a need to enhance stakeholders' comprehension of sustainability before proceeding with SSCM implementation.

2.3 Circular Supply Chain Management (CSCM):

As stated, sustainability practices are becoming a popular business trend for promoting SD in the industry. CE is seen as a strategic approach to managing resources, and its ability to support SD is gaining more recognition (Zhang *et al.*, 2023). The world, at the current level of practices, will exhaust many of its natural resources in the near future if there is no change within the way the products are sourced, produced, consumed, delivered, recovered and regenerated (Hazen *et al.*, 2017). The CE is a relatively new strategy to reduce negative environmental effects (Lahane *et al.*, 2020) and advance SDGs (Govindan *et al.*, 2020). Hence, certain countries recently approved laws and regulations increase pressure on businesses to incorporate CE criteria into their decision-making processes (Kannan *et al.*, 2020). CE pushes the boundaries of environmental sustainability by emphasising the idea of alerting products in such a way that there must be workable links between ecological systems and economic growth (Genovese *et al.*, 2017). CE philosophy is developing into a powerful driving force behind sustainability, and it has started to be distinguished as a great potential to assist organisations to accomplish a breakthrough in sustainability execution (Lahane *et al.*, 2020). CE practices can aid in recovering valuable materials from the waste stream through facilitating product reuse and repair, as well as establishing restorative industrial systems (Ruggieri *et al.*, 2016). These measures provide benefits for the supply chains of companies in relation to sustainability and enhance the sustainable performance of the firms (Govindan *et al.*, 2020; Khan *et al.*, 2021). The CE has become an essential component of sustainability as it offers industrial companies a competitive advantage through the ability to revamp and restructure their processes (such as production, supply chain management and guidance), leading to decreased resource usage, waste and emissions (Jabbour *et al.*, 2019).

Integrating CE in SCM would begin to extend the boundary of SSCM by reducing the need of virgin materials, which could increase the circulation of resources within supply chains systems (Genovese *et al.*, 2017; Farooque *et al.*, 2019). The consolidation of CE into SCM has been referred to as CSCM in literature. CSCM, as defined by Farooque *et al.* (2019), "*the integration of circular thinking into the management of the supply chain and its surrounding industrial and natural ecosystems. It systematically restores technical materials and regenerates biological materials toward a zero-waste vision through system-wide innovation in business models and supply chain functions from product/service design to end-of-life and waste management,* *involving all stakeholders in a product/service lifecycle including parts/product manufacturers, service providers, consumers and users".*

CSCM significantly enhances all sustainability aspects concerning supply chains, including SSCM, Green Supply Chain Management (GSCM), closed-loop supply chains and environmental supply chains by incorporating a regenerative element (Farooque *et al.*, 2019). As shown in **Table 2.3**, sourced from Farooque *et al.* (2019), the discussion on sustainability in SCM has primarily focused on solutions for restoration, such as repair, refurbishing, remanufacturing and recycling. However, the idea of regeneration has not yet been explored within the realm of SSCM. Therefore, there is a necessity to improve the current sustainability principles by evolving SCM into CSCM.

Table 2.3 Sustainability in SCM and CE:

Sustainability in SCM (Terms)	**Sustainability Dimension**			**Integration of CE**	
	Environmental	**Economic**	**Social**	**Restorative**	**Regenerative**
Sustainable Supply Chain Management	√	√	√	√	
Green Supply Chain Management	√	√		√	
Environmental Supply Chain Management	√	√		√	
Closed Loop Supply Chains	√	√		√	
Circular Supply Chain Management	√	√	√	√	√

Source: Farooque *et al.* (2019).

Within CSCM, businesses work together with partners from different sectors to enhance the value of goods and materials. This approach provides a hopeful direction for supply chain managers to excel in resource efficiency and ultimately financial success. At the same time, it reduces adverse environmental, social, and economic effects (Farooque *et al.*, 2022). Zhang *et al.* (2021) developed a multi-dimensional CSCM framework, as shown in **Figure 2.1**, that covers SCM practices directly supporting supply chain circularity. These practices include closed-loop

SCM, remanufacturing SCM, recycling SCM, reverse SCM, and industrial symbiosis. Each dimension of CSCM exhibits a unique resource flow pattern to promote resource circularity in supply chains both within and across them.

Figure 2.1 A Multi-dimensional CSCM Framework by Zhang *et al.* (2021).

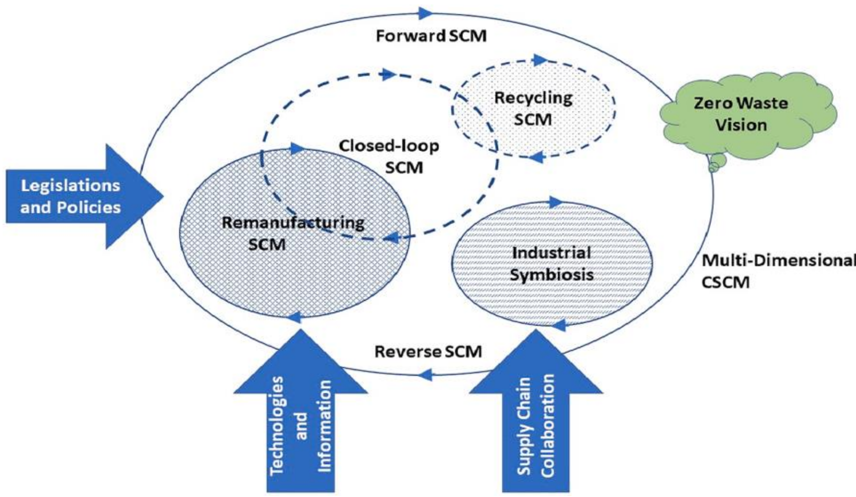


Figure 2.1 shows that the framework incorporates "legislations and policies" as a crucial factor in CSCM, along with "technologies and information" and "supply chain collaboration" as two supporting elements. Together, they help to promote various aspects of CSCM in order to drive supply chain circularity towards a zero-waste goal. The primary focus of traditional SCM research and practice has been on the forward SCM, which involves a linear progression of activities from acquiring raw materials to consumption, including inbound logistics, production, distribution and retail (Min *et al*., 2019). On the other hand, the reverse SCM emphasises the management of RL and value recovery processes for commercial returns, end-of-use products and end-of-life products (de Campos *et al.*, 2017). Clearly, CSCM needs to incorporate forward SCM and reverse SCM in order to achieve supply chain circularity, along with its closed-loop SCM dimensions, such as remanufacturing SCM, recycling SCM and industrial symbiosis (Zhang *et al.*, 2021). Circular archetypes may be categorised as either closed-loop circularity or open-loop circularity, depending on the manner in which resources are returned for further utilisation. The achievement of supply chain circularity is possible through closed-loop circularity, open-loop circularity or a hybrid

approach encompassing both (Genovese *et al.*, 2017; Farooque *et al.*, 2019). A closed-loop SCM system aims to restore the value of products through strategies such as reuse, repair, reconditioning, remanufacturing, recovering parts and recycling materials (Mishra *et al.*, 2023). The recovery of value in closed-loop SCM is often constrained because it may not always be feasible to reuse all materials found in returned products within the same supply chains (Farooque *et al.*, 2019). Hence, it is essential to take into account open-loop circularity, which involves expanding beyond the producer's initial supply chains to retrieve values from various supply chains by partnering with firms within the same industry or even across different sectors. Industrial symbiosis, for instance, enables the exchange of waste-to-resource materials, energy, water and/or by-products among closely located organisations that engage in enduring partnerships (Lombardi and Laybourn, 2012). With the expanded open-loop circularity, CSCM provides a wider range and increased possibilities for recovering value compared to the conventional closed-loop SCM (Farooque *et al.*, 2019; Zhang *et al.*, 2021). Hence, CSCM has a significant potential to enhance circularity within the supply chain (Zhang *et al.*, 2021; A. Zhang *et al.*, 2023).

Remanufacturing SCM considers manufacturing the products that have been returned to ensure their performance matches that of their original counterparts representing an elevated level of recovery (Chen *et al.*, 2015). Remanufacturing SCM can overlap with closed-loop SCM when all remanufacturing activities are carried out by an Original Equipment Manufacturer (OEM) (A. Zhang *et al.*, 2023). The archetype of circularity in a remanufacturing supply chain can take the form of closed-loop, open-loop or a combination of both. A closed-loop supply chain is established when a producer manages all remanufacturing activities internally. Conversely, if one or more remanufacturers handle all activities within the same sector, the supply chain transitions to open-loop circularity. In instances where the original producer only remanufactures a portion of the returns, both circularity archetypes coexist in the resulting supply chains (Zhang *et al.*, 2021).

Recycling SCM can be considered analogous to a closed-loop SCM, under the condition that all recycled materials are reintegrated back into the initial supply chain (A. Zhang *et al.*, 2023). Recycling likely possesses the lengthiest historical background out of all value recovery alternatives. The recycling process of widely available materials in municipal solid waste, such as paper, plastic, metals and glass, is regarded as the most preferred choice in terms of environmental and/or financial benefits (Cui and Sošić, 2019). Currently, the recycling of the material components in returned products is a more widely observed method of recovering value compared to the processes of refurbishing and remanufacturing (Chen *et al.*, 2015; Zhang *et al.*, 2021).

Reverse SCM can be described as the proficient and productive supervision of the sequence of tasks necessary for recovering a product from a consumer and then deciding whether to discard it or reclaim its value (Prahinski and Kocabasoglu, 2006). Reverse activities in supply chains consider inspections on gathered items; decisions are made regarding disassembly, reusing, recycling or disposing, based on the quality of the retrieved products (Abdulkader *et al.*, 2015). Reverse SCM sends end-of-use products and materials from downstream to upstream in a supply chain, regardless of open-loop or closed-loop circularity archetypes (A. Zhang *et al.*, 2023).

Industrial symbiosis involves bringing together industries that were previously separate to work together towards gaining a competitive edge through the sharing of materials, energy, water and by-products. Collaboration and the potential synergies that come from being close to one another are essential components of industrial symbiosis (Turken and Geda, 2020). Industrial symbiosis involves the reuse of wastes, by-products and intermediates among a network of companies, which are frequently situated together in an eco-industrial park, both within and outside the initial supply chain (Bansal and Mcknight, 2009; A. Zhang *et al.*, 2023).

In essence, CSCM represents a leading approach in GSCM and SCSM. It offers a well-defined route to implement sustainable growth within the supply chain, aiming for a zero-waste goal. It covers various aspects that enhance the circularity of the supply chain (Zhang *et al.*, 2021; A. Zhang *et al.*, 2023). This paves the way for the primary goal of the present study, which is to not only tackle the problem of supplier selection from the SCSM standpoint but also to concentrate on supplier selection from the CSCM perspective to maximise the advantages in terms of sustainability.

2.4 Reverse Logistics (RL) within the context of Circular Economy (CE):

RL refers to the efficient management of a series of activities needed to retrieve a product from a customer, aiming to either dispose of it or recover its value, as defined by Erol *et al.,* (2010). It offers businesses valuable insights to embrace sustainability-focused practices that can help them leverage the circularity of materials and effectively manage resources (Fernando et al., 2023). RL includes all the activities aimed at handling customer returns to suppliers, usually involving recycling, repairing, disposing or reusing items, all done at minimal cost (El Boudali *et al.,* 2022). RL is a complex process that requires specific focus to oversee it, encompassing additional skills that differ from those needed in conventional or traditional logistics (Mallick *et al.*, 2023). By implementing closed-loop systems, adopting clean production techniques, managing product life cycles and utilising RL, CE contributes positively to the environmental management of businesses (Haleem *et al.*, 2021).

The integration of CE with RL holds significance in creating both social and economic value (Guarnieri *et al*., 2020). Corporations currently prioritise RL in order to support the establishment and recycling of a flexible circular supply chain for waste reduction and beneficial influence on the overall business framework (Fernando *et al*., 2023). Hence, the CE has the potential to enhance SD through the utilisation of RL models associated with waste recycling, generation of value and fostering customer allegiance (Dev *et al*., 2020).

Finding suitable supply chain partners and ensuring that these partners possess the necessary skills and expertise to manage the RL processes constitute a significant challenge (Bakås *et al.*, 2022). According to Cricelli *et al.* (2021), collaboration with suppliers is regarded as a crucial facilitator in the management of RL. Chan *et al.*, (2020) developed a synchronised cycles supplier-manufacturer coordination model that integrates RL. The incorporation of RL in this model involves the supplier retrieving returned products from the buyers (manufacturers) and subsequently reprocessing them for resale. Their study revealed that the implementation of the synchronised cycles coordination model with RL leads to a decrease in overall system costs in contrast to the independent optimisation model that does not incorporate RL.

RL encompasses a variety of strategies, such as reutilisation, resale, recycling, appropriate disposal, remanufacturing, incineration, repackaging and managing product returns (Makaleng and Lambert, 2021). One of the critical components of RL pertains to the process of product return, encompassing defective items, maintenance, repairs, product refurbishment and surplus management *(*Bernon *et al*., 2018). The success of the RL process relies on the participation and collaboration of all supply chain members (Debacker *et al.*, 2020). Moreover, fostering vertical and horizontal partnerships among manufacturers, suppliers, distributors, customers, non-profit groups or research institutions enhances the effectiveness of reverse circular processes (Biancolin *et al*., 2023).

Producers frequently take on a leading role in funding initiatives and investments focused on promoting sustainable practices within the supply chain. Due to their main responsibility for creating and designing products that later undertake recycling or regeneration, producers are the main players in overseeing the flow of returns along the supply chain (Parsa *et al*., 2020). According to Fernando *et al.* (2023), product returns may result in a reduction in revenue for the organisation if the item is not correctly transferred from the customer or/and buying companies to the producer/supplier. Therefore, companies must integrate their logistical operations with RL protocols to improve their revenue opportunities. Additionally, efficient RL protocols for product returns are closely linked to the idea of a CE, leading to profitability improvements. Hence, organisations have the capability to enhance their CE strategies through the effective coordination of RL protocols with their suppliers, which is considered as the producers of the supplied items, in order to guarantee adequate handling of returned products.

Therefore, organisations possess the ability to improve their CE strategies by efficiently integrating RL protocols with their suppliers, who are recognised as the manufacturers of the supplied goods, to ensure proper management of returned products.

2.5 Supplier Selection Problem towards Sustainability and Circular Economy (CE):

2.5.1 Supplier Selection Process:

The process of selecting suppliers is widely regarded as a critical function within purchasing management, of significant importance and a crucial responsibility. Within the sphere of procurement management, the supplier selection process stands out as a key duty that holds considerable weight (Wetzstein *et al.*, 2016). It is well established that a substantial portion, specifically 60%, of manufacturing costs is directly influenced by the suppliers of raw materials, underscoring the indispensable role suppliers play in enabling organisations to operate efficiently (Arabsheybani *et al.*, 2018). Furthermore, the act of selecting suppliers may transcend mere operational considerations to become a strategic decision with enduring consequences on the overall performance of supply chains within organisations (Luthra *et al.*, 2017).

Currently, the process of supplier selection and evaluation has experienced a heightened level of complexity within the sustainability framework. This has led to an expansion in the range of criteria considered for selection, including a more intricate balancing act between sustainability factors (e.g. environmental and social aspects) and the conventional criteria, such as product cost, quality, delivery time and flexibility (Trapp and Sarkis, 2016; Khan *et al.*, 2018). As a result, a crucial challenge facing procurement managers lies in how to assess and choose the most effective suppliers that satisfy their sustainability needs (Amindoust *et al.*, 2012). Supplier selection and assessment within the realm of sustainability can further aid organisations in attaining supplementary advantages, such as improved financial outcomes, equitable treatment towards suppliers and customers, a promising corporate image, societal transformation, favorable interpersonal connections and cross-organisational knowledge acquisition (Baskaran *et al.*, 2012).

In the industrial supply chains, choosing sustainable suppliers has undoubtedly become one of the most important choices that can aid firms in achieving their sustainability goals (Grimm and Hofstetter, 2014). Thus, once the inputs (such as raw materials and parts/components) supplied from suppliers into production/manufacturing comply with the sustainability requirements and standards, the overall sustainability of the supply chains might potentially be achieved (Sarkis and Dhavale, 2015). Hence, the choice of sustainable suppliers is a crucial choice that impacts the overall sustainability performance of companies (Khan *et al.*, 2018).

In the era of CE, as elaborated earlier, there is a shift towards CSCM, which seeks to promote regenerative and restorative practices in order to achieve zero waste. Organisations are now emphasising not only sustainable supplier selection but also selecting suppliers who enhance circular practices (Govindan *et al.*, 2020; Kannan *et al.*, 2020; Alavi *et al.*, 2021; Ecer and Torkayesh, 2022; Liu *et al*., 2022).

2.5.2 Sustainable Supplier Selection (SSS):

The last decade has experienced a notable increase in worldwide consciousness and apprehension regarding sustainability. Consequently, this study examines earlier research on sustainable supplier selection from 2013 to the present, aiming to deliver a thorough summary of the most recent findings, trends, and effective strategies in sustainable supplier selection, which will assist in pinpointing gaps in the current literature. There are several types of models available for sustainable supplier selection process, and they are exceedingly important to the overall supplier selection process and have a remarkable impact on the selection results (Taherdoost and Brard, 2019).

Azadnia *et al.* (2013) proposed an integrated approach of FUZZY-Analytical Network Process (FANP) in order to solve the sustainable supplier selection problem. In their research, greenhouse effect, pollution and environmental protection were considered as environmental elements. Cost and service were categorised as economic elements, with risk and social reputation included in social sustainability. Moreover, Govindan *et al.*, (2013) focused on the environmental, social and economic criteria for supplier evaluation based on the triple bottom line concept. They conducted a qualitative performance assessment by employing fuzzy numbers to determine the criteria weights, followed by the introduction of fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) to establish the ranking of suppliers. A concern about their research was the use of a hypothetical illustrative example rather than a real-world application.

Ghadimi and Heavey (2014) gathered the most important criteria of sustainable supplier selection in the medical device industry and categorised them into three dimensions of sustainability, using an efficient Fuzzy Interference System (FIS). Additionally, Mani *et al.,* (2014) provided a methodology for selecting socially responsible suppliers, using Analytic Hierarchy Process (AHP) technique and social parameters. To choose the best sustainable suppliers, Azadi *et al.* (2015) created an integrated Data Envelopment Analysis (DEA) - Enhanced Russell measure (ERM) model in a fuzzy setting. In a different study, Orji and Wei (2015) introduced a unique modelling strategy that combines data on supplier behaviour in a fuzzy environment with a system dynamics simulation modelling technique to produce a decision support system that is more trustworthy and accountable. Furthermore, Lin *et al.* (2015) used the analytic network process (ANP) to solve a sustainable supplier selection problem at Taiwanese Electronics Company. Similar to this, Gold and Awasthi (2015) suggested a two-step F-AHP solution for the problem of selecting a sustainable global supplier that takes sustainability risks from sub-suppliers into account.

More work done by Sarkis and Dhavale (2015) recognised that one of the environmental concerns in selecting sustainable suppliers is the "use of environmental and pollution control technology", in which the sustainable supplier is expected to use appropriate greenhouse gases reduction technologies and install pollution control equipment as necessary in its operation. In addition, Su *et al.* (2016) proposed the a hierarchical grey DEMATEL method to identify and assess criteria and options in the context of SSCM when there is insufficient information. Luthra *et al.* (2017) proposed a framework to evaluate sustainable supplier selection by using an integrated AHP and VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), a multi-criteria optimisation and compromise solution approach, with 22 sustainable supplier selection criteria and three dimensions of criteria (economic, environmental and social). Using an integrated AHP-VIKOR approach as a solution methodology to assess the sustainable supplier selection decisions from a supply chain perspective, Luthra *et al.*, (2017) suggested an integrated framework for sustainable supplier selection and assessment in supply chains. They mentioned that further work is still needed for the sustainable supplier selection problems in developing countries' research area.

Fallahpour *et al.* (2017) developed a comprehensive list of sustainability criteria and sub-criteria and measured the importance and applicability of these criteria and sub-criteria through a questionnaire survey. They also used a new hybrid model by integrating fuzzy preference programming, with FUZZY-TOPSIS. They demonstrated that decision makers may identify the criteria that have the greatest impact on suppliers' sustainability performance by evaluating their importance and applicability for real-life contexts.

Song and Liu (2017) summarised the sustainable supplier selection criteria drawing the greatest attention in previous literature; they did a novel integrated method based on pairwise comparison method, DEMATEL, and rough set theory. Moreover, Vahidi *et al.*, (2018) proposed a novel bi-objective two-stage mixed possibilistic-stochastic programming model to address sustainable supplier selection and order allocation problem under operational and disruption risks.

Khan *et al.*, (2018) proposed a supplier sustainability performance evaluation framework based on an integrated model of fuzzy- Shannon Entropy to determine the sustainability criteria weights and FIS to prioritise suppliers. They noticed that more sustainable supplier selection studies still need more attention, particularly from emerging countries. Moreover, Kannan (2018) used fuzzy AHP-VIKOR approach for sustainable supplier selection that takes sustainability from sub-suppliers' risks into account. Moreover, Cheraghalipour and Farsad (2018) identified 18 sub-criteria for sustainable supplier selection in plastics industry. They used Best Worst Method (BWM) to find the global importance weight for each determined criteria, then used a Revised Multi-Choice Goal Programming (RMCGP) method to solve a proposed bi-objective mathematical model.

Furthermore, El Mariouli and Abouabdellah (2019) defined 28 criteria that are related to the sustainable supplier selection process using a new MCDM mathematical model. Memari *et al.* (2019) also presented an intuitionistic fuzzy TOPSIS method to select the right sustainable supplier that concerns nine criteria and thirty sub-criteria for an automotive spare parts manufacturer. Another study by Hendiani *et al.,* (2020) used a novel trapezoidal fuzzy BWM to develop a fuzzy sustainable supplier index, which was based on the aggregated weights and performances of sustainability triple bottom line criteria. Wu, Lin and Barnes (2021) proposed an integrated approach for sustainable supplier selection in the chemical industry, using Grey Relational Analysis (FGRA), Failure Mode and Effects Analysis (FMEA) and cloud computing-entropy weight method (EWM). An integrated BWM, fuzzy Shannon entropy and fuzzy MULTIMOORA model for sustainable supplier selection was put forth by Shang *et al.* (2022).

The existing models limit the consideration of "CE" as major dimension with its related criteria for supplier selection; nonetheless, it is frequently disregarded and typically categorised in the current models under the "environmental" sustainability dimension. Despite the interconnection and mutual support between the dimensions of "environmental sustainability" and "circular," they differ theoretically as previously mentioned in the introduction part. Consequently, considering circular criteria under the sustainability dimension may lead to confusion, affecting decision-makers' choices during comparisons (Echefaj *et al.*, 2022). This hinders organisations' ability to make well-informed decisions if they do not manage to differentiate between sustainable practices and circular practices and assess the two practices independently in order to support SDGs.

Several authors classified the supplier selection methods into different classifications (Asthana and Gupta, 2015; Zavadskas *et al.*, 2016; El Mariouli and Abouabdellah, 2019; Taherdoost and Brard, 2019). These classifications were Artificial Intelligence, Multi-Attribute Decision Making (Categorial Method), Mathematical Programming and Combined/Hybrid Approaches. The advantages and disadvantages of the classifications, as well as their related techniques, are summarised in **Table 2.4**.

Table 2.4 Classifications of sustainable supplier selection techniques

Sustainable Supplier Selection Approaches/Methods			
Classification	Approach/Method	Disadvantages	Advantages
Artificial Intelligence	- FIS	- The collection and processing of supplier data by experts take a lot of time. - Also, it demands specialised software and requires qualified personnel.	- Easy to be integrated with other methods. - Predicts new outcomes based on past data. - Gives precise results.
Multi-Attribute Decision Making (Categorial Method)	- AHP - ANP - DAMETAL - Fuzzy Set Theory - Bayesian	- Subjective methods.	- Simple method - Quick evaluation process - Low cost to implement.
Mathematical Programming	- DEA	- Difficulty in dealing with subjective criteria - Absence of optimal solution and difficulty analysing the result obtained from the method.	- Models the constraints and deal with an objective function to select the optimal supplier.
Combined/Hybrid Approaches	- Fuzzy and ANP (FANP) - AHP +QFD - Fuzzy _ AHP (FAHP) - Fuzzy + TOPSIS - Fuzzy+DEA - Bayesian framework + MCMC - Grey theory + DAMTEL - AHP + VIKOR - DAMETAL + rough set theory - fuzzy- Shannon Entropy and FIS - fuzzy AHP-VIKOR - BWM – RMCGP - Fuzzy-BWM - FGRA- FMEA- EWM. - BWM, fuzzy Shannon entropy, and fuzzy MULTIMOORA methods	- Computational complexity.	- Integrates important subjective and objective criteria into utility function value. Additionally, it can help decision-makers manage a variety of information, including preferences of stakeholders, connected or conflicting criteria, and uncertain environments.

Source: Asthana and Gupta (2015); Zavadskas *et al*. (2016); El Mariouli and Abouabdellah (2019); Taherdoost and Brard (2019).

It is noted that hybrid/combined approaches for sustainable supplier selections are the most popular approach among others. This aligns with the previous literature published by Zavadskas *et al.* (2016), as they mentioned in their study that hybrid approaches are gaining a higher recognition in sustainability issues due to their ability to effectively assist the decision makers in handling miscellaneous information.

2.5.3 Sustainable Circular Supplier Selection (SCSS):

As previously stated, in accordance with the principles of CE philosophy, which focus on restorative and regenerative practises to achieve zero waste, CSCM holds the potential to significantly enhance supply chain sustainability for both businesses and organisations. Hence, the sustainable circular Supplier selection (SCSS) highlighted environmental and social considerations within the domains of the CE and sustainable supplier selection (Liu *et al*., 2022).

The integration of CE principles into supply chains compels suppliers to furnish raw materials that are technically restorative, regenerative, and do not pose adverse impacts on the environment and economic advancements (Genovese *et al.*, 2017). Although studies on CE practises in various fields have been conducted in the past, the problem of selecting sustainable suppliers within a CE is relatively new. SCSS has only been the subject of a small number of research papers thus far.

The "circular" dimension was taken into account for the first time as a separate dimension in addition to other dimensions in a study conducted by **Govindan *et al.* (2020)**; they suggested a hybrid solution for strategic operational level supplier evaluation, selection and order distribution based on FUZZY-DEMATEL, FANP and mathematical programming. They considered only three main criteria: (1) Circular, (2) Quality and (3) On time delivery, together with 13 sub-criteria. Although they did a recognised approach in weighting criteria and selecting suppliers, only circular and traditional criteria were considered overlooking social criteria that could be examined in their future study. Furthermore, **Kannan *et al.* (2020)** combined the fuzzy BWM and the interval VIKOR technique to evaluate and prioritise sustainable suppliers in circular supply chains. The evaluation criteria were delineated into three distinct classifications: economic, social and circular considerations. Despite employing an appropriate evaluative methodology rooted in two effective techniques, the researchers formulated criteria exclusively pertaining to the economic and social dimensions, thereby overlooking any additional environmental criteria outside of those associated with CE principles. This affected the achievement of the full viewpoint of sustainability in the context of CE. Moreover, they did not consider the interdependency among the criteria within the weighting process, although it might improve the calculation results of the criteria weights. **Kusi-Sarpong *et al.* (2021)** conducted their study on SCSS for a textile company in Pakistan and created an integrated framework to rank sustainable circular suppliers. They graded the suppliers using the VIKOR approach after first extracting the criteria weights using the BWM method. Regarding the criteria of selecting suppliers, they categorised the criteria into four main categories with 17 sub-categories. The four main categories were Organisational, Regulatory and Institutional, Technological and Infrastructural, and Supply Chain collaboration. Although this study involved four main criteria, social criteria were again neglected.

Perçin (2022) proposed a group decision model based on an integrated Analytic hierarchy process (AHP) and Complex proportional assessment (COPRAS) methodology in an interval-valued intuitionistic fuzzy-sets (IVIFS) environment in order to deal with the uncertainty that influences decision makers' judgments in solving the circular supplier selection problem. They defined only the criteria created to the economic, social and circular dimensions, ignoring all other environmental considerations. However, their methods ignored the interdependency relation between the criteria, despite the fact that interactions among the different criteria were observed. The generalisation of their method was weak as only one sector was examined.

Ecer and Torkayesh (2022) proposed a Stratified Fuzzy Decision-Making Approach for Sustainable. They defined only the criteria created to the economic, social and circular dimensions. They revealed that the proposed approach's failure to handle the interdependency among the evaluation criteria was one of its main limitations. Nevertheless, considering the interdependence among the evaluation criteria may enhance the accuracy of the importance weighting (Govindan *et al.*, 2020).

As previously discussed, suppliers, being the original producers of the supplied items in the supply chains, play a crucial role in handling RL for product returns. It has been highlighted in current literature that effectively carrying out RL protocols with supply chain partners responsible for product returns is essential to ensure successful circular practices. Thus, it is necessary to consider this aspect when selecting and assessing suppliers, ensuring their willingness and ability to manage RL for facilitating product returns. Hence, the review on SCSS identified a gap wherein there was no criterion reflecting the supplier's capability to promote RL contractual agreements with manufacturers for undertaking RL activities associated with product returns. **Table 2.5** summarises the above-mentioned previous studies about the SCSS area.

Table 2.5 A Summary of the Previous Sustainable Circular Supplier Selection Studies:

Author	Evaluation method	Econo-mic	Enviro-nment	Social	Circular	RL Agreement	Measuring interdependency between criteria.	Industry
Perçin, (2022)	Integrated AHP and Complex proportional assessment (COPRAS) methodology in an Interval-valued intuitionistic fuzzy-sets (IVIFS)	√		√	√	X		Cement
Ecer and Torkayesh, (2022)	Stratified Fuzzy Decision-Making Approach	√		√	√	X		Textile
Kusi-Sarpong *et al.* (2021)	BWM And VIKOR			√		X	√	Textile
Kannan *et al.* (2020)	Fuzzy BWM and Interval VIKOR		√	√	√	X		Wire-and-cable industry
Govindan *et al.* (2020)	FUZZY-DEMATEL and FANP	√	√		√	X	√	Automotive timing belt manufacturer.

2.5.4 Sustainable Circular Supplier Selection (SCSS) Criteria:

To gain a comprehensive understanding of evaluating suppliers' performance towards sustainable and CE perspectives, selection criteria are grouped into four primary dimensions, as indicated in **Table 2.6**, by synthesising the current literature. These dimensions are Economic, Environmental, Social and Circular.

Table 2.6. Sustainable Circular Supplier Selection (SCSS) Criteria

ECONOMIC	
Cost	The factors that display every expense and the price of material purchased.
	(Govindan *et al.*, 2013; Azadnia et al., 2013; Ghadimi and Heavey, 2014; Gold and Awasthi, 2015; Sarkis and Dhavale, 2015; Azadi *et al.*, 2015; Fallahpour *et al.*, 2017; Jauhar and Pant, 2017; Luthra *et al.*, 2017; Song, Xu and Liu, 2017; Vahidi *et al.*, 2018; Awasthi *et al.*, 2018; Cheraghalipour and Farsad, 2018; Alikhani *et al.*, 2019; Memari et al., 2019; El Mariouli and Abouabdellah, 2019)
Quality	The level of quality of the materials provided.
	(Govindan *et al.*, 2013; zadnia *et al.*, 2013; Ghadimi and Heavey, 2014; Gold and Awasthi, 2015; Lin *et al.*, 2015; Orji and Wei, 2015; Sarkis and Dhavale, 2015; Jauhar and Pant, 2017; Luthra *et al.*, 2017; Song *et al.*, 2017; Fallahpour *et al.*, 2017; Awasthi *et al.*, 2018; Cheraghalipour and Farsad, 2018; Alikhani *et al.*, 2019; Memari *et al.*, 2019; El Mariouli and Abouabdellah, 2019)
Delivery time and services	The supplier's efforts in providing the customer with the material and resolving any issues that may arise.
	(Govindan *et al.*, 2013; Azadnia *et al.*, 2013; Ghadimi and Heavey, 2014; Gold and Awasthi, 2015; Sarkis and Dhavale, 2015; Jauhar and Pant, 2017; Luthra *et al.*, 2017; Song, Xu and Liu, 2017; Fallahpour *et al.*, 2017; Awasthi *et al.*, 2018; Vahidi *et al.*, 2018; Cheraghalipour and Farsad, 2018; El Mariouli and Abouabdellah, 2019)
Flexibility	The level of flexibility of supplier in supplying material and price of material.
	(Govindan, Khodaverdi and Jafarian, 2013; Ghadimi and Heavey, 2014; Gold and Awasthi, 2015; Fallahpour *et al.*, 2017; Luthra *et al.*, 2017; Awasthi, Govindan and Gold, 2018; El Mariouli and Abouabdellah, 2019)
Financial Stability	The financial status of the supplier that analyzed according to the information about the annual turn-over of the supplier and their financial structure upon the past history.
	(Alidrisi, 2014; Suraraksa and Shin, 2019)
ENVIRONMENTAL	
Environmental Management System (ISO 14001)	Eforts of supplier in environmental management and the certification related environmental management systems.
	(Govindan *et al.*, 2013; Orji and Wei, 2015; Sarkis and Dhavale, 2015; Su *et al.*, 2016; Fallahpour *et al.*, 2017; Luthra *et al.*, 2017; Song *et al.*, 2017; Vahidi *et al.*, 2018; Cheraghalipour and Farsad, 2018; Alikhani *et al.*, 2019)
Green Products/Design	How much of the supplier's items are eco-friendly.
	(Amindoust et al., 2012; Orji and Wei, 2015; Su et al., 2016; Fallahpour et al., 2017; Luthra et al., 2017; Alikhani, Torabi and Altay, 2019)
Green transportation	Minimising the environmental impact of transporting the required shipment.
	(Fallahpour et al., 2017)
Life cycle cost management	Incorporating life cycle cost management into GHG emissions mitigation.
	(Hsu *et al.*, 2013)
Involvement in initiatives for carbon management	Incorporating low-carbon principle into product design.
	(Hsu *et al.*, 2013)
Carbon accounting and inventory	Using different standards, like ISO 14064-Parts I and II, to keep track of these GHG emissions and pay for them.
	(Hsu *et al.*, 2013)
Green technology	How technology is used to make green products.
	(Fallahpour *et al.*, 2017; Vahidi *et al.*, 2018)
GHG emissions/effect	Gases and substances emitted from the manufacture and transport the products
	(Gold, 2018; Cheraghalipour and Farsad, 2018; El Mariouli and Abouabdellah, 2019)
Carbon Disclosure Report	Reports regarding GHG emissions.
	(Hsu *et al.*, 2013; Luthra *et al.*, 2017; Yu, Yang and Chang, 2018)
SOCIAL	
Training related Carbon Management	Employee awareness of carbon management practices, relevant education and training need to be launched to promote environmental consciousness.
	(Hsu *et al.*, 2013)
Workers' rights	The supplier's respect of its worker's rights; employment insurance, standard working hours, employments compensations.

	(Bai and Sarkis, 2010; Amindoust et al., 2012; Govindan, Khodaverdi and Jafarian, 2013; Sarkis and Dhavale, 2015; Gold and Awasthi, 2015; Song, Xu and Liu, 2017; Fallahpour et al., 2017; Luthra et al., 2017; Vahidi, Torabi and Ramezankhani, 2018; Awasthi, Govindan and Gold, 2018; Cheraghalipour and Farsad, 2018; Alikhani, Torabi and Altay, 2019; Memari et al., 2019; El Mariouli and Abouabdellah, 2019)
Occupational health & safety systems	Supplier's efforts to make sure employees are healthy and safe at work, such as giving medical insurance, training for safety at work, and the right tools.
	(Bai and Sarkis, 2010; Amindoust *et al.*, 2012; Dai and Blackhurst, 2012; Azadnia *et al.*, 2013; Govindan *et al.*, 2013; Mani *et al.*, 2014; Ghadimi and Heavey, 2014; Orji and Wei, 2015; Gold and Awasthi, 2015; Luthra *et al.*, 2017; Song, Xu and Liu, 2017; Fallahpour *et al.*, 2017; Vahidi *et al.*, 2018; Cheraghalipour and Farsad, 2018; Memari *et al.*, 2019; El Mariouli and Abouabdellah, 2019)
Society's rights / social responsibilities	Suppliers' competency in improving sustainability initiatives, such as social responsibilities, cleaner environmental/production.
	(Büyüközkan and Çifçi, 2011; Gold and Awasthi, 2015; Sarkis and Dhavale, 2015; Luthra *et al.*, 2017; Cheraghalipour and Farsad, 2018; Vahidi *et al*., 2018; Alikhani *et al*., 2019)
Information Disclosure	Providing details on the materials used, carbon emissions, and toxins emitted during production to the supplier's customer and other interested parties.
	(Amindoust *et al.*, 2012; Azadnia *et al.*, 2013; Orji and Wei, 2015; Luthra *et al.*, 2017; Yu *et al.*, 2019)
Supportive Activities	Supplier's respect to supportive activities at work; discriminations, growth at work, attention to religious and cultural issues at work**.**
	(Fallahpour *et al*., 2017; Bai and Sarkis, 2010;Govindan *et al*., 2013;Song *et al*., 2017)
CIRCULAR	
Eco-friendly raw materials	Making use of recyclable raw resources to make products (Govindan *et al.*, 2020).
	(Gupta and Barua, 2017; Govindan *et al.*, 2020; Kannan *et al.*, 2020a)
Respecting environmental standards and regulations in the process of recycling	Using environmental standards during the recycling process (Govindan *et al.*, 2020).
	(Rashidi and Saen, 2018; Govindan *et al.*, 2020; Kannan *et al.*, 2020a)
Air pollution resulting from recycling process	Take into account reducing air pollution during recycling (Govindan *et al.*, 2020).
	(Rashidi and Saen, 2018; Santos *et al.*, 2019; Govindan *et al.*, 2020; Kannan *et al.*, 2020a)
Clean technology for recycling	Employing proper and green technology for recycling the returned products (Govindan *et al.*, 2020).
	(Govindan *et al.*, 2020; Kannan *et al.*, 2020a)
Eco-friendly packaging	Using appropriate and environmentally friendly technology to recycle the returned goods (Govindan *et al.*, 2020).
	(Govindan *et al.*, 2020; Kannan *et al.*, 2020a)

2.6 Literature review findings and knowledge gap:

Our review findings suggest that it is essential to incorporate sustainable and circular practices in the supplier selection process. This reinforces the fact that SCSS is gaining more attention in the age of CE and sustainability. Hence, a more thorough supplier selection and evaluation approach must take into account economic environment, social and circular factors, which are often overlooked in the traditional approach. Numerous studies were found addressing the topic of choosing sustainable suppliers by adopting different MCDM methods, including, but not limited to, AHP, VIKOR, BWM and TOPSIS. The effectiveness and efficiency of these methods have been validated by different researchers in the context of supplier assessment. On the contrary, the supplier selection problem under sustainability and CE has only been addressed in a few numbers of articles, although it is becoming an important research area as mentioned before. As a result, there are very limited studies addressing SCSS up until this point. Therefore, a number of knowledge gaps are described below:

- Few studies have focused on the SCSS problem, but there is insufficient literature on a thorough SCSS model incorporating economic, environmental, social and circular aspects for evaluating supplier sustainability and CE performance.
- Literature has demonstrated that integrating CE into supply chain practices can improve businesses' environmental and economic management by operating closed-loop systems, product life cycle management, and RL. Furthermore, effective collaboration among the supply chain partners of buyer firms, including suppliers, is recognized as a key enabler in enhancing sustainability and CE initiatives. However, existing literature has not given adequate consideration to promoting collaborations among participants in circular supply chains to boost sustainability performance. As a result, this study aims to address this gap by introducing a criterion for assessing suppliers' performance, known as the "Reverse Logistics Agreement," designed to promote collaboration between purchasing organizations and their suppliers in the implementation of CE principles. It aims to assess suppliers' performance based on their expertise and capabilities for managing RL operations with the buying organisations for handling returned products, to guarantee product circularity. Consequently, this criterion could improve the overall SCSS process.
- SCSS is a particular instance of a MCDM problem, in which providers must be evaluated according to the weights of the criteria. The weights of the criteria must be carefully chosen in MCDM problems since they have a direct impact on the ranking order of the alternatives. Hence, considering the interdependency relation between the supplier selection criteria may lead to more accurate importance weights. Nevertheless, it has been demonstrated that only two studies, namely Govindan *et al.*, (2020) and Kusi-Sarpong *et al.*, (2021) have conducted SCSS models that took into account the interdependency among the criteria. However, these two studies had some limitations. For instance, Govindan *et al.*, (2020) proposed an integrated fuzzy Analytic Network Process (ANP) and fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach for circular supplier selection. This research endeavour was the pioneering effort to incorporate circularity, quality, and on-time delivery as selecting supplier criteria. The study effectively showcased the advantages of the suggested approach through its application to an Iranian automobile timing belt manufacturing company. However,

the study exhibits certain limitations. It did not incorporate the social dimension and its corresponding criteria in the proposed approach. Furthermore, the lack of any further environmental criterion unrelated to circularity was observed. While Kusi-Sarpong et al. (2021) introduced a hybrid approach that combines the use of the Best Worst Method (BWM) and VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) to assess the sustainability of suppliers in the context of the Circular Supply Chain (CSC). They employed the BWM (Best Worst Method) technique to determine the weights of the criteria and then utilised the VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) method to rank the suppliers. Afterward, they proceeded to implement their proposed approach within a textile manufacturing company situated in Pakistan. Despite proposing a comprehensive evaluation approach utilising two efficient methodologies, there are two notable shortcomings in their approach. The absence of the use of the uncertainty concept in their approach poses challenges for experts in conducting paired comparisons questionnaires and assigning scores to suppliers. These omissions diminish the accuracy of the proposed approach. Moreover, they established their proposed approach based on four main categories: Organisational, Regulatory and Institutional, Technological and Infrastructural, and Supply Chain Collaboration. Under these main criteria, they included only some economic, environmental, and circular sub-criteria, but they failed to incorporate any social criterion into their proposed approach. Hence, it has noted a gap in the literature in the development of a SCSS model that incorporates economic, environmental, social, and circular dimensions along with their sub-criteria. These studies have also failed to utilise any MCDM approach that accounts for the interdependency relationship between the criteria while incorporating the concept of uncertainty.

- By assessing the importance and applicability of supplier selection criteria, decision-makers can gain insights into the most impactful criteria on suppliers' sustainability performance (Fallahpour *et al.*, 2017). Nonetheless, a gap has been identified in the assessment of creating a comprehensive set of criteria within the realms of sustainability and CE, along with evaluating the importance and applicability of these criteria. This evaluation can prove valuable for decision-makers aiming to enhance their sustainable circular supplier selection process.
- According to the few studies that addressed the SCSS problem, they were performed based on a single industrial sector. Therefore, it may be difficult to generalise the methods and criteria

used by them. As a result, it can be said that there is a lack for proposing SCSS model that could be generalise for different sectors.

As a result, this study aims to close the identified knowledge gap by developing a sustainable circular supplier selection (SCSS) model for decision makers using the FUZZY-DEMATEL technique to measure the interdependency between criteria, including new criteria, which is “Reverse Logistics Agreement”. This model does not only help them define and measure the suitable selection criteria but also identify the best possible suppliers in the contexts of sustainability and circularity. By evaluating and ranking the proposed criteria of the model, this study principally helps decision makers to differentiate among different criteria examining both sustainability and CE perspectives. **Table 2.7** illustrates the way in which the study's aim, which involves introducing the SCSS Model, fulfils the current knowledge gap.

Table 2.7. Filling knowledge gap by proposing Sustainable Circular Supplier Selection (SCSS) Model:

Gap	How will the proposed SCSS Model fill it?
There is an absence in previous literature of proposing supplier selection model that integrates sustainability and circularity dimensions, which are economic, environment, social and circular.	Proposing, for the first time, a SCSS Model including four dimensions: economic, environment, social and circular.
There is an absence in previous literature of criteria that evaluate the suppliers’ performance based on whether they guarantee their ability to arrange the RL activities with the manufacturing firms (buyers) to for managing return purchased products when needed to achieve circularity of the residue product.	Proposing a SCSS Model, including (Reverse Logistics Agreement) criterion under the circular dimension, for the first time, to evaluate to what extent are the suppliers able to guarantee that they will manage the reverse logistics activities between the manufacturing firms to ensure facilitating the return process. This criterion will be conducted for the first time in literature.
There is an absence in literature of proposing a SCSS based on economic, environment, social and circular dimensions that consider interdependency among the criteria.	Proposing a SCSS Model based on economic, environment, social and circular dimensions using MCDM technique called FUZZY-DEMATEL, for the first time, to consider the interdependency relation among the proposed criteria.
There is a lack of measuring the importance and applicability in real-life context of a comprehensive list of sustainable circular supplier selection criteria.	Measuring the importance and applicability of the proposed criteria using questionnaire-based survey before including them in the SCSS Model.
There is an absence of proposing SCSS model that could be generalised for different sectors.	Proposing a SCSS Model using FUZZY-DEMATEL technique based on different sectors, for the first time.

2.7 Chapter Conclusion:

This chapter set the research context, reviewed SSCM, CE concept and its importance for integration to SSCM and reviewed sustainable supplier selection and circular supplier selection problems. The literature confirmed that it is crucial for organisations to select their suppliers according to sustainability and circularity contexts to improve their overall supply chain management. However, despite the studies that addressed sustainable circular supplier selection model, there is still a gap in addressing a supplier selection model based on the three pillars of sustainability (economic, environment and social) and the circular dimension. Moreover, it has been shown that there is an absence in previous literature for criteria that evaluate the suppliers' performance based on whether they guarantee their ability to arrange the RL activities with the manufacturing firms (buyers) or to manage return purchased products when needed to achieve circularity of the residue product. Moreover, literature showed that there is a suggestion for a SCSS based on economic, environment, social and circular dimensions that consider the interdependency among the criteria and proposing SCSS model that could be generalised for different sectors. The chapter highlighted the approaches used for supplier selection, and it was found that combining/hybrid approaches are most useful.

Lastly, it presents how the study aim, which is proposing a SCSS Model, based on the three pillars of sustainability (economic, environment and social) and the circular dimension will fill the gap of knowledge found in literature. The research methodology will be discussed in the next chapter.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Introduction

This section of the dissertation outlines the research strategy and rationale in order to explain each of the steps performed together with the associated justifications (Jackson, 2013). Therefore, this chapter will present and discuss the research methodology adopted for this study in order to develop the Sustainable Circular Supplier Selection Model (SCSS Model), which can bridge the knowledge gap identified in Chapter 2.

Since this study is related to business and management science, the researcher adopted a research model developed by Saunders *et al.*, 2019, also known as "research onion”. The metaphor of the research onion, as shown in **Figure 3.1**, is used to illustrate the layers of essential elements in creating a suitable and efficient research design. The research philosophy, approach, methodological choices, strategy and techniques chosen to address the research aim and objectives of this study will be discussed and justified in the following sections by going through each major layer of this onion.

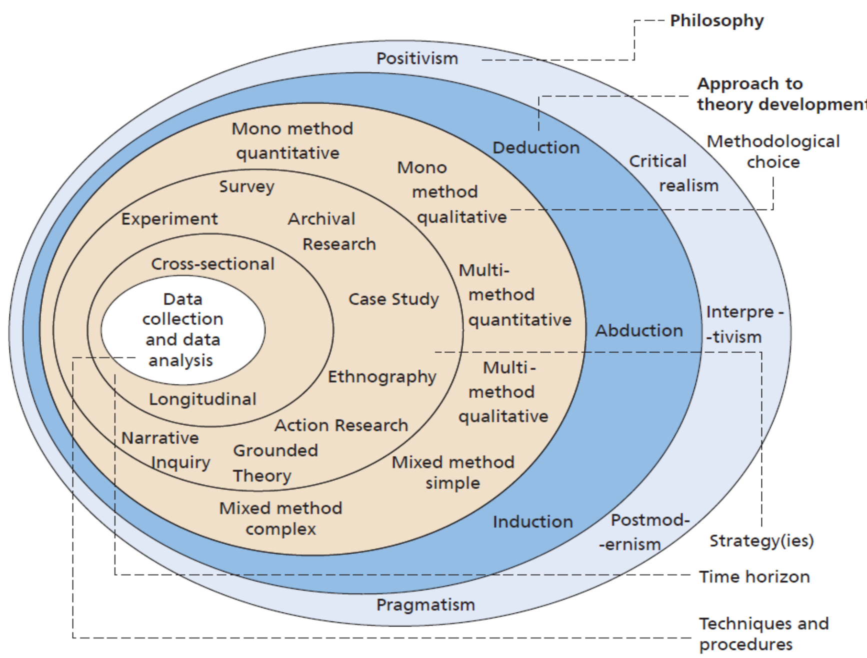


Figure 3.1 The research onion

Source: (Saunders *et al.*, 2019)

3.2 Research Philosophy

In order to clarify alternative tactics and methodologies for a particular research project and ascertain which is more likely to be successful, it is extremely useful to understand the philosophical positioning of the research. According to Saunders *et al.*, (2019), a set of presumptions and attitudes about the advancement of knowledge comprises research philosophy. These assumptions will underlie the research strategy and research methods chosen (Kuang and Sumara, 2021). In management research, there are five main research philosophies: *positivism, critical realism, interpretivism, postmodernism and pragmatism* (Saunders *et al.*, 2019). Before discussing such research philosophies, distinguishing between their physiological assumptions is necessary. This would be achieved by taking into account the variations in the physiological assumptions frequently stated by academics working within each philosophy. These three assumptions of philosophy are *ontology, epistemology and axiology*.

3.2.1 Research Philosophical Assumptions:

As mentioned before, there are three research philosophical assumptions in management research, which are shown in **Table 3.1** .

Table 3.1 A comparison of three research philosophical assumptions:

Ontological assumptions	***Epistemological assumptions***	***Axiological assumptions***
Nature of Reality	Nature of Knowledge	Role of Values
- The concepts that researchers hold regarding the functioning of the world and the nature of reality. - The ontological convictions of researchers shape their areas of study, influence their perspectives and methodologies, and dictate their focal points and analytical approaches.	- How researchers know what they say they know, what information is real, true, and acceptable, and how they might share this knowledge with other people. - The epistemological assumptions' researchers determine what kind of information they can add to the world as a result of their work.	- The influence of morals and ethics on the conduct of research. - Reflecting on how researchers, navigate their personal principles alongside the values of the individuals they examine.

Source: Saunders et al., (2019)

3.2.2 Five Management Philosophies:

As mentioned before, there are five research philosophies in management research which are shown in **Table 3.2**:

Table 3.2 A comparison of five study philosophies in business and management research:

Ontology	***Epistemology***	***Axiology***	***Typical methods***
	Positivism		
External, real, independent (This is called universalism) Ordered (granular things)	How does science work? Facts that can be seen and measured. Law-like generalisations Numbers Contribution of causal explanation and forecast	Research is conducted in an unbiased manner, with the researcher remaining detached from the data and preserving an objective viewpoint.	Usually, it's based on deduction, has a lot of organisation, uses big samples, and measures. Usually, quantitative methods are used to analyse data, but all kinds of data can be looked at.
	Critical realism		
Layered (the empirical, the real and the true). External, independent. Intransient Objective structures. Causal systems.	Epistemological relativism. Knowledge that is rooted in history changes over time. Facts are made up by people. Historical explanation of what caused what as a contribution.	Value-laden study. A researcher admits that their worldview, cultural background, and education can affect their results. The researcher tries to reduce bias and mistakes as much as possible.	Backward-looking, in-depth historical study of structures that already existed and new forms of agency. There are a variety of methods and kinds of data (qualitative or quantitative) to fit the topic.
	Interpretivism		
Complex and full. Through tradition and language, society is made. Having more than one meaning, perception, or reality Flux of processes, events, practices.	Theories and ideas are too basic. Pay attention to tales, stories and how people see and understand things. As a contribution, new understandings and worldviews are important.	Value-driven study. Researchers are a part of what is being looked into subjective. Researchers' interpretations are the key to making an addition. Researchers are self-aware.	Most of the time, inductive. Small amounts, thorough research. Qualitative ways of analysis, but a lot of different kinds of data can be understood.
	Postmodernism		
Noun Complex and full.	Ideologies decide what counts as "truth" and	Value-constituted Research.	Most of the time, deconstructive, which means reading books

Power relationships make up the social world. Some meanings, interpretations, and truths are pushed aside and drowned out by those of others. Change of events.	"knowledge" and what does not. Focus on absences, silences, meanings, interpretations, and opinions that have been pushed down or silenced. As a contribution, showing how power works and challenging the most popular ideas	Power relations are a part of both the researcher and the study. At the expense of others, some study stories are shut down and silenced. Researchers are very self-reflective. As a contribution, showing how power works and challenging the most popular ideas	and real life against each other. Deeper looks into strange things, silences, and gaps. Different kinds of data, and usually qualitative ways to analyse them
Pragmatism			
Complex, full, outside "Reality" is how thoughts play out in the real world. Changes in methods, experiences, and ways of doing things	The meaning of information in certain situations. Theories and knowledge are "true" if they help people do things well. Pay attention to situations, how things are done, and why they matter. As a contribution, problem-solving and planning for the future	Value-driven research Researchers' doubts and beliefs led to and kept up their study.	The research problem and research question follow. Multiple, mixed, qualitative, and quantitative methods, as well as action research. Emphasis on useful solutions and results

Source: Saunders et al. (2019)

– *POSITIVISM PHILOSPHY*

Positivism is a natural scientist's philosophical perspective that calls for using observed social reality to generate generalisations that resemble laws (Saunders *et al.,* 2019). Positivism holds fast to the idea that any single piece of "genuine" knowledge gained by perception (the faculties), including measurement, is reliable. Because positivism restricts the researcher to merely collecting data and impartially interpreting it, research findings are frequently observable and quantifiable (Dudovskiy, 2022). According to Saunders *et al.,* (2019), positivist philosophy as **Ontological** consideration, organisations and other social things are real to the researcher in the same way that physical objects and natural phenomena are real. As part of objectivism **epistemology**, researchers concentrate on observable and quantifiable facts and employ causal linkages to gather data and form generalisations that resemble laws made by scientists. According to **axiology**, the researcher must keep a distance and remain impartial to the data in order to prevent influencing the research results by using a procedure that is well-organised and highly structured, such as sampling, measurement, questionnaires and focus group discussions. This form of philosophy is often deductive since the researcher must use quantitative observations that enable statistical analysis.

– ***CRITICAL REALISM PHILOSPHY***

Critical realism is a philosophical branch that delineates a distinction between the ontological realm of the 'real' and the epistemic realm of the 'observable' (Zhang, 2023) . Reality is the most significant philosophical consideration for critical realists, and an organised, multi-layered ontology is essential (Fleetwood, 2005). According to Bhaskar and Danermark (2006), **ontologically**, critical realism embodies a dual characteristic of heightened inclusiveness. It exhibits a high level of inclusivity in terms of potentially relevant causal levels of existence, or, conversely, it maintains a minimal ontological restrictiveness, thereby permitting the specific determinations and their interrelations to be ascertained empirically on a case-by-case basis. Furthermore, it demonstrates extensive inclusivity by being able to integrate the perspectives of alternative meta-theoretical stances while evading their associated limitations. **Epistemologically**, critical realism provides a clearer indication compared to other stances regarding the appropriate orientation and framework for explanatory investigations, which progress from observable phenomena to the underlying mechanisms responsible for their emergence, within their intricate mutual determination. Simultaneously, predominantly due to its precise understanding of the dynamics of the scientific progression, it manages to circumvent the biases present in other stances that tend to emphasise a single aspect (such as experience or interpretation) of the entire research endeavour at the expense of others. Finally, **methodologically**, critical realism transcends both reductionist approaches and straightforward non- or anti-reductionist viewpoints by embracing ontological pluralism and advancing a constructive notion of the subject matter of disability research as a necessarily layered system, denoting a structure that fundamentally corresponds to multiple levels of existence.

– ***INTERPRETIVISM PHILOSPHY***

Similar to critical realism, interpretivism emerged as a subjectivist critique of positivism. Anti-positivism is another name for the research philosophy known as interpretationism, which views positivism as antithesis. Such a type may result in a skewed perception of social reality. The goal of adopting interpretivism is for scholars to create fresh interpretations of social situations and worlds. When conducting business and management research, researchers consider organisations from the perspectives of various groups. Interpretivism philosophy as **Ontological** consideration, it focuses on complexity, richness, multiple interpretations and meaning making; thus, it is considered as explicitly subjectivist. **Epistemologically**, the researcher uses naive theories and concepts and focuses on narratives, stories, perceptions and interpretations to develop new understandings and worldviews as contribution. This has the **axiological** implication that interpretivists acknowledge the critical significance that their interpretation of study materials and data, and consequently their own values and views, play in the research process. The **methodology** underlines qualitative analysis over quantitative analysis, which is typically inductive. Moreover, the researcher uses small samples and in-depth analysis, but a range of data can be interpreted.

- ***POSTMODERNISM PHILOSPHY***

From a philosophical standpoint, postmodernism symbolises the dissolution of the concept of certainty and a certain amount of upheaval that results from linking systems of universal temperament (Farhangpour and Abdolsalami, 2016). Postmodernism acknowledges the foundational **ontological** principle of relativism. Concerning **epistemology**, it asserts that the definition of "truth" and "knowledge" is dictated by dominant ideologies that highlight voids, unspoken aspects and marginalised understandings, expressions and significance. In order to make some research narratives repressed and silenced at the expense of others, as well as radically reflexive, it is important to expose power relations and question prevalent viewpoints as contributions and axiological assumptions. In this case, the **methodology** is usually deconstructive. It involves reading texts and realities against each other, doing in-depth investigations of oddities, silences and absences and using different kinds of data. In general, it is typically qualitative methods of analysis.

– ***PRAGMATISM PHILOSPHY***

Pragmatist research philosophy considers dealing with the "facts". Pragmatic philosophy, epistemology and axiology are all about making practice better. Pragmatists use many different types of study **methods** because each of their research topics is different. If the researchers are getting tired of the battle of **ontological, epistemological and axiological** assumptions among the different philosophies and would rather do research that will make a difference in organisational practice, they should shine a light on the philosophy of pragmatism. The idea behind pragmatism is that researchers should use the way that works best for the problem they are trying to solve. Also, there are different ways to do it, like mixed, multiple, qualitative, quantitative and action research.

3.2.3 Philosophical Assumptions of this Study:

The researcher of this study concluded that the PRAGMATISM research philosophy is the most appropriate philosophical stance for the study based on the discussion of the five key business and management philosophies.

This study aims to develop a model with suitable supplier selection criteria in the context of sustainable development and circular economy in addition to identifying the interdependency relationship between such criteria. Through identifying these criteria and their relationships, the model will help practitioners to meet the goals of sustainability and circularity. This is definitely aligned with pragmatism, as according to its epistemological assumption, pragmatism is concentrating on applied and practical research (Saunders *et al.*, 2019) in which pragmatism philosophy is mostly relevant to the supplier selection research as discussed in Ahmed and Alam (2019).

Regarding the axiological assumption, since that this research presented mixed method approach (qualitative and quantitative approaches), this reflects the pragmatism philosophy according to (Saunders *et al.,* 2019). Moreover, this aligned with Saunders *et al.,* (2019) and Bougie and Uma (2020) viewpoints that the ontological assumption of pragmatism depends on various views to be chosen to answer a research question in the greatest way.

Finally, the researcher of this study believes it is essential to combine qualitative methods (Semi-structured interviews) and quantitative methods (Questionnaire) to analyse the collected data to find solution for the research problem. This confirms Saunders *et al.,* (2019) that the pragmatist's belief that it is completely possible to work with diverse types of methods and knowledge is only confirmed if a research problem does not clearly suggest that one particular type of knowledge or approach should be embraced.

3.3 Research Approach

According to Saunders *at al.* (2019)**,** choosing the type of research approach is very important because of two reasons. First, it helps the researcher make a more informed choice regarding his/her study design, which encompasses more than just the methods used to gather data and analyse them. It is the general structure of a piece of research that involves concerns about the types of evidence that are gathered from where they are sourced, and how they are processed to offer useful responses to the researcher's initial research question. Second, it will assist the researchers in considering research techniques and methodological decisions that will benefit them and, more importantly, identify those that will not.

3.3.1 Research Approach Types:

According to Saunders *et al.,* (2019), there are three different research procedures that can be utilised for business-related research: deductive, inductive and abductive. These three methodologies are explained below.

- ***Deductive Research:*** It is used for theory testing. This approach tends to create a rigorous methodology that forbids alternate explanations for what's happening. Traditionally, researchers are more likely to work with quantitative data with deductive approach.

  Since the deductive method emphasises structure, quantification, generalisability and testable hypothesis, the positivist research philosophy is most likely to support it.
- ***Inductive Research***: It is used for theory building. This approach looks at specific facts and comes to general conclusions. It works in the manner that is opposite to deductive research. Therefore, the inductive researcher begins with the specifics and then the generals. The setting in which such events take place is likely to be of particular relevance to research that uses an inductive approach to thinking. Researchers who take this method are more likely to work with qualitative data and a variety of data collection procedures in order to develop distinct views on occurrences. As a result, interpretivist philosophy is most likely to have an impact on the inductive method due to its connection to the humanities and emphasis on the importance of personal interpretations.

- ***Abductive Research:*** Rather than moving from theory to data (as in deduction) or from data to theory (as in induction), an abductive technique swings back and forth, effectively merging deduction and induction.
- Abductive methods are in line with the study of numerous business and management scholars. The versatility of the abductive approach allows researchers from a range of research ideologies to apply it. In fact, some would argue that since pure deduction or pure induction are so challenging (or even impossible) to accomplish, the majority of management researchers really use at least a tiny bit of abduction.

3.3.2 Research Approach of this Study:

This investigation aligns with abductive reasoning within the three research approach categories mentioned previously to accomplish the study's goals and objectives. The initial phase of this research involves examining existing literature to establish selection criteria for suppliers in sustainable and CE contexts. Subsequently, the researcher revised the list of criteria through qualitative data analysis and conducting semi-structured interviews with experts in the supply chain management field. Afterward, a survey was distributed to a specific group of professionals to assess the importance and applicability of these criteria in real-world scenarios using quantitative data analysis. Furthermore, a second survey was conducted to evaluate the interdependence among the identified criteria in order to recognise causal relationships using FUZZY-DEMATEL methodologies. Towards the end of the study, the researcher developed and implemented a SCSS Model in multiple case companies through action research in two international organisations and incorporated their feedback as reliable testing employing both quantitative and qualitative data analysis. This SCSS Model is defined as a “Modification of Theory” (Seuring *et al.*, 2021). However, this matches the theory of Abductive approach as stated in Saunders *et al.,* (2019) *“Theory generation or modification, incorporating existing theory where appropriate, to build new theory or* ***modify existing theory****”*. This enables the researcher to contribute both theoretically and empirically/practically. As a result, this study supports the concept of abductive reasoning because it first relied on expert interviews to gather their ideas and then integrated them into the development of the proposed SCSS Model before testing its implementation it in actual practice. This also confirms with the view of Lorino (2018) that most organisations and management researchers have primarily used the abductive approach in their studies.

3.4 Research Methodology

In order to achieve the research objectives and answer the research questions, the researcher followed the methodology for the research process shown in "**Figure 1.1. Research methodology of the research process"** in Chapter 1 of the study.

Any research must depend on one of three methodologies: qualitative, quantitative or mixed methods. One way to distinguish between quantitative research (numbers) and qualitative research (words, photographs, video clips and other similar material) is to make a distinction between numerical data (numbers) and nonnumeric data. In this sense, the term "Quantitative" is widely used to refer to any technique for obtaining or analysing data that generates or uses numerical data, such as a questionnaire or graphing. On the other hand, the term "Qualitative" is widely used as a synonym for any data collection or analysis technique that generates or makes use of non-numerical data. The data analysis techniques are categorised based on Saunder's research onion, as illustrated at the outset of the chapter. These categories include Monomethod Quantitative, Monomethod Qualitative, Multimethod Quantitative, Multimethod Qualitative, Mixed Method Simple and Mixed Method Complex. According to Saunders et al., (2019) many business and management study designs are likely to integrate quantitative and qualitative methodologies. Hence, in this study, the researcher decided to employ a Mixed Method (simple) strategy due to its relevance to the business and management domains, integrating both quantitative and qualitative methodologies. Creswell (2003) and Viale *et al.,* (2022) advised using mixed method to enhance understanding of the research problem, particularly when the researcher's knowledge is established on Pragmatism philosophy, which is similar to the philosophy of this study. According to Ahmed and Ammar (2019), research that is related to supplier selection can benefit more from the mixed method. Table **3.3** lists the main procedures followed in this study for achieving the research goals. Hence, by applying quantitative methodologies and qualitative interpretation of the empirical data in this study, the researcher will be able to triangulate the findings and boost confidence in the **SCSS Model**, which is the main aim of the study.

Table 3.3 Summary of Methodological Choice of the Study:

Steps of Data Collection for this Study		*Mixed Method*	
		Qualitative Method	*Quantitative Method*
Data Collection for developing the proposed approach	*1st Step*	Investigating the current practices of sustainable circular supplier selection process via semi-structured interviews to add the needed criteria for the list conducted from the previous literature.	
	2nd Step		Measuring the significance and the applicability levels of the proposed criteria according to the experts' opinion via a 5-point Likert-Scale questionnaire to make the inclusion and exclusion criteria finalize the list.
	3rd Step		Using FUZZY-DEMATEL approach to determine a pair-wise comparison to measure the interdependence relation between the proposed criteria to propose the SCSS Model.
Data Collection for applying and validating the proposed approach	*4th Step*	Testing the suggested **SCSS Model** by employing an action research methodology on two specific case companies and assessing the viewpoints of the participants regarding the implementation of the proposed **SCSS Model** through a combination of qualitative and quantitative questions.	

In conclusion, the Mixed Method is deemed relevant and reliable as it enables the researcher to:

- Describe and analyse the sustainable circular supplier selection practices in real-life context; and
- Identify the criteria of sustainable circular supplier selection as well as measuring their interdependence relationships.

3.5 Research Strategy

In this study, the research strategy outlines the best techniques to achieve objectives. According to Saunders *et al.*, (2019), the researcher can take into account a number of research strategies, including ethnography, action research, grounded theory, survey research, archival research, case study research and experimental research, which are briefly explained below:

- ***Experimental Research:*** It measures how closely several factors are related. Studying the chance that changing one variable (the independent variable) will change another (the dependent variable) is the goal of experiment research. As a result, it uses hypotheses as opposed to research questions.

- ***Survey***: It is a widely used and accepted method in business and management research since it primarily addresses the "what, who, where, how much and how many" questions. It facilitates the researcher's ability to collect numerical data for subsequent quantitative analysis utilising descriptive and inferential statistics. Additionally, sampling allows for the provision of results that are representative of the entire population at a lower cost than gathering data from the entire population, giving the researcher more control over the research process.

- ***Archival Research:*** In this strategy, administrative records and documents serve as the main source of data. Despite its association with the past, the word "archival" can also refer to recent documents. Any research issue, whether exploratory, descriptive, or explanatory, that focuses on the past and changes over time can be addressed using this strategy. However, the ability of the researcher to answer research questions will certainly be restricted by the nature of the documents and administrative records.

- ***Case Study:*** It is a detailed, in-depth investigation of a single subject, such as an individual, a team, an organisation, an event, phenomenon, or problem. In this strategy, the topic is examined in-depth to understand problems in a practical situation. The purpose of this strategy is to fully understand the study's context and determine if the results may be generalisable or not. When conducting research into case study, it is crucial to include the social context and culture, which implies that this form of study is typically qualitative and inductive. In addition to "what?" and "how?", the case study approach is also excellent at producing responses for the question "why?". This is why case study research is frequently used in explanatory and exploratory studies.
- ***Ethnography:*** In this strategy, individuals are being observed in their natural settings while the significance of their cultural relationships is deciphered. However, ethnography is used in study groups. Its goal is to convey the participants' individual perspectives on the world and show it from their point of view.
- ***Action Research:*** It is an iterative, emergent process of inquiry with implications for participants and the organisation that goes beyond the confines of the research project. Its goal is to create solutions to real-world organisational problems through participation and collaboration.

  Increased organisational learning is the goal of an action research strategy, which is accomplished through identifying issues, planning solutions, implementing solutions and evaluating solutions.
- ***Grounded Theory:*** It can be used to describe a methodology, an investigational strategy, or the conclusion of a research process. To develop theoretical justifications of social interactions and processes, grounded theory is used in a range of contexts, including business and management. This strategy can be used to study a variety of business and management issues because these issues are mostly a function of people and their behaviours, e.g. consumers and employees. Its aim is to 'discover' or build a theory based on data obtained from social actor descriptions.
- ***Narrative Inquiry:*** A narrative is a story interpreted by the researcher from events. A qualitative research interview participant conveys a narrative. Thus, the qualitative interview's nature can be described as "narrative." The researcher may find it beneficial

to analyse the participant's experiences as a cohesive narrative rather than isolated data points. Nonetheless, narrative inquiry possesses a distinct definition and objective as a research strategy.

In this study, the primary objective is to develop a **SCSS Model** utilising the MCDM technique known as FUZZY-DEMATEL. The researcher has utilised different research strategies, namely survey and action research, which will be further discussed in the following section along with their data analysis techniques.

3.5.1 Survey strategies conducted in this study:

To fulfill the research objectives and their related research questions, research strategies including "Surveys" such as In-Depth Semi-Structured Interviews, a 5-point Likert Scale Questionnaire and a Pair-wise Comparison Questionnaire, together with "Action Research" research strategy are adopted. These strategies will be further discussed in the following section along with their data analysis techniques. **Table 3.4** presents the survey methodologies applied to each research objective alongside their corresponding research question.

Table 3.4 Survey Strategies of the study:

Research Objective (RO)	**Research Question (RQ)**	**Type of Survey Strategy**
(RO1)	**(RQ1.2)**	
To develop a list of supplier selection criteria for sustainability and CE with four dimensions (Economic, Environmental, Social, Circular), with a particular focus on the application in the MENA region.	What are the economic, environmental, social and circular criteria that are essential for selecting suppliers towards sustainability and CE according to the MENA region circumstances.	In-depth Semi-Structured Interviews
(RO2)	**(RQ2)**	**Type of Survey Strategy**
To find out the importance and applicability levels of criteria for supplier selection that refer to sustainability and CE, particularly within the context of the MENA region's specific circumstances.	What are the importance levels of the proposed criteria and to what extent are they applicable for practical /industrial practices within the MENA region?	5-point Likert Scale Questionnaire.
(RO3)	**(RQ3)**	**Type of Survey Strategy**
To develop a **SCSS Model** using the FUZZY-DEMATEL technique to measure the interdependency relationship among the proposed criteria.	What is the influence of individual criteria on the interconnected criteria that affect the process of making decisions regarding the selection of suppliers?	Pairwise Comparison Questionnaire.

- In-depth Semi-Structured Interviews:

To determine whether there is a relevant motivational need in the field for recognizing sustainable and circular supplier selection processes, comprehensive, semi-structured interviews were carried out in Phase (1) of the study. The purpose of these interviews was to gather insights from experts regarding the identified knowledge gap in the current literature, specifically the absence of sustainable and circular supplier selection criteria integrated into a structured model. Furthermore, the interviews aim to investigate additional criteria that the experts believe should be included in the proposed SCSS Model. These criteria will supplement the list established by the researcher through the literature review, forming a preliminary list. In a similar study focusing on supplier selection carried out by Marzouk and Sabbah (2021), two participants in a semi-structured interview were deemed sufficed for creating the initial list of the supplier selection approach prior to the distribution of the questionnaire.

The semi-structured interviews were conducted through the utilisation of open-ended questions. Open-ended questions possess a heightened likelihood of prompting a contemplative reply in contrast to closed questions, thus affording the investigator with a more profound insight into the interviewee's perspectives, interpretations of events, understandings, experiences and standpoints. When implemented proficiently, qualitative interviewing holds the capacity to attain a degree of complexity and refinement that is unachievable through alternative approaches, specifically structured interviews or survey-based methods (Silverman, 2017). Appendix I includes the full sample of the semi-structured interview used in this study. **Table 3.5** shows the summary of the participants' profiles.

The interviews involved eight experts from five industrial companies within Egypt, as one of the MENA region's industrial countries. The researcher referred to the "Industrial Development Center" in Egypt to identify the firms that adopt sustainable development strategies and are classified as large manufacturing and exporting companies. Moreover, the researcher reached some companies when meeting their representatives in one of the "Industrial Advisory Board" that performed annually in Alexandria, Egypt. Subsequently, phone calls and emails were employed to locate suitable companies. The researcher identified the following criteria for the case companies' selection to guarantee the case companies' strength and availability:

- The companies that are having clear commitment to sustainability practices.
- The companies that are certified ISO 14001.
- The companies that are willing to share information.
- The accessibility of the researcher.

Moreover, the selection of the experts in each firm was based on following considerations:

- A minimum of eight years of experience is required to guarantee a thorough understanding and expertise in the area of supply chain management, with a specific emphasis on procurement and purchasing activities, such as supplier selection processes or the like.
- Possessing a profound understanding that enables the provision of thorough and informing insights concerning the process of selecting suppliers.
- Experts who are willing to expose their knowledge and experience truthfully.

Table 3.5 Summary profiles of the interviewees:

Job Title	Years of Experience	Main Business
Purchasing Manager	21	Food Industry
Procurement Head	20	Operation and Maintenance Management Company
Purchasing Manager	18	Petrochemicals
Section Head of Tendering & Practices Sector.	15	Petrochemicals
Purchasing Manager	14	Metal products
Head of Quality Department	10	Sanitary Ware and Ceramic Tiles
Procurement Specialist	9	Metal products
Procurement Specialist, General Department of Material	8	Petrochemicals

The semi-structured interview questionnaire was a mix between open-ended and closed questions, and a 5- point Likert scale. It comprised 7 questions organised into 3 distinct sections. The first section featured 2 general questions concerning the type of field and the workforce size of the company. The subsequent section contained 3 questions that explored whether the companies adopt sustainability and CE practices, along with the drivers and barriers faced in implementing SSCM.

The final section comprised two questions; the initial question inquired about the existing supplier selection process utilised by these companies. In the second question, the researcher provided the interviewees with a list of 24 supplier selection criteria derived from earlier literature and then requested their suggestions on additional criteria that could enhance the supplier selection process in relation to sustainability and CE contexts based on their experiences.

After completing the semi-structured interviews, the researcher included the criteria suggested by the participants and developed a preliminary version of the 5-point Likert Scale Questionnaire for the upcoming phase of the research, which aimed to assess the **importance** and **applicability** levels of the proposed criteria. The validity of the questionnaire draft was evaluated by consulting the same experts. This was to make sure that all questions were properly designed to meet the intended purposes. Adjustments to the questionnaire were implemented following input and feedback from experts, as shown in **Table 3.6**. Several statements were revised to enhance the questionnaire's clarity.

Table 3.6 Feedback on questionnaire and changes addressed through the pre-test:

Focus	**Description**	**Feedback and recommended changes**
Content	Are the questions' contents relevant to the study? Are the inquiries important for the research purpose?	The content of the questions was acceptable and appropriate for the research area, according to all experts.
Instructions/Guidelines and cover page	Are the questionnaire's instructions clear?	It was beneficial and simple to figure out the cover page, which provides the study topic and the research aim and objectives. To get respondents' attention, some terms in the instructions for the sections should be bolded and underlined.
Questions	Are all the words used in the questions for measuring the importance and applicability levels clear?	In general, the questions' words were clear. Some experts advised using straightforward language that all managers and employees can comprehend. As a result, several words were changed appropriately.
Layout	How appropriate is the questionnaire's layout or design?	All experts concurred that the sections were arranged and laid out in a very logical and easy-to-read manner.
Length	How long have the experts found the survey to be acceptable?	The experts determined that 20 to 30 minutes was deemed a reasonable amount of time to finish the questionnaire.

After finalising the criteria for selecting sustainable, circular suppliers based on the literature review, in-depth semi-structured interviews and experts feedback on the draft questionnaire's content validity, a questionnaire was developed to assess a final list of 26 criteria (refer to Appendix II). The analysis methods of the questionnaire will be discussed in the following section.

- **5-point Likert Scale Questionnaire for measuring importance and applicability levels:**

The aim of this questionnaire was to assess the importance of each identified criterion and to what extent each of them is applicable in a real-life context. Specifically, the questionnaire was designed to serve a number of purposes:

- Measure the importance and applicability of each criterion.
- Quantify the relative importance of each criterion.
- Identify the correlation between the importance and applicability of each criterion to determine whether an important criterion is deemed more or less applicable.

The questionnaire involved two main sections. In the first section, there were questions about the respondent's background. The second section consisted of economic, environmental, social and circular criteria. Respondents were required to utilise a five-point Likert Scale in assessing the importance and applicability of each criterion. The level of importance was scrutinised to ascertain the perceived significance, while applicability indicated the feasibility of implementing the criteria in practical scenarios. The use of a five-point rating scale was favored by many studies to mitigate respondent confusion and enhance response rates (Taherdoost, 2019). Concerning importance, the scale ranges from 1 (*not at all important)* to 5 (*extremely important).* As for applicability, the scale ranges from 1 (*not at all applicable)* to 5 (*extremely applicable)*.

Concerning the results of the questionnaire, Relative Importance Index (RII) was used to determine the relative importance of each proposed criterion. The RII ranges from 0 to 1, with 0 not inclusive. It shows that the higher the value of RII, the more important the sustainable circular criteria were and vice versa. The formula RII is as follows:

$$RII = \frac{\sum \mathrm{w}}{A \times \mathrm{N}} \quad \text{Equation 1.}$$

Where, W= weighting that is assigned to each variable by the respondent, A = highest weight and N = total number of respondents. According to Chen *et al.*, (2010) five important levels are transformed from RI values: high (H) ($0.8 \leq RI \leq 1$), high-medium (H–M) ($0.6 \leq RI \leq 0.8$), medium (M) ($0.4 \leq RI \leq 0.6$), medium-low (M-L) ($0.2 \leq RI \leq 0.4$) and low (L) ($0 \leq RI \leq 0.2$).

Meanwhile, another statistical analysis was performed to determine the relationship between the importance and applicability levels of each proposed criterion. Despite the fact that the distribution of the datasets (importance and applicability) is not normal, the "Mann–Whitney *U* test," was used to test the null hypothesis: no significant difference exists between the two sets of data (importance and applicability). The Mann–Whitney U test was independently developed by Mann and Whitney (1947). It is a nonparametric test that compares two unpaired groups. In other words, it requires that the two independent groups have the same distribution and are homogeneous (Nachar, 2008). The Mann-Whitney U test indicates that when the result of the P value >0.05, there is no statistical difference between the two variables. Moreover, a reliability test was done to make sure that the data collected could be used for further study. According to Yahya *et al.* (2021), Cronbach's alpha is the most common analysis for multiple Likert questions to determine whether the scale is reliable. Therefore, an internal reliability assessment using Cronbach's alpha was conducted for both data sets (importance and applicability). SPSS software was applied to run all statistical tests.

The questionnaire was sent to 80 experts from academia and industry within the MENA (Middle East and North Africa) region. The non-probability sampling method of purposive sampling was implemented. The academics were selected based on their experience and contributions in the field of supply chain management. The industrial experts, on the other hand, were chosen based on their positions and years of experience in the supply chain field, particularly in purchasing and procurement activities. 52 respondents completed and returned the questionnaire, representing 65% response rate, which was higher than the appropriate level, 15% according to Fallahpour *et al.*, (2017). For correlation research, Fraenkel and Wallen (2007) suggested that a sample size of at least 50 was needed to provide enough evidence. In other words, a total of 52 questionnaires returned is deemed sufficient.

- **Pair-wise Comparison Questionnaire for Fuzzy Decision-Making Trial and Evaluation Laboratory (FUZZY-DEMATEL):**

Next, the interdependency relationship between all identified selection criteria must be uncovered. To achieve this, the fuzzy DEMATEL method was used, together with a questionnaire, to establish the pair-wise comparison of 22 criteria, after excluding 4 criteria according to the previous questionnaire results. The 4 criteria were excluded due to their RII and their p-value. The questionnaire structure is explained in Appendix III. A panel of 20 experts was assembled to conduct a pairwise comparison among all selection criteria, with an aim to address their relative importance, i.e. which criterion is more or less important than others. The selection of the experts was made based on their experience (a minimum of eight years' experience) and expertise in their area (individual profiles). The experts were highly skilled and capable of making decisions regarding selecting and evaluating suppliers. Profiles of these experts can be found in Appendix V.

- **Fuzzy Decision-Making Trial and Evaluation Laboratory (FUZZY-DEMATEL) technique:**

Various methods, widely recognised in academic literature, are available for modelling complex relations among factors while differentiating them, including the Interpretive Structural Modelling (ISM), Analytical Hierarchical Process (AHP), Analytical Network Process (ANP) and Structural Equation Modeling (SEM) (Mangla *et al.*, 2018; Farooque *et al*., 2019; Liu *et al.*, 2021). In recent years, the DEMATEL technique has gained popularity for its ability to comprehend the structure and influence relationships among elements (Chen and Huang, 2022). The DEMATEL focus is on graph theory and involves examining intricate causal connections using quantitative approaches, such as matrices and diagrams (Farooque *et al*., 2019). The DEMATEL technique was introduced in 1973 by the Geneva Research Centre of the Battelle Memorial Institute to visualise the structure of complex causal relationships among factors through matrices or diagraphs (Chiou, Hsu and Chen, 2011; Muhammad and Cavus, 2017; Si *et al*., 2018; Raut *et al*., 2019). In particular, DEMATEL serves as a form of structural modelling methodology that holds significant value in examining the interdependency relationship among criteria for establishing causal links within a framework (Si *et al*., 2018). Considering such relationship among the identified selection criteria could lead to the derivation of importance weights that exhibit greater reliability (Ecer and

Torkayesh, 2022). **Table 3.7** provides a comparison of DEMATEL with the other methods mentioned above, which justifies the choice of DEMATEL in this study.

Table 3.7. A comparison of DEMATEL with ISM/AHP/ANP/SEM.

Factor	DEMATEL	ISM	AHP	ANP	SEM
Principle	Causal relationships among variables by categorising them into cause-and-effect groups.	Contextual relationships among variables by considering their influential power and interdependencies.	Based on a hierarchical structure.	Based on network structure.	Theoretical advancement.
Pros	Micro-oriented approach and generates impact-relation maps to illustrate causal connections	Macro focuses and can dissect intricate systems into smaller subsystems.	Easy to understand.	Handle interdependency between criteria.	Well-established.
Cons	Relies on crisp values. Cannot get partial ranking orders of alternatives.	Requires a significant amount of matrix computation resources.	It does not consider possible interdependence among different criteria and assumes the criteria independently	Complex to implement.	Requires large sample size.

Source: Adopted from Mangla *et al.* (2018); Farooque *et al*. (2019); Liu *et al.* (2021).

In fact, both DEMATEL and ISM have the capability to examine the interdependency relationship between various factors. When comparing DEMATEL and ISM, DEMATEL proves to be more beneficial as it offers the extent of influence of the factors and employs heterogeneous elements for the examination (Liu *et al.*, 2021). Although ISM is easy to understand and has the widest range of uses, it requires a significant amount of matrix computation resources; in comparison, DEMATEL uses less information and its computing is easier than ISM (Wang *et al.*, 2018). Hence, ISM is a macro-focused strategy that dissects intricate systems into smaller subsystems, while DEMATEL is more micro-focused. DEMATEL measures the strength of both direct and indirect connections between variables and illustrates causal links using impact-relations maps (Kumar and Dixit, 2018; Wang *et al*., 2023). Consequently, DEMATEL was deemed more appropriate than ISM in this study.

AHP is widely used due to its simplicity and is employed to illustrate the hierarchical structure of variables, but it falls short in handling complex interdependence among factors. In contrast, DEMATEL is known for its superiority over AHP in accurately capturing interdependencies demonstrating graphical cause-and-effect relationships among criteria (Farooque *et al.*, 2020).

ANP and DEMATEL are applied to assess the relationships among factors, yet DEMATEL offers a unique perspective compared to the ANP-based approach (Song *et al*., 2020). ANP is an extension of AHP to model interdependency relationship among criteria within a hierarchy for more complex relationships. ANP has been used by numerous scholars, yet the relationships noted among variables in these studies were not optimal and comprehensive due to the challenge of eliminating the possibility of interrelationships within the criteria (Kumar and Dixit, 2018). While ANP is suitable for capturing feedback and interdependencies, its complexity may require large data and expertise, which is impractical in most situations (Nyimbili *et al.*, 2023). Hence, it is crucial to determine the correct method to address this issue. DEMATEL appears to be a suitable method for facilitating a clear strategic hierarchical and relational structure (Hashemkhani *et al.*, 2019). The DEMATEL technique is employed to identify the causal factors, distinguish the cause-effect relationships among them and visually represent the structure of the relationships through direct-relation matrices. Therefore, DEMATEL serves as a robust and valuable structural modelling tool for addressing MCDM challenges.

SEM, being a statistical method, does not inherently establish causality through its analysis. Furthermore, it often necessitates distinct parametric assumptions for the dataset in addition to a substantial sample size (Wang *et al*., 2018; Farooque *et al.*, 2019). The key benefit of the DEMATEL method over other methods lies in its ability to determine the causal relationship among the criteria (Özdemirci *et al.*, 2023). Moreover, DEMATEL statistically significant results can be achieved with a small sample size since it is not based on statistical analysis (Asadi *et al.*, 2022). In other words, DEMATEL technique generates acceptable results from smaller samples

(Hwang *et al.*, 2016). Therefore, in the current study, the researcher found that DEMATEL is much better than SEM to accomplish its aim.

The key advantages of DEMATEL technique can be summarised as follows (Wang et al., 2023):

- It analyses both direct and indirect impacts, establishing causal relationships.
- It guides decision makers in understanding and visualising relationships among factors.
- It ranks factors based on the calculated weights of key factors.

In summary, the DEMATEL method assists in visualising the causal relationship structure among factors, creating graphical outputs that show causal relationships among variable factors and pinpointing the most influential factors. DEMATEL has certain limitations; for instance, it evaluates the connections among decision factors using crisp values to form a structural model. Nevertheless, in numerous practical scenarios, human judgements are frequently unclear, and crisp numerical values are insufficient for determining the vague interdependency relationships among criteria (Suo *et al.,* 2012; Nyimbili *et al.* , 2023) Therefore, the utilisation of fuzzy set theory was implemented in many studies to enhance the conventional DEMATEL methodology, resulting in the development of Fuzzy DEMATEL, hence known as FUZZY-DEMATEL (Farooque *et al.*, 2020). Zadeh (1965) developed fuzzy set theory, which introduced the idea of a membership function. The fuzzy hypothesis supports vague and unclear issues as well as faulty human judgements (Mavi and Shahabi, 2015). In this context, as noted by Akyuz and Celik (2015), the Triangular Fuzzy Number (TFN) stands out as the most widely used form of fuzzy number.

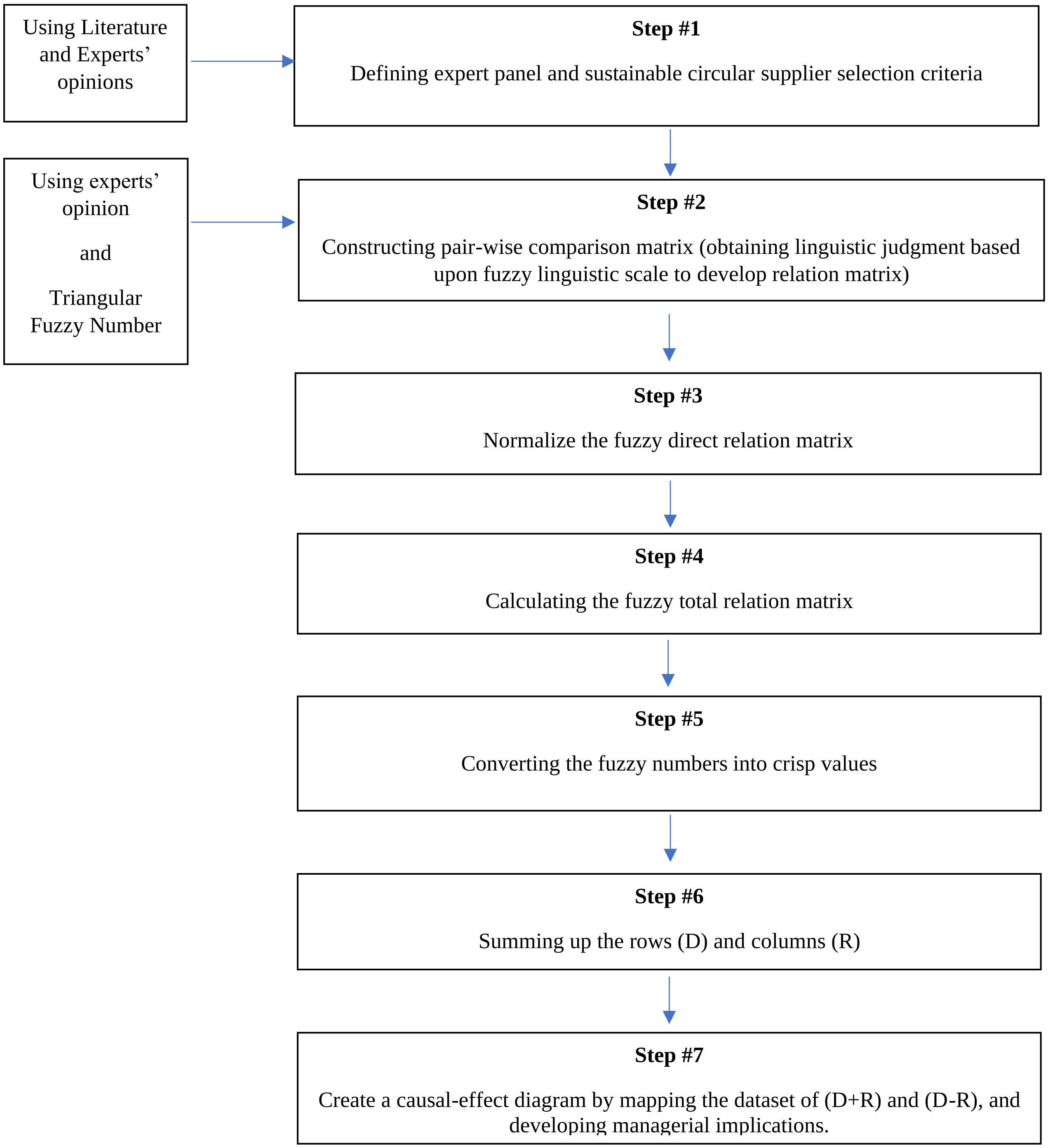
The relationship between the causes and consequences of criteria can be transformed by FUZZY-DEMATEL into an intelligent structural model of the system (Rouhani *et al*., 2014). This approach is used to address MCDM issues in various fields, such as manufacturing sector for supplier selection, educational sector to evaluate the learning management sector evaluation criteria and construction sector for analysing occupational risks (Mavi and Shahabi, 2015; Muhammad and Cavus, 2017; Seker and Zavadskas, 2017; Govindan *et al.*, 2020).

Based on the discussions above about the FUZZY-DEMATEL technique, it was suggested to develop the **SCSS Model** by combining the FUZZY-DEMATEL technique to construct impact relation maps and identify cause and effect groups of criteria with fuzzy set theory to deal with the ambiguity of human thoughts (experts' opinions).

Another limitation of DEMATEL technique is that it cannot get partial ranking orders of alternatives or account for the desire level of alternatives as in the GRA and VIKOR approaches (Si *et al.*, 2018). Therefore, another MCDM technique called Fuzzy-TOPSIS was adopted to rank the alternatives (suppliers) in the proposed **SCSS Model,** and more details will be discussed in Chapter 6.

As a result, it is believed that the combination of “Fuzzy-DEMATEL” can help to determine the most (or least) significant criterion and develop the ranking of suppliers considering both sustainability and circularity. The key steps of the FUZZY-DEMATEL will be clarified in the next section. According to (Si *et al.*, 2018), the extended DEMATEL models, such as the FUZZY-DEMATEL technique, may have a limited range of applications since they require extensive computations to accurately analyse the complex interrelations among components; therefore, a cloud-based was used to execute the FUZZY-DEMATEL approach. **Figure 3.2** illustrates the steps of the FUZZY-DEMATEL methodology done by the researcher.

Fig. 3.2. FUZZY-DEMATEL flowchart of sustainable circular supplier selection criteria



The steps of FUZZY-DEMATEL methodology:

***Step 1**: To define an expert group and the criteria.*

In this step, a panel of 20 experts from the industrial sector was formed. These experts' profile can be found in Appendix V. They were asked to review the list of 22 sustainable circular supplier selection criteria as shown in **Table 3.8**.

Table 3.8 Sustainable Supplier Selection Criteria

Sustainable Supplier Selection Criteria			
Economic	**Environmental**	**Social**	**Circular**
Cost (EC1)	Environmental Mgt. Systems (ENV1)	Training Related Carbon (SO1)	Eco-friendly raw materials (CR1)
Quality (EC2)	Green Design (ENV2)	Worker's Rights (SO2)	Respecting environmental standards and regulations in the process of recycling (CR2)
Delivery and services (EC3)	Green Transportation (ENV3)	Occupational Health & Safety (SO3)	Air pollution resulting from recycling process (CR3)
Flexibility (EC4)	Green Technology (ENV4)	Society's Rights/ Social responsibilities (SO4)	Clean technology for recycling (CR4)
Financial Stability (EC5)	GHG emissions (ENV5)	Information Disclosure (SO5)	Eco-friendly packaging (CR5)
	Carbon Disclosure Report (ENV6)		Reverse Logistics Agreement (CR6)

Source: Findings derived by the researcher.

***Step 2**: To generate the fuzzy direct relation matrix.*

After recognising the selecting/evaluating criteria, a pair-wise comparison was performed using a five-point fuzzy linguistics scale (1 = no influence, 2 = very low influence, 3 = low influence, 4 = high influence, and 5 = very high influence), which is widely utilised to assist experts in evaluating the interrelationships among criteria, as shown in **Table 3.9**. The arithmetic mean of all experts' opinions is computed to generate the direct relation matrix z.

$$z = \begin{bmatrix} 0 & \cdots & \tilde{z}_{n1} \\ \vdots & \ddots & \vdots \\ \tilde{z}_{1n} & \cdots & 0 \end{bmatrix} \qquad \text{Equation 2.}$$

The membership function TFN is used in this step, A=(L, M,U), where L, M and U denote lower, medium and upper numbers of the fuzzy sets (x≤ y≤ z), respectively .

Table 3.9 Fuzzy Linguistic Scale.

Code	Linguistic terms	Triangular Fuzzy Number		
		L	**M**	**U**
1	No influence	0	0	0.25
2	Very low influence	0	0.25	0.5
3	Low influence	0.25	0.5	0.75
4	High influence	0.5	0.75	1
5	Very high influence	0.75	1	1

Step 3*: To normalise the fuzzy direct relation matrix*

The normalization of the fuzzy direct-relation matrix can be obtained using the following formula:

$$\tilde{x}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r}\right)$$

Where;

$$r = \max_{i,j}\left\{\max_i \sum_{j=1}^{n} u_{ij}, \max_j \sum_{i=1}^{n} u_{ij}\right\} \qquad i,j \in \{1,2,3,\dots,n\} \qquad \text{Equation 3.}$$

Normalising the fuzzy direct relation matrix in DEMATEL is a crucial process that guarantees the analysis's reliability and comparability. By standardising the values, the model is able to offer valuable insights into the connections between criteria and their significance.

Step 4*: Calculate the fuzzy total-relation matrix.*

In this step, the fuzzy total-relation matrix is formed by the following formula:

$$\tilde{T} = \lim_{k \to +\infty} (\tilde{x}^1 \oplus \tilde{x}^2 \oplus \dots \oplus \tilde{x}^k)$$ Equation 4.

If each element of the fuzzy total-relation matrix is expressed as $\tilde{t}_{ij} = (l''_{ij}, m''_{ij}, u''_{ij}$, it can be calculated as follows:

$$[l''_{ij}] = x_l \times (I - x_l)^{-1}$$
$$[m''_{ij}] = x_m \times (I - x_m)^{-1}$$
$$[u''_{ij}] = x_u \times (I - x_u)^{-1}$$

Step 5: *Defuzzify into crisp values*

This step is the process of converting the fuzzy numbers into crisp value through the CFCS (Converting Fuzzy data into Crisp Scores) defuzzification method, which is proposed by Opricovic and Tzeng (2003). The CFCS has been used to obtain a crisp value of total-relation matrix. The steps of CFCS method are as follows:

$$l_{ij}^n = \frac{\left(l_{ij}^t - \min l_{ij}^t\right)}{\Delta_{min}^{max}}$$
$$m_{ij}^n = \frac{(m_{ij}^t - min\ l_{ij}^t)}{\Delta_{min}^{max}}$$
$$u_{ij}^n = \frac{(u_{ij}^t - min\ l_{ij}^t)}{\Delta_{min}^{max}}$$

So that

$$\Delta_{min}^{max} = \max u_{ij}^t - \min l_{ij}^t$$ Equation 5.

Calculating the upper and lower bounds of normalised values:

$$l_{ij}^s = m_{ij}^n / (1 + m_{ij}^n - l_{ij}^n)$$ Equation 6.

$$u_{ij}^s = u_{ij}^n / (1 + u_{ij}^n - l_{ij}^n)$$ Equation 7.

The output of the CFCS algorithm is crisp values.

Calculating the total normalised crisp values: Equation 8.

$$x_{ij} = \frac{[l_{ij}^s(1 - l_{ij}^s) + u_{ij}^s \times u_{ij}^s]}{[1 - l_{ij}^s + u_{ij}^s]}$$

***Step 6**: Summing up the rows (D) and columns (R)*

This step is to find out the sum of each row (D) and each column (R). The sum of rows (D) and columns (R) can be calculated as follows:

$$D = \sum_{j=1}^{n} T_{ij}$$ Equation 9.

$$R = \sum_{i=1}^{n} T_{ij}$$ Equation 10.

*"D"*refers to the overall effects of one criterion (i) on the other criterion (j), while "*R*"refers to the overall effects experienced by criteria (j) due to criteria (i).

***Step 7**: Create a causal-effect diagram by mapping the dataset of (D+R) and (D-R)*

In the final step, the causal-effect diagram is composed using the values of (D+R) and (D-R). According to Akal and Kineber (2022), the horizontal axis (D+R), named "Prominence", indicates the total effects in terms of influenced and influential power of each criterion. That is, (D+R) stands for the degree of prominence of the criteria in the sustainable circular supplier selection process. On the other hand, the vertical axis (D-R), called "Relation", shows the net effect that the criterion contributes to the sustainable circular supplier selection process. If the (D-R) > 0, the criterion is regarded as a causal criterion, and if the (D-R) <0, the criterion is an effect criterion.

3.5.2 Action Research conducted in this study:

Action research strategy was used in Phase (4) of the research process as presented in **Figure 1.1** and it was mainly utilised to answer Research Question (4) corresponding to Research Objective (4) as shown in **Table 3.10**.

Table 3.10 Research objective and research question achieved by Action Research:

(RO4)	**(RQ4)**	**Action Research with two case companies**
To test the proposed **SCSS Model** within a practical setting through the implementation of an action research pilot.	How efficiently could the suggested **SCSS Model** enhance the process of supplier selection within the contexts of sustainability and CE in practice?	

Action research encompasses the process of identifying a specific issue, developing and executing a plan for rectification and evaluating the outcomes of the intervention (Adebanjo *et al.*, 2013). Therefore, the researcher utilised action research to test the effectiveness of the SCSS Model in addressing the problem of sustainable circular supplier selection in a practical situation, involving two specific case companies. Moreover, action research is the integration of theory and action in an emergent inquiry process, combining scientific knowledge with existing organisational knowledge. It aims to tackle real organisational issues alongside the individuals within the system being studied (Maestrini *et al.*, 2016). Therefore, action research is a suitable methodology for the present study, as the researcher aimed to thoroughly examine the inherent challenges within the supplier selection process, including the absence of sustainable and circular criteria for supplier selection, and to propose practical solutions for enhancement, using the proposed SCSS Model. The approach of action research acknowledges the intricacies of the dynamic socio-technical systems of the case organisation as the project progresses (Shani and Coghlan, 2021). This methodology is constructed to bridge the gap between research and practical application (Eden and Ackermann, 2018). The utilization of action research was deemed appropriate for this study due to its alignment with the FOUR fundamental characteristics of action research, outlined by Burns (2000) as follows:

- *Situational* – The study identified a problem of sustainable circular supplier selection process within the two case companies' environment and attempted to resolve it.
- *Collaborative* – A group comprising experts from each case company and researcher collaborated to work on the proposed SCSS Model.
- *Participatory* – Experts team members at each company were actively involved in executing the proposed SCSS Model.
- *Self-evaluative* – The modifications and their execution were consistently assessed within the two case companies to enhance supplier selection towards sustainability and CE contexts.

The primary characteristics of this action research entail the emphasis on resolving practical issues, the engagement between the researcher and experts who have firsthand experience of the workplace, the development of enhancement strategies within the institution and the generation of theoretical and practical insights (Näslund *et al*., 2010). In comparison to a case study, action research centres on possible interventions for problem resolution, whereas the case study method offers a framework for observing occurrences, gathering and scrutinising data and presenting findings (Yin, 2016). Due to the involvement of the supplier selection problem with supply chain management, a field classified as applied research, action research is deemed appropriate. This is attributed to the inherent nature of supply chain management in facilitating the identification of research inquiries pertinent to business managers (Näslund *et al.*, 2010). As referring to Tay and Aw (2021), who utilised action research in logistics supplier selection, choice of action research as a methodology in this part of the study can be attributed to several reasons:

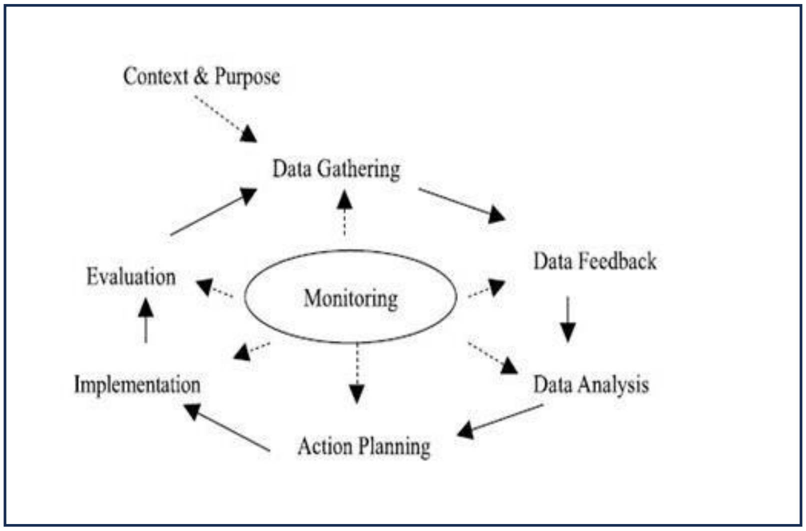
- Action research assists the researcher to have direct access to the investigation area; specifically, the procurement department, which plays a crucial role in the supplier selection process.
- Action research motivates participants, who are seen as decision makers in the supply selection process, to work closely with the researcher to address issues within the supplier selection process for the purpose of enhancing sustainability and contexts. This collaboration also involves implementing and evaluating the improvements.
- Action research has the ability to improve the existing supplier selection process in a way that directly supports sustainability and CE initiatives.

To support the implementation of action research, it is imperative that data are analysed and verified in alignment with the deliberate execution of the action research cycle. For the purposes of this study, the action research cycle by Coughlan and Coghlan (2002) has been chosen as the foundational basis, as it is designed for the field of management studies. The action research cycle phases will be presented below.

- **Action research cycle phases:**

The proposed action research cycle by Coughlan and Coghlan (2002) is delineated through a series of preliminary steps and operational steps. A visual depiction of this cycle can be observed in **Figure 3.3**.

Figure 3.3. Action Research Cycle



Source: (Coughlan and Coghlan, 2002)

The preliminary steps are designed to comprehend the context and purpose, thereby emphasising the justification for undertaking the process (what necessitates or makes this process important?) and investigation while deliberating on how the study can enhance the current understanding of a specific matter. The preliminary steps were based on in-depth semi-structured interviews with a panel of experts from manufacturing companies, as explained in detail in Chapter 4, indicating that despite the existing sustainability and CE initiatives in these manufacturing entities, there exists a noticeable deficiency in practicing the proper methods for selecting suppliers in alignment with sustainable circular principles. Consequently, the researcher initiated the implementation of the action research through the subsequent procedures: (1) Dispatching the itinerary for visits: Prior to commencing the action research, the investigator forwarded a research protocol elucidating the primary purpose of the necessary visits to the designated companies, to facilitate the execution of the action research (See Appendix IV), (2) Evaluating the suggested model: Following the agreement of the companies' participants for the visits, the researcher visited each company and discussed with the participants, acknowledged experts in procurement and supply chain management, who held decision-making roles in supplier selection. Subsequently, the investigator elaborated on the proposed SCSS model and its implementation. The key objective of assessing the suggested model was to explain the working principles of the proposed SCSS model, alongside its pragmatic advantages, and express an explanation of the selection criteria by integrating any additional details requested by the participants. The operational phases of the action research cycle are delineated as the six main steps of action research, as proposed by Coughlan and Coghlan (2002):

1- Data gathering:

Data collection methods vary depending on the context. Data are collected by means of observation, deliberations, and conducting interviews. Hence, this phase was regarded as the primary stage, the researcher initiated the collection of initial information and data from each company. The interviewees were prompted to provide specific insights into the procedures employed by each organisation in handling the supplier selection process and supplier evaluation. Furthermore, the researcher inquired with the interviewees regarding the documentation associated with supplier selection and evaluation.

2- Data feedback:

In this phase, the action researcher delivers the accumulated data to the organisation system in order to facilitate its accessibility for analysis. Hence, after the data collection outlined in the prior phase, an assessment was conducted regarding the efficacy of the gathered information and its significance in facilitating the formulation of enhancement initiatives. At times, the researcher collects the data and prepares the report; at other instances, the organisation takes on the data collection, while the action researcher either facilitates or engages in the feedback sessions. The adequacy of data appraisal enabled the execution of the analytical process and strategising of the intervention.

3- Data analysis:

The crucial element of data analysis within action research lies in its collaborative nature. This collaborative process involves not only the researcher but also individuals from the organisation system, such as the management team, working together. Such collaborative endeavours are grounded on the belief that the interviewees possess the most profound understanding of their organisation, are aware of what strategies are feasible and, ultimately, will be responsible for executing and ensuring the success of any proposed actions. Thus, their active engagement in the analysis phase is of utmost importance. It is essential that the criteria and methodologies used for analysis are thoroughly discussed and directly aligned with the research objectives and intervention goals. Hence, in this stage, the researcher examined the existing supplier selection procedures in each organisation and emphasised the primary shortcomings that are evident in selecting suppliers with regards to sustainability and CE viewpoints.

4- Action Planning:

In light of the analysis conducted, subsequent actions are being strategised. Similarly, due to analogous rationales as the data gathering phase, the planning of actions is a collaborative effort. The researcher and the participants in this phase determine responsibilities and establish a suitable timeline. According to Coughlan and Coghlan (2002), important questions become apparent, such as (1)What changes are necessary? (2) Which parts of the organisation require these changes? (3) What kind of changes are needed? (4) Whose assistance is crucial? (5) How can commitment be fostered? Addressing these pivotal questions is essential and forms a part of the change strategy. Hence, this phase addressed the steps of the upcoming implementation of the proposed SCSS Model for each company.

5- Implementation:

The organisations execute the planned action, entailing the implementation of the intended modifications and the seamless execution of the strategies in conjunction with participants within the organisation. Hence, the researcher in this phase assisted the participants of each company in evaluating suppliers based on the proposed SCSS Model. The participants were tasked with identifying specific suppliers as substitutes to one another in order to operationalize the SCSS Model for supplier selection and prioritisation. Subsequently, the researcher instructed the participants to assess their suppliers in alignment with the criteria outlined in the proposed model utilising a 5-point Likert scale ranging from 1 to 5 for each criterion. Following this, a MCDM technique known as Fuzzy-TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) was employed to rank the suppliers. The TOPSIS technique was first developed by Hwang (1979). The TOPSIS methodology states that the optimal option will be the one that is farthest from the negative ideal solution and closest to the positive ideal solution. TOPSIS is one of the generally applied MCDM techniques in literature for ranking alternatives which are VIseKriterijumsa Optimizacija I Kompromisno Resenje– multi-criteria optimization and compromise solution (VIKOR), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), and Multi-Objective Optimization by Ratio Analysis (MOORA) techniques (Emovon, 2020). The primary advantages of TOPSIS approach over other MCDM approaches for addressing complex decision-making problems are its user-friendly nature, its ability to consider all kinds of criteria (both subjective and objective), its logical reasoning that is easily grasped by practitioners, the simplicity of its calculation processes, its mathematical representation of optimal alternative criteria, and the straightforward input of important weights (Wangchen, 2012). **Table 3.11** provides a comparison of TOPSIS with the other well-known MCDM, which justifies the choice of TOPSIS in this study.

Table 3.11 A comparison of TOPSIS/MOORA/PROMETHEE/VIKOR:

Factor	TOPSIS	MOORA	PROMETHEE	VIKOR
Principle	The optimal option will be the one that is farthest from the negative ideal solution and closest to the positive ideal solution	It evaluates the existing options through ratio systems, where the performance of each alternative in relation to a specific criterion is compared to a denominator that encompasses all alternatives associated with that criterion..	evaluates the alternatives by taking into account the variances of each alternative with respect to every criterion.	It emphasises the evaluation and selection among a set of options during conflicting considerations.
Pros	The method possesses a logical and easily understandable framework, and the concept is presented in a relatively straightforward mathematical format. The computation process is uncomplicated. It ensures consistency and reliability. The method fully utilizes the available information, which does not	The alternatives are ranked considering both beneficial and non-beneficial criteria	It assists decision makers in identifying an option that aligns most effectively with their circumstances.	It is accommodating to variations in values during the evaluation period. It is capable of determining not just an individual ranking but also balanced solutions among the rankings.

	need to be independent. Results are achieved fairly quickly in comparison to alternative methods. The number of steps remains constant, irrespective of the number of attributes.			
Cons	Employing precise values to choose among options; consequently, human evaluations in certain instances, like preference ratings, could be inaccurate because of the precise value hierarchy of alternatives.	The primary obstacle that it lies in the requirement for accurate evaluations during their examination	It does not take into account the absolute performance values, but rather evaluates them solely through their comparative differences via pairwise comparisons. This limitation constrains the options available to decision-makers when delineating their preferences and may lead to a distortion of the resultant findings.	There may be potential inaccuracies in the computations. Initial weights are required. The compromise should be structured in a manner that can receive approval to address the issue.

Source: (Chang et al., 2008; Moradian et al., 2019; Aydin and Gümüş, 2022; Zapletal, 2022; Singh et al., 2024).

Despite the fact that TOPSIS is a highly helpful tool for ranking alternatives, it has the drawback of using crisp values to select the alternatives; as a result, human assessments in some cases such as preference ratings, may be imprecise due to the crisp value ranking of alternative (Chang *et al*., 2008). To address this limitation, the TOPSIS method integrated fuzzy environments to apply fuzzy linguistic values to the explicitly provided crisp values in the evaluation of grades, facilitating the selection of alternatives (suppliers). This modified application of the TOPSIS approach is a useful tool that matches human thought in a real-world setting (Yeşim , 2012). The Steps of the Fuzzy TOPSIS Method used in this study are clarified as follows:

Step 1: Create a decision matrix.

Step 2: Create the normalized decision matrix.

Step 3: Create the weighted normalized decision matrix.

Step 4: Determine the fuzzy positive ideal solution (FPIS, A) and the fuzzy negative ideal solution ($FNIS, A^-$).*

Step 5: Calculate the distance between each alternative and the fuzzy positive ideal solution A^* and the distance between each alternative and the fuzzy negative ideal solution A^-.

Step 6: Calculate the closeness coefficient and rank the alternatives.

Finally, the results of the fuzzy TOPSIS technique will assist the case study experts in selecting their suppliers in terms of sustainability and circularity contexts, thereby achieving the study's purpose.

6- Evaluation:

Upon completion of the implementation process, the experts' satisfaction was evaluated in relation to the usefulness of the proposed **SCSS Model** in supplier selection. Another questionnaire was devised to evaluate:

- The experts' contentment with the proposed **SCSS Model**.
- The strengths and weaknesses of the proposed **SCSS Model**.
- The potential course of action for incorporating this model into their procurement management practices.
- This questionnaire was divided into two sections. Within the first section, the 7-point Likert scale was employed to judge the satisfaction of experts with the implementation of the proposed SCSS Model. According to Kusmaryono et al. (2022), a Likert scale featuring response choices of odd numbers (5, 7, 9, or 11) has the potential to reduce bias in the responses provided by survey participants. Among various rating scales, the 7-point Likert Scale stands out for its detailed nature and enhanced accuracy. Differing from the 5-point Likert scale, this scale offers respondents a broader spectrum of seven response options, thereby minimising potential misinterpretations. Hence, the 7-point Likert scale was used due to its dependability, user-friendliness, applicability to small sample sizes and ability to yield a genuine reflection of participants' perspectives. The second section was conducted using open-ended questions. According to Foddy (1993), close-ended questions constrain

the participant to the provided list of options, whereas open-ended questions enable the participant to articulate a viewpoint freely, uninfluenced by the researcher. Therefore, utilising open-ended questions encompass the potential for unearthing the spontaneous responses provided by individuals, thereby circumventing the bias that could arise from prompting individuals with specific responses (Benediktsson *et al.*, 1992). The open-ended questions comprised a variety of question types that granted interviewees the liberty to articulate their viewpoints in their own words, encompassing questions that address the potential drawbacks, not solely the positives, of implementing the proposed SCSS Model.

3.6 Time Horizon

The choice of a suitable time horizon will be influenced by methodological choice and associated strategies. There are two different types of time horizon data: Cross-sectional and Longitudinal, which will be discussed below with reference Saunders *et al.* (2012):

– ***Cross-sectional:*** It is likely that the study will be cross-sectional, focusing on a specific event (or phenomena) at a certain moment in time.

  Cross-sectional studies are frequently used for survey methodology. They might be trying to explain the frequency of an occurrence or the relationships among various variables in various organisations. They might, however, also make use of qualitative or numerous research techniques.

– ***Longitudinal:*** This type is used by the researcher, when he/she wants to collect data over multiple points in time. The ability of longitudinal research to examine change and development over time is its main strength. The researcher may have some degree of control over some of the factors in this type. Whenever the researcher wishes to resemble a diary more, the best choice is longitudinal horizon.

The researcher depended on **cross-sectional data** as the main purpose of this research is to propose a SCSS Model with four dimensions (Economic, Environment, Social, and Circular) during a specific period of time to evaluate and select suppliers in the context of the sustainability and CE.

3.7 Chapter Conclusion:

This chapter introduces and explores the research methodologies selected to develop the SCSS Model, which is the primary aim of this research. The research design relied on Saunders *et al.*, 2019 research onion, as a guideline in order to compare different strategies and select the best one. Regarding the first layers of the research onion, the chosen research philosophy was "Pragmatism" philosophy, as this study combined both qualitative methods (Semi-structured interviews) and quantitative methods (Questionnaire) to address the research problem. For the approach to theory development, since the main aim of this study is to develop a SCSS Model, which is defined as a "Modification of Theory", the study relied on "Abductive" reasoning in order to fulfill the research aim and objectives.

Relating to the methodological choices, a Mixed Method (simple) was used, which combines both quantitative and qualitative methods. Quantitative methods were used when performing questionnaires-survey strategy based, i.e., (1) Questionnaire for measuring the importance and applicability levels of the proposed sustainable circular supplier selection criteria, using 1-5 Likert Scale, (2) Questionnaire for pairwise comparison between the proposed sustainable circular supplier selection criteria using FUZZY-DEMATEL technique. On the other hand, qualitative methods were used in performing in-depth semi-structured interviews when investigating the current practices of sustainable circular supplier selection process, in addition to testing the proposed SCSS Model through conducting action research with two case studies. Concerning the time horizon of the study, cross-sectional data were utilised as the primary aim of this research is to formulate a method for supplier selection criteria focused on sustainability performance within the context of the CE, encompassing four dimensions (Economic, Environmental, Social and Circular) over a defined timeframe by employing literature reviews and in-depth semi-structured interviews to examine and analyse sustainable supplier selection in the context of the CE. The next chapter of the study will outline two steps in phase (1) of the research process. First, it will detail how the in-depth semi-structured interviews were carried out to uncover any additional relevant criteria needed, along with their outcomes. Second, it will describe how the suggested list of sustainable circular supplier selection was developed based on questionnaire results regarding the significance and applicability of each criterion.

CHAPTER 4

Identifying Sustainable Circular Supplier Selection Criteria

4.1 Introduction

This chapter addresses Research Questions 1.2 (RQ1.2) of the study to assess the existing literature gap in real-life industrial practices. It introduces a Sustainable Circular Supplier Selection Model (SCSS Model), with a list of sustainability and circular economy (CE) criteria. The aim is to identify the key selection criteria under each of the four primary dimensions: economic, environmental, social and circular, meeting the circumstances of the MENA region. Additionally, the validation of these supplier selection criteria will be conducted by field experts to assess their importance and applicability levels. This validation helps to address Research Question 2 (RQ2) as outlined in Research Objective 2 (RO2). The research objectives and their corresponding questions are presented in **Table 4.1.**

Table 4.1: Research Objective 1 (RO1) and Research Objective 2 (RO2) and their related Research Questions:

Research Objective 1 (RO1)	**Research Question 1.2 (RQ1.2)**
To develop a list of supplier selection criteria for sustainability and CE with four dimensions (Economic, Environmental, Social, and Circular), with a particular focus on the application in the MENA region.	What are the economic, environmental, social and circular criteria that are essential for selecting suppliers towards sustainability and CE according to the MENA region circumstances.
Research Objective 2 (RO2)	**Research Question 2 (RQ2)**
To find out the importance and applicability levels of criteria for supplier selection that refer to sustainability and CE, particularly within the context of the MENA region's specific circumstances.	What is the importance level of the proposed criteria and to what extent are they applicable for practical /industrial practices within the MENA region?

The objective of RQ1.2 was to analyse the current supplier selection processes associated with sustainability and the application of CE principles. It was addressed through the execution of an empirical study that employed comprehensive semi-structured interviews with a panel of eight experts from diverse large-scale industrial organisations. Furthermore, it pursued to examine the recommendations proposed by these experts regarding supplier criteria to enhance the supplier selection process within sustainable and CE contexts and to support the existing list derived from previous literature.

Upon successful completion of RQ1.2, a comprehensive list of 26 supplier selection criteria was formulated (24 being extrapolated from extant literature and 2 originating from expert recommendations). Subsequently, RQ2 was posed to determine the levels of importance and applicability of these 26 criteria, thereby ensuring their significance and feasibility for implementation in practical contexts prior to their application through the FUZZY- Decision Making Trial and Evaluation Laboratory (FUZZY-DEMATEL) technique for the clarification of their causal relationships.

4.2 In-depth Semi-structured interviews:

In-depth semi-structured interviews were conducted with eight experts from five different industrial companies located in Egypt. Each of these companies, by the time this research was carried out, employed at least 1500 staff. The experts were chosen for their extensive experience in supplier selection and innovation; all of the experts have been chosen (for at least more than 8 years). Due to the confidentiality of the companies, their names were not mentioned in the study; however, the researcher named them with codes, Company A, Company B, Company C, Company D and Company E. The in-depth semi-structured interviews were divided into four main sections, as shown in **Table 4.2**. The semi-structured interview will be presented in Appendix I.

Table 4.2: Semi-structured interview design:

Interview Stages	**Contents**
1st Section	Information about the type of field and the workforce size of the company.
2nd Section	Sustainable Supply Chain Management (SSCM) investigation. Drivers and Barriers of implementing SSCM Asking about managing Circular Economy (CE) in their operations
3rd Section	Investigating their Current Supplier Selection Process
3rd Section	Investigating their Current Supplier Selection Process Interviewees' recommendation criteria for sustainable circular supplier selection

The interview's initial focus was on learning about the companies' core businesses and assessing their progress towards attaining sustainability and CE throughout their supply chains, particularly the upstream portion. This is due to the fact that every company's entire sustainability performance begins with the sustainability performance of its suppliers (Memari *et al.*, 2019) .

- **Implementation of sustainable supply chain management (SSCM):**

This section aimed to investigate whether the interviewees' companies were using sustainability techniques in all aspects of their supply chains and what motivated them to do so. Specific questions were asked to determine whether or not the businesses handle supply chain activities with sustainability considerations. **Table 4.3** shows their statements about the implementation of SSCM and the reasons behind it.

Table 4.3: Interview statements related to SSCM implementation:

Company code	Statement
(A)	*"Yes, as our company is ISO certified for many certificates related to sustainability, such as ISO 14001:2015 (Environmental Management System), OHSAS 18001:2007 Certificate (Occupational Safety and Health Management System, and ISO 50001:2011 Certificate (Energy Management System)"*
(B)	*"At our company, environmental protection is a passion. Investing in sustainable development is as much of a priority as investing in our production improvements. The company's environmental management system is ISO 14001 accredited, and its safety management system is OHSAS 18001 certified"*
(C)	*"As we are ISO 14001 and ISO 18001 certified, we strive to uphold sustainability standards in all our operations, which is done by minimising the use of all materials, supplies and energy and using renewable and recyclable material. Also, we are promoting products that contribute to energy conservation and do not damage the environment. Moreover, we are adopting an environmentally transportation policy. As our company currently exports to 50 countries worldwide, our buyers/customers require the sustainability of our business model as a major condition for doing business with us."*
(D)	*"Our organisation takes all reasonable steps to maintain a healthy and safe working environment and ensures compliance with the local laws, regulations, and standards relating to occupational health, safety and environmental protection because we are ISO 14001, OHSAS 18001, and ISO 50001:2011 certified."*
(E)	*"As our company believes that the implementation of a good HSE (Health, Safety, and Environment) system will in turn contribute to or determine the success and continued development of the business, also because of ISO 14001, and OHSAS 18001 requirements."*
(F)	*"For sure as we are ISO 14001 and ISO 18001 certified. Also, our business policy has long included social responsibility and sustainable development into its basic operations. By taking a proactive stance and rallying our staff, we have already made significant progress towards making our brands more creative and ethical.*

Source: Research Data

According to **Table 4.3**, all interviewees gave an affirmative response, meaning that their companies implement sustainable practices throughout their supply chain operations. **Table 4.4** summarises the drivers/motivators for implementing SSCM at these companies.

Table 4.4: Drivers of SSCM implementation:

Company code	Reasons
(A)	- ISO 14001certified (Environmental Management System) - ISO 18001 certified (Occupational Safety and Health Management System - ISO 50001 certified (Energy Management System)
(B)	- Investing in sustainable development practices - ISO 14001 certified - ISO18001 certified
(C)	- ISO 14001 certified - ISO18001 certified - Promoting products that contribute to energy conservation and do not damage the environment. - Export condition.
(D)	- ISO 14001 certified - ISO18001 certified. - ISO 50001 certified
(E)	- Belief that the implementation of a good HSE system will in turn contribute to or determine success and continuous development. - ISO 14001 certified - ISO18001 certified
(F)	- Business policy - ISO 14001 certified - ISO18001 certified

The responses from the interview participants offer significant perspectives on the factors and approaches influencing the adoption of SSCM practices within their companies. The participants highlight a significant focus on adherence to regulations and ISO standards, environmental protection, the advantages to their business operations and social responsibility.

Regarding the ISO standards, the interviewees frequently stated that ISO certifications, especially ISO 14001 (Environmental Management System), ISO 18001 (Occupational Safety and Health Management System) and ISO 50001 (Energy Management System) reveal obligations to encounter industry standards and regulations which force them to follow sustainable practices while managing their supply chains. Moreover, interviewees of company (D) stated that conforming with local laws and regulations related to occupational health and safety and environmental protection is a reason for requiring their company to follow sustainability practices.

The protection of the environment is expressed as a fundamental principle by several interviewees. For example, the representative from company (B) emphasised that environmental conservation is viewed as a passion within their organisation, as he revealed that his company prioritises investments in sustainable development just as highly as improvements to their products. Additionally, the interviewee from company (C) mentioned that the company is committed to environmental care, as he highlighted that they promote products that support energy conservation and are eco-friendly. Moreover, the company is adopting a sustainable transportation policy aimed at minimising environmental impact.

Furthermore, the interviewees revealed that adopting SSCM offers advantages to their business operations in various significant manners. For instance, the interviewee from company (C) mentioned that adopting sustainable practices provides the company a competitive advantage in the global market, appealing to those global buyers who value environmentally and ethically responsible products. Moreover, the interviewee from company (E) revealed that addressing environmental and safety risks, the company can reduce liabilities and improve overall performance.

Additionally, some interviewees recognised the importance of social responsibility and ethical practices for integration sustainability. For instance, the interviewee from company (F) revealed that by embedding social responsibility and sustainable development into the operational context of his company, particularly through a proactive approach and employee engagement, innovation and enhancing the corporate brand value can be achieved.

In relation to the barriers faced in implementing SSCM, a compilation of barriers derived from prior literature, as presented in Chapter 2, aims to assess the levels of agreement of the experts concerning these challenges within a real-world context.

Table 4.5: Interviewees' opinions of barriers to implementing sustainable supply chain management (SSCM)

Barriers for implementing SSCM.							
Higher costs of sustainability and economic condition	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**
Results			2	6		3.75	0.46
Coordination effort and complexity	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**
Results				7	1	4.12	0.35
Insufficient communication and sharing information in the supply chain	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**
Results				1	7	4.87	0.35
Low "eco-literacy"	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**
Results			5	2	1	3.50	0.75
Lack of sustainable supplier	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**
Results				1	7	4.87	0.35
Lack of understanding about environmental management/sustainability	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**
Results			1	1	6	4.62	0.74
lack of sustainability standards and appropriate regulations	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**
Results					8	5	0
Misalignment of short-term and long-term strategic goals	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**
Results			2	6		3.75	0.46
Lack of effective evaluation measures about sustainability	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**
Results			1	6	1	4	0.53
Lack of qualified staff, training and education about sustainability	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**
Results				1	7	4.87	0.35
Complex in design to reduce consumption of resources and energy	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**

Results			1	5	2	4.12	0.64
Inadequate facility for adoptions of reverse logistic practices	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**
Results			1	6	1	4.0	0.53
Inadequate industrial self-regulation	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**
Results			1	2	5	4.5	0.75
Lack of top management commitment to initiate sustainability efforts	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**
Results				2	6	4.75	0.46
Lack of motivation towards employees (incentives)	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**
			2	5	1	3.87	0.64
lack of tools and resources	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*	**Average**	**Standard Deviation**
Results		1	6	1		3.0	0.53

As shown in the table above, the interviewees' opinions were varied regarding the barriers to implementing SSCM. The barrier "lack of sustainability standards and appropriate regulations" was rated as the highest one, with an average score of 5. This indicates the implementation of sustainable standards lacks robust legislative backup and inadequate governmental support.

After this, the barriers "Lack of sustainable supplier", "Insufficient communication and sharing information in the supply chain" and "Lack of qualified staff, training and education about sustainability" provided the following high score of 4.8. Consequently, it is imperative for organisations to establish comprehensive methodologies for the identification and evaluation of suppliers which prioritise sustainability performance. Moreover, organisations must manage their supply chains from the perspective of "supply chain transparency" to facilitate efficient information sharing and communication. Supply chain transparency refers to the act of revealing comprehensive and precise details regarding operations and products, including aspects such as their source and procurement, production methods, expenses and distribution processes (Bai and Sarkis, 2020). Organisations also have to equip employees with the essential training and knowledge to comprehend and apply sustainable practices.

- **Managing the Circular Economy (CE)**

The next section was designed to examine if the interviewees' companies thought about assessing CE in their operations. They also gave a justification for whether they were assessing CE or not. All interviewees concurred that their organisations have their own circularity ideologies, which are displayed **Table 4.6**.

Table 4.6: Interview statements related to managing CE:

Company code	Statement
(A)	*"Sure, indeed, our company provides the newest technology in industrial wastewater treatment and reuses it and recycling for solid waste as well. This is because our company already has a waste management system in place, which is the full process of managing wastes in a way that tracks their environmental impact performance across their entire existence"*
(B)	*"Yes, via recycling solid waste and considering them for using as raw materials for other industries, also we have water-treatment facility for recycling water. This is because our company is ISO 14001 accredited, and our manufacturing facilities comply with internationally recognised environmental regulations for waste management."*
(C)	*"Yes, as we are ISO 14001 certified, our company seeks to use recyclable or/and renewable materials wherever possible to align our environmental policy."*
(D)	*"Yes, as our company is ISO 14001 certified, we have a waste management philosophy. We are trying to avoid waste through operations or management, reuse the materials or products that are already made to be reusable and convert the waste into usable forms."*
(E)	*"Yes, as we are complying with the country's law regarding disposal of hazardous material, we are selling the non-hazardous waste to one of our contractors to be recycled, and the hazardous wastes are sent to a landfill area. And for sure that our company is ISO 14001 certified"*
(F)	*"Yes, as our company policy committed in its sustainable packaging policy follows the circular economy concept of its packaging materials, and our company is also dedicated to growing its usage of recycled materials. As part of a circular economy, we are also assisting in the development of industries that sort waste and create sustainable supply chains".*

Source: Research Data

According to **Table 4.6**, all interviewees gave an affirmative response, meaning that their companies follow the CE concept. **Table 4.7** summarises the reasons for CE management at these companies.

Table 4.7: Reasons for managing Circular Economy (CE):

Company code	Reasons
(A)	- Waste management system.
(B)	- ISO 14001 certified - Environmental regulation for waste management.
(C)	- ISO 14001 certified
(D)	- ISO 14001 certified
(E)	- ISO 14001 certified - Complying with the country's law regarding disposal of hazardous material
(F)	- Business Policy

- **Current Supplier Selection:**

It was evident from the earlier conversations with the interviewees that each one is taking sustainability and circularity into account in their business practices. As a result, they were asked how they were currently selecting their suppliers or whether they were taking both ideas (sustainable and circularity) into account. The findings revealed that every interviewee said they utilise a "checklist" and particular form to guarantee and check certain criteria, including consistent supply, product quality, delivery dates, and payment options. The comments from few interviewees are shown in **Table 4.8**. **Table 4.9** summarises the supplier selection criteria that each company was considering.

Table 4.8: Interviewees' statements about selecting suppliers:

Company code	Statements
(A)	*"Mainly, we evaluate our suppliers through a checklist, considering their quality, price, payment method, and delivery time. However, because our business encourages the purchase of environmentally friendly goods and services and the green economy in order to ensure sustainability, we take some environmental measures into account when examining our suppliers, such as ISO 14001 certification."*
(B)	*"We are selecting our suppliers upon inspection for quality checks, quantity, delivery time and purity of materials "*
(C)	*"Our suppliers are selected based on cost and flexibility of payment terms, time, delivery time and services."*
(D)	*"Our company selects suppliers according to the price, quality of goods and delivery time. We ensure the commitment of all our suppliers to continual improvement by applying procedures that improve health and safety to sustainability and business superiority"*
(E)	*"By testing suppliers' performance through a checklist considering quality, prices, and product specification conformance. Regarding sustainability, we choose our suppliers according to their conformance to the highest standards of environmental management and health and safety. We require a code of performance from our suppliers to ensure that all equipment, materials, plants, and machinery are safe for health, safety, and the environment and are maintained to an acceptable standard. In some cases, our technical department deals directly with the suppliers on site for inspection".*
(F)	*"We choose our suppliers objectively based on transparent criteria, including quality, price, delivery service, technology, financial stability and the impact of the given goods and services on the environment and society."*

Source: Research Data

Table 4.9: Criteria for selecting suppliers.

Company Code	Criteria for selecting suppliers
A	- Quality - Price, payment method - Delivery time - ISO 14001
B	- Quality - Quantity - Delivery time - Purity of materials
C	- Price - Quality - Flexibility of payment terms - Delivery time and services.
D	- Price - Quality of goods,

	- Delivery time - Health and safety commitment
E	- Quality - Prices, - Product specification - Conformance to the highest standards of environmental management and health and safety
F	- Quality, - Price - Delivery service - Technology - Financial stability - The impact of the goods and services given on the environment and society

The insights gathered from the respondents in Table 4.10 indicate that even though their organisations hold certifications in ISO 14001 and ISO 18001, which reflect a dedication to environmental management as well as health and safety, their criteria for supplier selection do not explicitly include sustainability and CE perspectives, as most tend to emphasise more conventional factors, such as Price, Quality, Payment term flexibility, Delivery schedules and services. This discrepancy highlights the inconsistency between their stated objectives and actual practices. Such inconsistency could also negatively influence the overall performance of SSCM.

Furthermore, this reflects the participants' opinions when identifying that the "a lack of sustainability standards and suitable regulations" is the primary barrier to implementing SSCM. The absence of clear and consistent external regulations can create uncertainty and impede the integration of sustainable practices across the supply chain, leading companies to have difficulty in determining what qualifies as a "sustainable" supplier. Consequently, this can result in varying practices and subjective assessments.

This supported the motivational need for the main contribution of this study, which is proposing a **Sustainable Circular Supplier Selection (SCSS) Model** for both real life corporate practices to be considered as a guide for manufacturing firms to follow when selecting their suppliers and for academic contribution by adding a new model for supplier selection towards sustainability and CE contexts.

- **Recommending sustainable circular supplier selection criteria:**

At the final stage of the interviews, the researcher of this study presented the interviewees with a list of 24 supplier selection criteria based on four dimensions (Economic, Environment, Social and Circular), as shown in **Table 4.10**, that was compiled by the researcher from previous literature and then asked them to suggest, based on their experience, any other criteria for selecting suppliers that may improve the process of selecting suppliers towards sustainability and CE contexts to be added to the list.

Table 4.10: Sustainable Circular Supplier Selection Criteria based on previous literature:

Sustainable Circular Supplier Selection Criteria			
Economic	**Environment**	**Social**	**Circular**
- Cost (EC1) - Quality (EC2) - Delivery time and services (EC3) - Flexibility (EC4)	- Environmental Management System (ENV1) - Green Product (ENV2) - Green Transportation (ENV3) - Life cycle cost management (ENV4) - Involvement in initiatives for carbon management (ENV5) - Carbon accounting and inventory (ENV6) - Green Technology (ENV7) - GHG Emissions (ENV8) - Carbon Disclosure and report (ENV9)	- Training related carbon management (SO1) - Workers' rights (SO2) - Occupational Health & Safety (SO3) - Society's rights/Social responsibilities (SO4) - Information Disclosure (SO5) - Supportive Activities (SO6)	- Eco-friendly raw materials (CR1) - Respecting environmental standards and regulations in the process of recycling (CR2) - Air pollution resulting from recycling process (CR3) - Clean technology for recycling (CR4) - Eco-friendly packaging (CR5)

Source: Conducted by the researcher of the study from previous literature.

Most of the interviewees did not suggest any other criteria; however, only one interviewee of Company (F) suggested that the Financial Stability and Reverse Logistics Agreement were critical to deal with suppliers in order to improve procurement sustainability and CE performance. The interviewee's statement about the suggestion was as follows:

*“**Financial Stability** is crucial, because supplier ‘s loss might be an unsuccessful event, as when a key supplier going out of business this may affect our entire supply chain. Moreover, financial stability gives our suppliers several opportunities, as they can more easily obtain new manufacturing tools and technologies and better supply rates by negotiating exclusive material deals as higher quality and more efficient production are frequently the results of new equipment. As a result, our bottom line improves when those factors come together.”*

*“… regarding **Reverse Logistics agreement**, I think it may improve the circular economy practices for our supply chain, via establishing an agreement between our company and the suppliers for managing any returns of the excess purchased items back to these suppliers, which will help us also to minimise waste and disposables. The agreements will consider as promised undertakings that seek to guarantee that excesses return to the suppliers’ manufacturer through reverse logistics.”*

After the suggestion of the interviewee regarding the two criteria, the **"***Financial Stability"* and *"Reverse Logistics agreement",* the researcher returned to search in previous literature about the supplier selection area to explore whether these two criteria had already been mentioned in previous literature or not, and it was found that "*Financial Stability" has* already been mentioned in previous literature by Suraraksa and Shin (2019), however, the criterion "*Reverse Logistics agreement"* was not mentioned in any of the previous literature.

Accordingly, the researcher of the study used them in the next steps of the research process, and made a definition based on the discussion with the interviewee for the “*Reverses Logistics agreement” criterion as: “Assessing the suppliers' expertise and abilities in managing reverse logistics operations to ensure product circularity”*

As a result, concluding "*Reverse Logistics agreement"* **in the proposed SCSS Model as a supplier selection criterion for the first time.**

4.3 A Validation Questionnaire “Importance and Applicability Questionnaire”:

After analysing the results of the semi-structured interviews mentioned above, an “Importance and Applicability Questionnaire" was adopted to validate a list of proposed selection criteria to be used in the proposed **SCSS Model** (24 criteria from the literature review and 2 from the in-depth semi-structured interviews' results: Financial Stability (EC5) and Reverse Logistics Agreement (CR6)). The questionnaire aims to measure the degree of importance and applicability of each selection criteria towards sustainability and CE in a real-life context. The questionnaire structure will be presented in Appendix II.

The importance level was analysed to determine the degree of perceived importance, whereas the applicability showed whether the criteria could be applied in real practice. Fallahpour *et al.*, (2017) recommended that by measuring the importance and applicability of the criteria, decision makers can verify which criteria have the greatest influence on suppliers' sustainability performance. Thus, this was also considered as another contribution of this study by determining the importance and applicability of the sustainable and circular supplier selection criteria through a questionnaire-based survey. To measure the importance and applicability levels, a 5-point Likert scale was used as it can reduce the confusion of the interviewees and increase the response rate (Taherdoost, 2019). Concerning importance, the scale ranges from 1 (*not at all important)* to 5 (*extremely important).* For applicability, the scale ranges from 1 (*not applicable)* to 5 (*extremely applicable)*. A reliability test and descriptive statistics were used to analyse the data.

- **Questionnaire Results:**

Based on the analysis of results of the "Importance and Applicability Questionnaire", the criteria were finally selected and included in the proposed SCSS model, with respect to the following inclusion criteria:

- First: The Relative Importance Index (RII) assigned to each criterion should belong to the categories of either (High-Medium) or (High) level scores to ensure that the criteria are vital and important for performing sustainable circular supplier selection. This is based on the decision rule utilised by (Ismail *et al.* , 2015), where the RII scores regarding the (H) and (H-M) categories are deemed to have a substantial contribution.
- Second: To guarantee that each criterion, categorised as either (High-Medium) or (High) level scores, is applicable for implementation when evaluating suppliers in real-life contexts. This implies that the criterion must demonstrate a positive correlation between its level of importance and the degree of applicability. This will be determined through the Mann-Whitney U test . Therefore, the p-value should be larger than 0.05.

The results of the “importance and applicability” mean scores, Cronbach’s alpha, RII and Mann-Whitney U-test are shown in **Table 4.11**.

Table 4.11: Results of RII and Mann Whitney U test for Importance and Applicability measures:

Dimension	Criteria	Importance Mean Score	Applicability Mean Score	Importance Cronbach’s alpha	Applicability Cronbach’s alpha	RII	Mann Whitney U test *P-Value*
Economic	EC1	4.307	4.51	0.756	0.757	0.86 (H)	0.141
	EC2	4.78	4.71	0.746	0.752	0.95 (H)	0.502
	EC3	4.11	4.09	0.746	0.764	0.82 (H)	0.681
	EC4	3.57	3.48	0.753	0.771	0.71 (H-M)	0.610
	EC5	3.50	3.44	0.758	0.767	0.7 (H-M)	0.727
Environmental	ENV1	4.51	4.28	0.743	0.757	0.9 (H)	0.070
	ENV2	4.34	4.09	0.752	0.763	0.86 (H)	0.067
	ENV3	3.55	3.57	0.748	0.759	0.71 (H-M)	0.872
	ENV4	2.82	2.80	0.763	0.770	0.56 (M)	0.960
	ENV5	3.59	3.17	0.755	0.769	0.71 (H-M)	0.015
	ENV6	3.25	2.78	0.750	0.769	0.65 (H-M)	0.013
	ENV7	3.82	3.57	0.756	0.771	0.76 (H-M)	0.103
	ENV8	4.36	4.15	0.755	0.763	0.87 (H)	0.147
	ENV9	3.84	3.51	0.762	0.762	0.76 (H-M)	0.053
Social	SO1	3.69	3.34	0.753	0.765	0.73 (H-M)	0.080
	SO2	3.71	3.40	0.758	0.765	0.74 (H-M)	0.105
	SO3	3.76	3.57	0.746	0.769	0.75 (H-M)	0.177
	SO4	3.71	3.46	0.749	0.760	0.74 (H-M)	0.087
	SO5	3.92	3.63	0.754	0.775	0.78 (H-M)	0.096
	SO6	3.86	3.42	0.744	0.773	0.77 (H-M)	0.013
Circular	CR1	4.28	3.98	0.752	0.768	0.85 (H)	0.071
	CR2	4.44	4.21	0.741	0.767	0.88 (H)	0.085
	CR3	4.07	3.80	0.753	0.760	0.81 (H)	0.071
	CR4	3.96	3.78	0.738	0.756	0.79 (H-M)	0.312
	CR5	4.28	4.03	0.742	0.766	0.85 (H)	0.075
	CR6	3.88	3.73	0.747	0.765	0.77 (H-M)	0.417

- **Results of Relative Importance Index (RII):**

As mentioned above, the RII was taken as the first condition for including the criteria in the proposed **SSCS Model**. RII was used to determine the relative importance of the proposed criteria. The RII ranges from 0 to 1, with 0 not inclusive. It shows that the higher the value of RII, the more important the sustainable circular criteria were and vice versa.

Regarding the RII analysis based on the results in **Table 4.11**, it was shown that 10 criteria were having High (H) importance levels for sustainable circular supplier selection criteria with RII values between 0.80 and 0.95. These criteria were EC1, EC2, EC3, ENV1, ENV2, ENV8, CR1, CR5, CR2 and CR3.

The results also showed that the "Quality" criteria was highlighted as the most important criteria with RII for 0.95, which referred to a previous study done by (Stevic, 2017). Moreover, it had been noticed that 15 criteria had Medium-High (M-H) levels with RII values between 0.65 and 0.79 (as shown in **Table 4.11**). These criteria were EC4, EC5, ENV3, ENV5, ENV6, ENV7, ENV9, SO1, SO2, SO3, SO4, SO5, SO6, CR4 and CR6. The remaining criterion that had Medium (M) importance RII levels, was "ENV4" with RII score 0.56. This criterion was the only criterion that did not match the first condition to be included in the proposed **SCSS Model**, as its RII value was indicated as a (M) level.

Therefore, only 25 criteria with RII values (H) and (H-M) will be filtered for the second condition analysis (Mann-Whitney U test). The analysis aims to establish a possible relationship between their importance mean scores and applicability means scores. This process guarantees that the identified criteria are both important and applicable for usage in practical circumstances.

- **Results of Mann Whitney U test for Importance and Applicability measures:**

As mentioned above, the significance of the difference between the two sets (importance and applicability) of data's mean scores was determined using the Mann-Whitney U-test (Ho = the importance and applicability of the criterion should be statistically equal). The test was carried out in order to verify that the criteria classified as (H) and (H-M), based on their RII, can also be applicable to be utilised in practical circumstances.

This non-parametric test was carried out with the use of SPSS software. The results of the importance mean scores, applicability means scores, Cronbach's alpha and Mann-Whitney U-test had been showed in **Table 4.11**. The results showed that the *p*-value of 23 criteria was greater than 0.05, which indicates no significant distinction between the average scores of the importance and applicability of each of the 23 criteria. This means that there is a strong correlation between the importance and applicability of the 23 criteria. On the other hand, only 3 criteria (as highlighted in yellow in the above table) had *p*-values less than 0.05, which are involvement in initiatives for carbon management, carbon accounting and inventory and supportive activities, with p-values of 0.015, 0.0134 and 0.013, respectively. This means that there is a statistical difference between the results of the importance and applicability levels of these criteria. Hence, they were not included in the criteria of the proposed **SCSS Model**, as they did not match one of the two conditions, i.e., *p*-value > 0.05, to be included in the next research process.

The results showed that Cronbach's alpha for importance level was 0.758, and the applicability level was 0.772. Therefore, the results for both sets (importance and applicability) showed that the alpha was above the accepted level (0.7).

- **Interpretation of Questionnaire Results:**

As mentioned earlier in the evaluation of the RII results, there were 25 criteria classified as (H) and (H-M); however, the findings from the Mann-Whitney U test reveal that only 22 of these criteria exhibited a positive correlation (p-values greater than 0.05). Consequently, the following 22 criteria will constitute the definitive list of sustainable circular criteria that will be employed in the upcoming research process to propose the SCSS Model utilising the FUZZY-DEMATEL technique, as these criteria have been recommended by the expert panel based on their significance and applicability in real-world circumstances. This signifies that based on this stage of the research process, four criteria have been omitted as they failed to meet the two requirements for selecting the criteria, which are the RII (H-M) and (H) classifications, along with the positive correlation between their importance and applicability mean scores determined by the Mann-Witney U test. **Table 4.12** lists the four criteria as well as the reason for exclusion.

Table 4.12: The Excluded Criteria:

Criteria	**RII (H-M) or (H)**	***p*-value > 0.05**
Life cycle cost management (ENV4)	(M): Reject	0.960: Accept
Involvement in initiatives for carbon management (ENV5)	(H-M): Accept	0.015: Reject
Carbon accounting and inventory (ENV6)	(H-M): Accept	0.013: Reject
Supportive activities (SO6)	(H-M): Accept	0.013: Reject

Source: Questionnaire of measuring importance and applicability results

The table above shows that the criterion ENV4 did not satisfy the RII condition as its level is (M); however, it did comply with the condition regarding the p-value >0.05. ENV4 refers to the integration of life cycle cost management into GHG emissions reduction, which aims to predict future costs, a process that can be uncertain and challenging to forecast. This unpredictability may complicate the justification for employing life cycle costs in decision-making and pose difficulties for practitioners when selecting among suppliers (Kambanou, 2020).

Regarding the criteria ENV5 and ENV6, they fulfilled the RII condition with levels (H-M) yet did not satisfy the p-value condition since both had a p-value lower than 0.05. This suggests that both criteria demonstrate significance in the supplier selection process concerning sustainability and CE, but they pose challenges when evaluated in real-world scenarios.

Since ENV5 and ENV6 both pertain to carbon data from suppliers, they share common challenges that complicate their assessment by purchasing firms, as both are contingent upon "Carbon Transparency." Carbon transparency pertains to the provision of comprehensive carbon emission information to relevant stakeholders (Ott *et al*., 2017). Promoting carbon management transparency within supply chains presents significant challenges, as supplier companies frequently engage in voluntary disclosure programs in a superficial level (Jira and Toffel, 2013). However, such involvement may not necessarily result in meaningful transparency (Marquis *et al.*, 2016). For example, suppliers may refrain from addressing pertinent inquiries or they might restrict the dissemination of information to a select group of stakeholders (Stanny, 2013). This conduct hinders stakeholders (such as buying companies, NGOs and policymakers) from forming precise assessments regarding the supplier's carbon management objectives and the initiatives implemented to reach them (Villena and Dhanorkar, 2020). Consequently, businesses must enhance their disclosure and reporting strategies with efforts aimed at understanding the specific requirements of their suppliers while actively assisting them in establishing and fulfilling their own goals. By collecting information about suppliers' environmental objectives, initiatives and accomplishments, particularly in carbon management, companies can leverage these data to develop carbon-footprint labels for their products (Weele and Tubergen, 2017).

Regarding SO6, which assesses the Supplier's adherence to supportive workplace activities, discrimination, professional development and sensitivity to religious and cultural matters in the workplace, buying companies frequently possess restricted direct insight into the workplaces and operations of their suppliers. This limitation can hinder the evaluation of working conditions, employee welfare initiatives and other supportive measures.

Concerning the new criterion that will be introduced for the first time in a supplier selection model, known as the "Reverse Logistics Agreement," it meets all the requirements to be incorporated into the proposed SCSS Model of this research. This indicates that the experts who participated in this questionnaire unanimously agreed to recognise this criterion as a criterion for supplier selection towards sustainability and CE perspectives.

The final list of the 22 criteria that will be included in the next phase of the study to be used for FUZZY-DEMATEL technique will be presented in **Table 4.13**.

Table 4.13: The final list of Sustainable Circular Supplier Selection Criteria:

Dimension	Criteria	Description
Economic	Cost (EC1)	The elements that reflect every expense and the cost of the purchased products.
	Quality (EC2)	The degree of excellence of supplied material
	Delivery time and services (EC3)	The supplier's efforts to deliver the material and address any issues with it for the customer
	Flexibility (EC4)	The supplier's degree of flexibility in supplying material and payment.
	Financial Stability (EC5)	The supplier's financial situation based on the supplier's annual revenue and their financial structure as determined by their prior performance.
Environmental	Environmental Management System (ENV1)	Supplier's environmental management efforts and environmental management systems related certification.
	Green Product (ENV2)	How much of the supplier's goods are green.
	Green Transportation (ENV3)	Reducing environmental harm when transporting the required order.
	Green Technology (ENV4)	The technologies employed to produce eco-friendly products.
	GHG Emissions (ENV5)	Chemicals and gases released during product manufacturing.
	Carbon Disclosure and report (ENV6)	Reports on greenhouse gas emissions
Social	Training related carbon management (SO1)	To increase environmental awareness among employees, appropriate education and training initiatives must be conducted.
	Workers' rights (SO2)	Respect for workers' rights by the supplier, including employment insurance, set working hours, and benefits
	Occupational Health & Safety (SO3)	Efforts made by the supplier to ensure the health and safety of their workforce, including medical insurance, safety training, and the provision of the necessary tools.

	Society's rights/Social responsibilities (SO4)	Suppliers' capacity to advance sustainability, including social responsibility and cleaner production.
	Information Disclosure (SO5)	Providing details on the materials used, carbon emissions, and toxins emitted during production to the supplier's customer and other interested parties.
Circular	Eco-friendly raw materials (CR1)	Making use of recyclable raw materials to produce products.
	Respecting environmental standards and regulations in the process of recycling (CR2)	Using environmental standards during the recycling process.
	Air pollution resulting from recycling process (CR3)	When recycling products, taking into account reducing air pollution.
	Clean technology for recycling (CR4)	Using appropriate and environmentally friendly technology to recycle the returned goods
	Eco-friendly packaging (CR5)	Using recyclable materials in packaging.
	Reverse Logistics agreement (CR6)	The suppliers' expertise and abilities in managing reverse logistics operations to ensure product circularity.

4.4 Chapter Conclusion:

This chapter explains the investigation of the process of sustainable circular supplier selection in real-life corporate practices through conducting semi-structured interviews with a panel of experts. The results of the semi-structured interviews indicated that there is a lack of a proper tool to manage sustainable circular supplier selection; therefore, this strengthens the knowledge gap found in the literature review part of this study from practitioners' opinions. Moreover, there were two criteria that were recommended by the participants of such semi-structured interviews to be added to the list of criteria for selecting suppliers towards sustainability and CE contexts. There are two criteria: "Financial Stability" and "Reverse Logistics Agreement".

In addition, based on a thorough literature review and the findings of the semi-structured interviews, a set of 26 sustainable circular supplier selection criteria with four main dimensions—economic, environmental, social and circular—were assessed for their relative importance levels as well as the relation between their importance and their applicability to be used in real-life corporate practices through a questionnaire with 52 industrial experts from the MENA region.

The goal of this assessment questionnaire is to select the most important and useful sustainable circular supplier selection criteria that would be used next in the research process of this study, which is building an approach for selecting suppliers towards sustainability and CE using a multi criteria decision making approach called FUZZY-DEMATEL, which measures the interdependency relationship among criteria. The criteria were selected from the questionnaire results under two conditions: their RII levels and their *p*-value. The results showed that only 22 criteria met the two conditions.

Regarding the previously mentioned new criterion, the "Reverse Logistics Agreement" that will be the first time to be included in a supplier selection model. It matched all of the requirements (RII levels and p-value) to be included in the SCSS Model that this study proposed. This indicates that the experts who participated in this questionnaire were all given the go-ahead to use this criterion when selecting suppliers in the contexts of sustainability and the CE.

In the next chapter, it will be explained in detail how the FUZZY-DEMATEL technique was used in this study to measure how the criteria depend on each other.

CHAPTER 5

Development of Sustainable Circular Supplier Selection Model using FUZZY-Decision Making Trial and Evaluation Laboratory (FUZZY-DEMATEL) Technique

5.1 Introduction

As presented in chapters 2 and 4, both literature review and questionnaire analysis results have suggested that there is a lack of academic as well as practical knowledge in evaluating and selecting suppliers in both sustainability and circular economy (CE) contexts. Therefore, a reliable yet practical approach is needed to help businesses evaluate and select the best possible supplier in a structured manner.

Chapter 5, thus, aims to demonstrate the process of developing and measuring the interdependency relationship among a list of 22 criteria, which has been already discussed in Chapter 4. This chapter is organised as follows. Section one recalls the Research Objective (RO) and its associated Research Questions (RQ) that will be accomplished in this chapter. Section two presents the "Multi Criteria Decision Making (MCDM)" approach utilised to evaluate the interdependency relationship among the 22 criteria for supplier selection, known as "FUZZY-DEMATEL (FUZZY-DEMATEL)," and rationalises its selection results by comparing it with other MCDM methods. Section three explains the integration of the FUZZY-DEMATEL technique into the proposed Sustainable Circular Supplier Selection Model (SCSS Model) through a step-by-step approach. Section four summarises the outcomes of the SCSS Model development. **Table 5.1** describes Research Objective 3 (RO3) and its Research Questions 3 (RQ3).

Table 5.1 Research Objective 3 (RO3) and its related Research Questions 3 (RQ3):

(RO3)	(RQ3)
To develop a model for supplier selection criteria towards sustainability and CE using the FUZZY-DEMATEL technique to measure the interdependency relationship among the proposed criteria.	What is the influence of individual criteria on the interconnected criteria that affect the process of making decisions regarding the sustainable circular selection of suppliers?

5.2 Implementation of FUZZY-DEMATEL:

The application of the FUZZY-DEMATEL technique is shown in this section; each of the major steps is discussed below.

Step 1**:** A panel of 20 experts from the industrial sector was involved to determine the pairwise comparison to analyse the interdependency relationship among the 22 sustainable and circular supplier selection criteria, as shown in Chapter 4 **Table 4.13**.

Step 2: Experts made pair-wise comparisons between the criteria of sustainable and circular supplier selection using the scale provided in Chapter 3 **Table 3.9** to figure out the interdependencies among the criteria. The direct relationship matrix is shown in Appendix VI.

Step 3**:** The normalised fuzzy direct-relation matrix was attained using **Equation 3** explained in chapter 3. Appendix VII indicates the normalised fuzzy direct-relation matrix.

Step 4**:** The normalised matrix the inverse was first calculated, and then it is subtracted from the matrix I, and finally the normalized matrix is multiplied by the resulting matrix. Appendix VIII shows the fuzzy total relation matrix.

Step 5**:** Appendix IX shows the crisp total-relation matrix.

Step6**:** The summation of rows (D) and the summation of columns (R) of the sustainable circular supplier selection criteria were calculated by using the Equations (3.9) and (3.10) explained in chapter 3.

Step 7**:** The dataset (D+R) which refers to the “Prominence” and (D-R) which refers to the “Relation” of the sustainable circular supplier selection criteria were calculated. Therefore, by taking both the “Prominence” and the “Relation” into account, the study obtained the priority of each criterion’s importance in the dataset of the SCSS Model. As will be presented in this chapter, **Table 5.2** and **Figure 5.2** will show the results of the FUZZY-DEMATEL of the 20 experts. The “Causal-and-Effect” diagram delivers useful insights to evaluate each of the 22 criteria. Such diagram can help experts to uncover those criteria that have the most impact on the outcomes of supplier selection decisions, and thus, more attention can be made on the most influential criteria rather than all of them.

5.3 Results and Analysis of FUZZY-DEMATEL:

This section comprises the following two subsections:

(1) Section 5.3.1 "Depicting the "Cause-and-Effect" diagram of the sustainable circular supplier selection criteria":

This subsection clarifies how the "Cause-and-effect" diagram, which identifies the interdependency relationship among criteria of the sustainable circular supplier selection, has been represented based on the results derived from the previously outlined steps of the FUZZY-DEMATEL implementation.

(2) Section 5.3.2 "Analysing the "Cause-and-Effect" diagram of the sustainable circular supplier selection criteria":

This subsection presents the findings from the "Cause-and-Effect" diagram concerning sustainable circular supplier selection, along with the four quarters of criteria, represented in **Figure 5.1**, which employed by Si *et al*. (2018), aimed at enhancing the comprehension of the interdependency relationships among the criteria based on their prominence and relation.

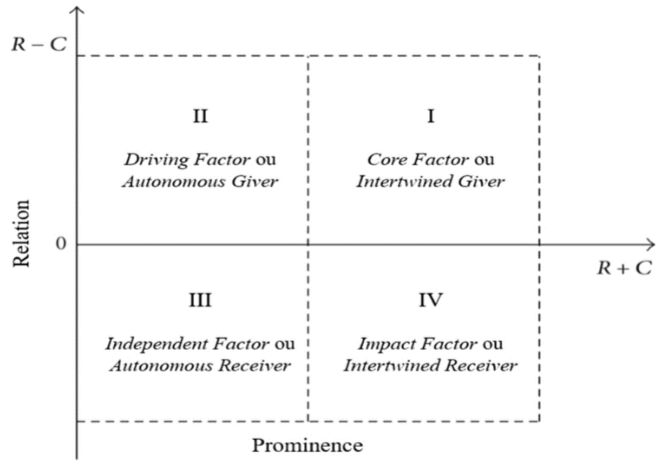
5.3.1 Depicting the "Cause-and-effect" diagram of the sustainable circular supplier selection criteria:

The "Cause-and-effect" diagram is a scatter graph with two major axes. While the horizontal axis is presented by "Prominence" values, the vertical axis is illustrated, using the indicator of the "Relation", which presents the net effect. **Table 5.2** presents the 22 sustainable circular supplier selection criteria, their vectors R and D, as well as their indices of the Prominence (D+R) and Relation (D-R). Notably, when the (D-R) value is positive, it indicates cause criteria, whereas a negative value signifies effect criteria. Furthermore, based on these values of (D+R) and (D-R), the "cause-and-effect" diagram has been drawn in **Figure 5.2.**

Table 5.2. Calculations (D+R) and (D-R) datasets of the sustainable circular supplier selection criteria

Criteria	R	D	D+R	D-R	Cause/Effect
EC1	1.692	0.57	2.262	-1.121	Effect
EC2	1.749	1.647	3.396	-0.103	Effect
EC3	1.085	0.65	1.734	-0.435	Effect
EC4	0.766	0.634	1.4	-0.132	Effect
EC5	0.279	1.632	1.911	1.352	Cause
ENV1	1.974	2.013	3.986	0.039	Cause
ENV2	1.738	1.705	3.443	-0.032	Effect
ENV3	1.296	1.045	2.34	-0.251	Effect
ENV4	0.792	2.112	2.905	1.32	Cause
ENV5	1.821	1.87	3.691	0.049	Cause
ENV6	1.572	1.15	2.721	-0.422	Effect
SO1	1.278	1.632	2.911	0.354	Cause
SO2	1.072	1.045	2.117	-0.028	Effect
SO3	1.56	1.686	3.246	0.126	Cause
SO4	1.73	1.423	3.153	-0.308	Effect
SO5	1.17	1.406	2.576	0.236	Cause
CR1	1.643	1.377	3.02	-0.266	Effect
CR2	1.447	1.576	3.023	0.13	Cause
CR3	1.701	1.848	3.55	0.147	Cause
CR4	1.511	1.795	3.307	0.284	Cause
CR5	1.387	0.915	2.302	-0.471	Effect
CR6	1.531	1.065	2.596	-0.466	Effect

Figure 5.1. The Four Quarters of DEMATEL by Si *et al. (2018)*.



The criteria of each quarter are classified as follows:

- Quarter I(**QI**): The criteria located in QI are classified as **core criteria** or intertwined contributors due to their high prominence and high relations.
- Quarter II (**QII**): The criteria located in QII are classified as **driving criteria** or autonomous giver as they possess low prominence but high relation.
- Quarter III (**QIII**): The criteria located in QIII are classified as **independent criteria** or autonomous receivers due to their low prominence and relation.
- Quarter IV (**QIV**): The criteria located in QIV are classified as **impact criteria** or intertwined receivers, being influenced by other factors and not easily enhanced directly, as they have high prominence but low relation.

These quarters play a crucial role in organising the criteria into distinct groups, each having a significance-based priority during the process of sustainable circular supplier selection. In **Figure 5.1,** the quarters begin with **QI,** which is the upper right-hand quarter; then **QII,** which is the upper left-hand quarter; followed by **QIII,** which is the lower left-hand quarter; and ends at **QIV,** which is the lower right-hand quarter. Regarding the priorities of the criteria in each quarter, they have been established based on their positions within the range that their group covers on the horizontal axis of prominence. By applying the principle outlined by Costa *et al.* (2019), the criterion located farther to the right is considered more prominent. According to Si *et al.* (2018), the classifications of the results of FUZZY-DEMATEL for each quarter are illustrated below in **Figure 5.2**. Meanwhile, **Table 5.3** provides a summary of the four quarters of the criteria, along with their "cause-and-effect" diagram from FUZZY-DEMATEL and the prioritisation of the criteria for each quarter.

Figure 5.2. The cause-and-effect diagram of the sustainable circular sustainable selection criteria.

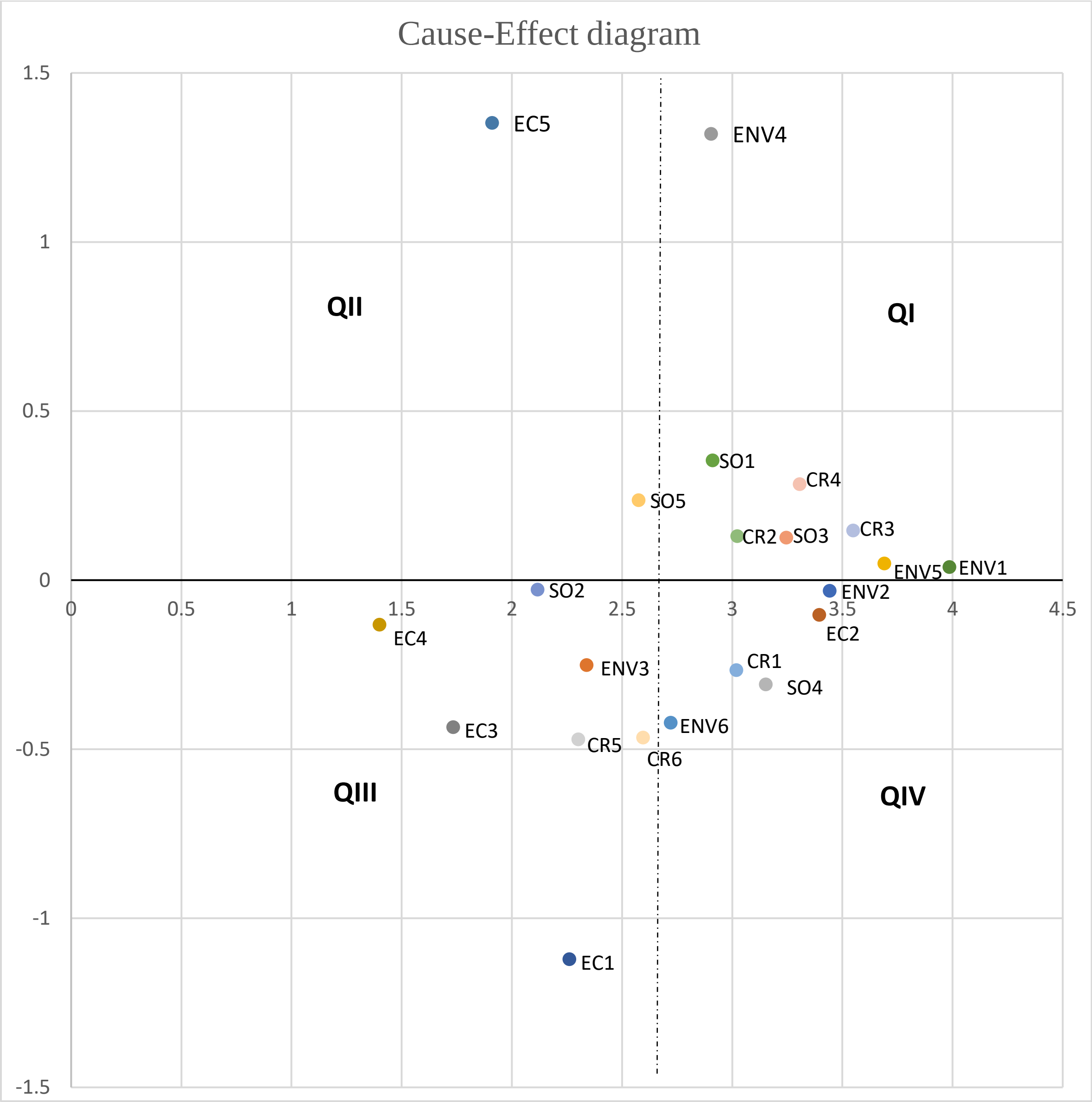


Figure 5.2 reveals the presence of the vertical axis, shown as a dotted line, which illustrates the average prominence. By following the procedures of DEMATEL (Akal and Kineber, 2022), the position of this axis on the causal diagram is the average of the "prominence" (D+R) values of

the 22 criteria, which equals to 2.79. With this axis as a reference point, particularly where it intersects the prominence's horizontal axis, the causal diagram can be segmented into four quarters.

Table 5.3 Characteristics of the four quarters of the sustainable circular supplier selection criteria.

Quarter No.	Location of the "Quarter" on the cause-and-effect diagram	Criteria of the Quarter	Prominence value (D+R)	Priority of the criterion in its Quarter
QI	The upper right-hand quarter	ENV1	3.986	1st
		ENV5	3.691	2nd
		CR3	3.55	3rd
		CR4	3.307	4th
		SO3	3.246	5th
		CR2	3.023	6th
		SO1	2.911	7th
		ENV4	2.905	8th
QII	The upper left-hand quarter	SO5	2.576	1st
		EC5	1.911	2nd
QIII	The lower left-hand quarter	CR6	2.596	1st
		ENV3	2.340	2nd
		CR5	2.302	3rd
		EC1	2.262	4th
		SO2	2.117	5th
		EC3	1.734	6th
		EC4	1.40	7th
QIV	The lower right-hand quarter	ENV2	3.443	1st
		EC2	3.396	2nd
		SO4	3.153	3rd
		CR1	3.02	4th
		ENV6	2.721	5th

5.3.2 Analysing the "Cause-and-effect" diagram of the sustainable circular supplier selection criteria:

The FUZZY-DEMATEL "cause-and-effect" diagram, as shown in Figure **5.2**, presents various findings that can be explored from various perspectives regarding the sustainable circular supplier selection process. The horizontal axis represents the (D+R), which represents the "Prominence" value of each criterion to specify its significance regarding the whole sustainable circular supplier selection process. According to the axis, the "Prominence" values range from 3.986 to 1.4. Furthermore, along this axis from the far right to the far left, the criteria can be ranked based on their level of significance from the highest to the lowest: ENV1, ENV5, CR3, ENV2, EC2, CR4, SO3, SO4, CR2, CR1, SO1, ENV4, ENV6, CR6, SO5, ENV3, CR5, EC1, SO2, EC5, EC3, and EC4.

On the vertical axis, each criterion is displayed along with its (D-R) value, which represents the "Relation" value of each criterion to specify its net effect on the overall sustainable circular supplier selection process. Depending on this axis, the (D-R) scores of the criteria vary from -0.471 to 1.352. Following this range from (D-R) =1.352 to (D-R) = -1.121, the sorting of the criteria in descending order of their (D-R) values are EC5, ENV4, SO1, CR4, SO5, CR3, CR2, SO3, ENV5, ENV1, SO2, ENV2, EC2, EC4, ENV3, CR1, SO4, ENV6, EC3, CR6, CR5 and EC1. Furthermore, regarding whether the sign associated with the "Relation" values of the criterion is positive or negative, the criterion may be described as either a net cause or a net effect of the other criteria for the selection of sustainable circular suppliers. Precisely, this categorisation can be delineated based on the point of intersection between the horizontal and vertical axes of "Prominence" and "Relation". As illustrated in **Figure 5.2**, 10 criteria (45%) lie above the horizontal axis of the prominence. Among them are **ENV1, ENV5, CR3, CR4, SO3, CR2, SO1, ENV4, SO5 and EC5**, all indicating elements considered as **cause** set due to their positive signs in the (D-R). On the other hand, beneath the horizontal axis of the prominence lie all the remaining 12 criteria (55%), which include **ENV2, EC2, SO4, CR1, ENV6, CR6, ENV3, CR5, EC1, SO2, EC3 and EC4**, exhibiting negative values of their (D-R); these factors constitute the sustainable circular supplier selection criteria within the **effect** group. **Table 5.4** shows the cause-and-effect criteria groups.

Table 5.4 Cause and effect groups of sustainable circular supplier selection criteria:

Cause Criteria	Effect Criteria
ENV1	ENV2
ENV5	EC2
CR3	SO4
CR4	CR1
SO3	ENV6
CR2	CR6
SO1	ENV3
ENV4	CR5
SO5	EC1
EC5	SO2
	EC3
	EC4

By categorising the criteria into either "cause" or "effect" groups, a significant implication can be presented to decision-makers within the buying firms. This can enhance their understanding of the complexities involved in managing the sustainable circular supplier selection process. The implication here is that the attainment of success in the evaluation of the 22 criteria in the sustainable circular supplier selection process is closely linked to the achievement of the 10 criteria within the given **cause** group. Moreover, this facilitates suppliers in discerning the key criteria (cause criteria) that necessitate prioritisation of resources, subsequently guiding their focus towards enhancing these criteria.

5.4 Discussion and Recommendation:

This section discusses the 4 quarters of the "cause-and-effect" diagram and their related criteria, as presented in **Figure 5.2** and supported by **Table 5.3**. Additionally, it provides recommendations for enhancing the performance and the outcomes of these quarters' related criteria.

- ***Quarter I (QI):***

This quarter is the upper right-hand quarter, which represents a high degree of prominence and a strong degree of relation. Eight cause criteria were listed in this quarter, considered as the core influential criteria that affect other sustainable circular supplier selection criteria. It means that suppliers should prioritise improving these criteria. The criteria priorities of significance according to the prominence values are Environmental Mgt. Systems (ENV1), GHG emissions (ENV5), air pollution resulting from recycling process (CR3), clean technology for recycling (CR4), Occupational Health & Safety (SO3), respecting environmental standards and regulations in the process of recycling (CR2), Training Related Carbon (SO1) and Green Technology (ENV4).

It is noted that criterion "Environmental Mgt. Systems (ENV1)" has been identified as a high significant positive impact among all criteria due to its high (D+R) value 3.986. Environmental Management System is defined as a series of methodical procedures and practices that empower a supplier to reduce its environmental impacts, encompassing the structural framework of the organisation, strategic planning and execution of policies (e.g., ISO 14001 and TQEM) aimed at environmental preservation (Song *et al*, 2017). Suppliers that have obtained certifications for EMS, such as ISO14001, are able to assert that an entity has established a system of management which records its environmental facets and influences and has recognised a continual enhancement of a pollution prevention procedure over time (Villanueva-Ponce *et al.*, 2015). Acquiring this certification enables companies to enhance their eco-friendly reputation, promote environmental stewardship and gain external credibility (Ozusaglam *et al*., 2018). The manufacturing activities, such as within the suppliers activities, generate a notable quantity of waste, deplete natural resources and consume energy excessively in the event of lacking environmentally management control systems (Ong *et al*., 2019). These findings indicate that it is necessary for the supplier to be ISO 14001 certified and possess a clearly established environmental system in order to effectively implement and adhere to practices that ensure environmental conservation, so as to be preferred by purchasing companies during the sustainable circular supplier selection process.

The criterion "GHG emissions (ENV5)", came in the second place in this quarter, which is also considered one of the most important and influential criteria that affect the whole process of sustainable circular supplier selection, due to its high (D+R) value 3.691.This criterion pertains to emissions and substances released during the production and transportation of goods at the facilities of the suppliers (El Mariouli and Abouabdellah, 2019). Numerous prominent corporations in both developing and developed nations have recently initiated the adoption of strategies aimed at minimising GHG emissions to ensure their competitiveness in the international market. The failure to decrease GHG emissions may result in the termination of business relationships with suppliers and other companies (Hashmi et al, 2021). The emission of carbon dioxide (CO2) is the primary GHG emission that presents a global environmental threat (Oyewole *et al*., 2023). Therefore, suppliers must evaluate their carbon footprint capabilities and establish goals to decrease GHG emissions in their operations (Hashmi *et al*., 2021).

Moreover, the findings indicate that "air pollution resulting from recycling process (CR3)" is also identified as a significant cause criterion with high (D+R) value 3.55. This factor pertains to the degree to which suppliers are decreasing air pollution during recycling operations (Govindan *et al.*, 2020). Emissions emanating from the recycling facility have been observed to have detrimental impacts on the individuals residing in close proximity indoors. Hence, it is imperative for suppliers to oversee and regulate emissions stemming from recycling operations in order to alleviate the detrimental impacts on human health, plant life and the environment. In order to facilitate a proficient and productive air quality management and strategising process in the context of recycling operations, it is imperative to establish an "Emission Inventory" that enables the precise identification and quantification of emissions during recycling activities (Zhao *et al*., 2017). Moreover, suppliers can utilise "air pollution control system" while engaging in recycling activities in order to reduce emissions resulting from the recycling process.

The criterion "clean technology for recycling (CR4)" was identified in the findings as a significant causal criterion with high (D+R) value 3.307, indicating the assessing whether suppliers utilise appropriate and environmentally friendly technology for recycling products that are returned (Govindan *et al*., 2020). Industry 4.0 technologies, among other factors, have a beneficial impact on emissions (Ronaghi *et al*., 2020), thereby aiding in CE as highlighted by (Chauhan *et al* ., 2022). Environmental and financial performance are positively affected by these technologies (Tang *et al*., 2022). In order to attain an optimal economic efficiency, a company should implement a suitable recycling strategy or energy-saving technology, as required by regulations concerning carbon emissions (Chen *et al.*, 2017) . Moreover, it is important to take into account the use of clean and appropriate vehicles for the collection of recycling products, as it impacts transportation emission (Li *et al*., 2019). Additionally, suppliers should make use of technology in recycling processes that make use of renewable energy resources, which can be classified as "cleantech" because of its capability to produce minimal or zero emissions (Münch *et al*., 2022).

Additionally, the criterion "Occupational Health & Safety (SO3)", was highlighted in the results as a significant causal criterion that affects other criteria with high (D+R) value 3.246. This criterion refers to the evaluation of the supplier's efforts to make sure employees are healthy and safe at work, such as giving medical insurance, training for safety at work and the right tools (Luthra *et al.*, 2017). It is the aspect of the company that guarantees the welfare of all parties involved, so it is commonly expected that companies prioritise the well-being of their workers and the local communities while conducting business (Münch *et al*., 2022).

Another criterion identified as a significant causal criterion in the sustainable circular supplier selection criteria is called "respecting environmental standards and regulations in the process of recycling (CR2)", with a high value of (D+R) 3.023. This criterion assesses whether suppliers adhere to environmental standards when recycling (Govindan *et al.*, 2020). Therefore, it is crucial for suppliers to follow any environmental standards or regulations addressing recycling activities management, such as "Egyptian Environmental Affairs Agency", the regulatory body that sets the environmental action plan and supervises any violations of the environmental law including mismanagement of all waste types in Egypt. Similarly, the "Guidelines on Recycling of Solid Waste" in South Africa concentrate on the recycling aspect of a comprehensive waste management system.

Moreover, the criterion "Training Related Carbon (SO1)" is considered a significant causal criterion, which has a great effect on the other sustainable circular supplier selection criteria, with high (D+R) value 2.911. It refers to employee awareness of carbon management practices, relevant education and training need to be launched to promote environmental consciousness (C. W. Hsu *et al.*, 2013).Training employees and enhancing sustainability-related skills are considered crucial components of corporate sustainability efforts. This is done to enhance employees' performance shortly after training and to cultivate a more sustainable corporate culture in the long term (Law *et al*. , 2017). Markey *et al*. (2016) found in their study a strong correlation indicating a relationship between organisational initiatives for reducing carbon emissions and the involvement of employees in the process of motivating, facilitating and/or executing these initiatives. Hence, it is imperative for suppliers to take into account the engagement of their employees via training programs in order to enhance their involvement in encouraging for carbon reduction efforts in the organisational setting.

The last cause criterion in this quarter was the "Green Technology (ENV4)", with a high (D+R) value 2.905, which is quite close to the prominence average value. Green Technology refers to the utilisation of technology by suppliers in order to create environmentally friendly products. Hence, it is imperative for suppliers to make significant investments in green technology. This involves distributing resources, such as funds, knowledge and properties, towards the implementation and utilisation of technologies that mitigate adverse environmental effects (e.g. waste management), employ natural processes (e.g. nutrient recycling), conserve energy, develop environmentally friendly goods, mitigate pollution, elevate their social image and enhance commitment to environmental solutions (Saunila *et al.*, 2019; X. Zhang *et al.*, 2023).

- ***Quarter II (QII):***

This quarter is the upper left-hand quarter, which represents the driving criteria possessing a low degree of prominence but a strong relation. Only two cause criteria were listed in this quarter: "Information Disclosure (SO5)" and "Financial Stability (EC5)". The associations among the criteria in this quadrant and other criteria are relatively lower than those in the first quadrant. These driving cause criteria can influence a few other criteria of the sustainable circular supplier selection criteria. However, suppliers should prioritise them after the eight criteria of QI.

The Information Disclosure criteria (SO5), which was given top priority this quarter, involves evaluating suppliers based on the information they provide about the materials they use, carbon emissions and pollutants released during the manufacturing process to both customers and other stakeholders (Luthra *et al.*, 2017). Supply chain information disclosure plays a crucial role in enhancing corporate investment efficiency and serves as an indicator of a company's long-term sustainable growth (Gao *et al.*, 2023). Investors depend not just on the information provided by a company but also take into consideration the information disclosed by other companies in the supply chain when making investment choices (Wu and Xu, 2022). Disclosing this confidential and valuable data can offer transparent signals to the market, despite the potential advantages it may also offer to competitors (Chen and Wang, 2020). Moreover, firms that provide environmental information disclosure to buyers can positively influence the market by helping the public better grasp their commitment to corporate environmental responsibility (Jensen *et al.*, 2019). Supply chain information is intricately connected to the upstream and downstream businesses (Gao *et al*., 2023). Violations of information disclosure diminish the effectiveness of operations within the capital market and have an adverse impact on the interests and rights of investors (Li *et al.*, 2024). Violation of information disclosure encompasses profit manipulation, inaccurate asset listings, deceptive statements and material omissions (Chen et al., 2005). The characteristics of suppliers is one of the factors that impact the violation of corporate information disclosure; therefore, suppliers' information disclosures have an impact on companies' governance and can prevent violations from happening (Li *et al.*, 2024). Hence, it is crucial for suppliers to disclose their information to their purchasing organisations to prioritise themselves. This is particularly important because companies that exhibit strong environmental performance are more motivated to disclose information and set themselves apart from those that have weaker environmental performance (Zhang and Jin, 2022).

Additionally, the criterion "Financial Stability (EC5)" was the second criterion in QII, which is also classified as a driving criterion of the sustainable circular supplier selection criteria. It refers to the financial status of the supplier that is analysed according to the information about the annual turnover of the supplier and their financial structure. These results are consistent with Armoh *et al.* (2023), who argued that Financial Stability is typically a key factor when choosing suppliers, as financial problems often lead to a decline in supplier performance. The financial stability of suppliers indicates the ability of suppliers to meet the current contractual obligations with the buying organisation, thereby ensuring the continuous readiness of future supplies (Handfield *et al*., 2015) . Furthermore, the financial stability of suppliers plays a crucial role in enhancing the efficiency of the whole procurement processes through the reduction of expenses associated with the need to re-advertise tenders (Ojijo, 2023). A procurement organisation, therefore, is advised to thoroughly examine and analyse the financial records of potential suppliers in order to make informed choices regarding the suppliers' financial stability (Armoh et al., 2023). For this reason, Financial Stability is considered to be one of the key indicators of supplier selection, as the financially stable supplier ensures owning resources to invest in sustainability and circular initiatives.

- ***Quarter III (QIII):***

This quarter is the lower left-hand quarter, which represents a low degree of prominence and a weak relation. The criteria under this quarter are considered as independent criteria and can be improved independently as they have low values of interactions with the other criteria.

Seven effect criteria were listed in this quarter: Reverse Logistics Agreement (CR6), Green Transportation (ENV3), Eco-friendly packaging (CR5), Cost (EC1), Worker's Rights (SO2), Delivery and services (EC3) and Flexibility (EC4). Regarding CR6, suppliers have the opportunity to launch initiatives that establish reverse logistics programs, including product take-back systems and recycling efforts, to ensure the smooth return of products from their customers to their facilities. Moreover, suppliers have to enhance the efficiency of their transportation pathways, combine cargo consignments and investigate the implementation of more environmentally sustainable transportation modalities in order to mitigate their emissions in order to improve ENV3. To improve CR5, suppliers are required to select sustainable packaging materials that are recyclable, biodegradable or reusable and to reduce packaging waste through the optimisation of packaging designs and dimensions. Regarding EC1 improvement, suppliers must identify chances to lower costs while maintaining sustainability. This could entail enhancing processes, implementing energy-efficient strategies or launching waste reduction programmes. Additionally, they explore pricing models that reflect the environmental and social advantages of sustainable practices. To enhance SO2, suppliers need to guarantee adherence to labour regulations, which encompass equitable pay, secure working environments and the absence of discrimination. Suppliers must allocate resources towards systems and processes that guarantee prompt and effective delivery of products and services to enhance EC3. To improve EC4, suppliers must improve their ability to adjust to evolving market dynamics and customers' demands. Although these criteria might not directly and profoundly influence other criteria, they remain crucial for improving their performance towards sustainability and CE.

Quarter IV (QIV):

This quarter is the lower right-hand quarter, which represents the influential criteria, possessing a relatively high level of prominence but displaying a lower degree of relation. It is subject to being influenced by various other criteria. Despite the fact that these criteria require improvements, they could not be directly improved as they came under the effect group criteria. Five effect criteria were listed in this quarter: Green Design (ENV2), Quality (EC2), Society's Rights/ Social responsibilities (SO4), Eco-friendly raw materials (CR1) and Carbon Disclosure Report (ENV6). The criterion "Green Design (ENV2)" has the highest prominence value in this quarter, which suggests that it is a net receiver in the sustainable supplier selection criteria. This criterion assesses whether the supplier's produces are green (Luthra *et al.*, 2017). Green design can signify the route that every supply chain component will adhere to (Villanueva-Ponce *et al.*, 2015). Consequently, the ability of the supplier to manufacture environmentally friendly materials or components will impact the final products of the purchasing manufacturer.

Regarding the criterion “Quality (EC2)”, it is also suggested that it is a net receiver. This criterion refers to assessing the level of quality of the materials provided (Luthra *et al.*, 2017). The quality level of procured items is a crucial consideration in the process of supplier selection due to its direct impact on the quality of the final product and the satisfaction of customers (Giri *et al*, 2022). Hence, suppliers must take into consideration the quality of products they are producing as it would affect the final design of the product.

The criterion “Society's Rights/ Social responsibilities (SO4)” lies in the third place in this quarter. It refers to assessing the suppliers’ competency in improving sustainability initiatives, such as social responsibilities and cleaner production. Irresponsible behaviour by suppliers has the potential to result in negative perceptions from the public, harm to reputation and significant financial burdens in terms of legal responsibilities for corporations (Zhang *et al*., 2017). If every partner both upstream and downstream within the supply chain demonstrates dedication to social responsibility, the supply chain has the potential to attain sustainable development (Chen *et al*., 2018). Hence, it is crucial for suppliers to enhance their sustainability efforts concerning societal rights and promoting cleaner production.

The criterion “Eco-friendly raw materials (CR1)” is also considered as an effect criterion with high prominence value. It refers to the evaluation of suppliers' utilisation of recyclable raw materials in the production process (Govindan *et al.*, 2020). Green sourcing, which aims to purchase eco-friendly raw materials, is particularly advantageous for cost savings when there is high demand variability, high prices of virgin raw material and low expected recycling prices (Rogetzer *et al*., 2018), thereby fostering initiatives towards a CE.

The last criterion in this quarter is the “Carbon Disclosure Report (ENV6)”, which is considered as an effect criterion with high prominence level. It refers to evaluating the supplier’s reports regarding GHG emissions. These days, a range of stakeholders are showing interest in environmental issues like climate change, GHG emissions and carbon emissions (Harymawan *et al.*, 2020). Buyers looking to create carbon-footprint product labels in order to distinguish their products in the market should involve their suppliers to gather carbon-emission data (Jira and Toffel, 2013). When suppliers provide more transparency regarding their carbon emissions, it enables buyers to compare their performance with that of their rivals and uncover possibilities for reducing costs and risks within their supply chains (Villena and Dhanorkar, 2020). Therefore, the transparency of suppliers might assist purchasers in enhancing their decision-making processes in order to reduce the potential risks linked to carbon emission.

5.5 Chapter Conclusion:

This chapter demonstrates how FUZZY-DEMATEL technique can be used to evaluate the interdependencies of all sustainable circular criteria and integrate them with the proposed **SCSS Model**. The evaluation of criteria interdependence was conducted through the application of the FUZZY-DEMATEL technique in order to uncover the cause-and-effect relationship among all criteria. To achieve this, the criteria are divided into four quadrants according to their relation and prominence values. The conversion of the intricate causal interconnection of the criteria into a visible structural drawing was facilitated through the cause-and-effect diagram. This, in turn, facilitates decision-making by recognising and differentiating the cause-and-effect criteria being assessed.

The analysis of the results shows that the criterion "Environmental Mgt. Systems (ENV1)" has the greatest influence among all selection criteria. Additionally, the results indicate that the criteria GHG emissions (ENV5), air pollution resulting from recycling process (CR3), clean technology for recycling (CR4), Occupational Health & Safety (SO3), respecting environmental standards and regulations in the process of recycling (CR2), Training Related Carbon (SO1) and Green Technology (ENV4) are also having a great influence on the other sustainable circular criteria. These criteria are positioned in the first quadrant of the cause-and-effect diagram, so they are the core criteria in the process of sustainable circular supplier selection. Therefore, it is recommended that procurement entities seeking to choose suppliers with a focus on sustainability and CE aspects should initially assess suppliers based on the above-mentioned core criteria as the first priority, as these criteria notably affect other sustainable circular criteria. The next chapter will report the validation of the proposed **SCSS Model** through implementation in a real-life context.

CHAPTER 6

Sustainable Circular Supplier Selection (SCSS) Model Testing

6.1 Introduction

The objective of this chapter is to test the Sustainable Circular Supplier Selection (SCSS) Model in a practical setting. An action research pilot approach was employed to offer a comprehensive evaluation of the supplier selection process within manufacturing industries, aiming to pinpoint areas that require enhancements and could benefit from the adoption of the proposed SCSS Model. The chapter is divided into two sections. The first section illustrates the execution of the proposed SCSS model by two manufacturing enterprises via the operation of the action research cycle. The second section summarises the principal findings of the model testing. To recall, this chapter aims to achieve Research Objective 4 **(RO4)** and its related Research Question 4 **(RQ4)** as shown in **Table 6.1**.

Table 6.1: Research Objective 4 (RQ4) and Research Question 4 (RQ4):

(RO4)	**(RQ4)**
To test the proposed **SCSS Model** within a practical setting through the implementation of an action research pilot.	How efficiently could the suggested **SCSS Model** enhance the process of supplier selection within the contexts of sustainability and Circular Economy (CE) in practice?

6.2 Action research - Case Company (A):

Company (A) is one of the largest commercial and industrial organisations in Egypt within the Middle East and North Africa (MENA) region. It manufactures home appliances, laptops and audio systems. The company was established in 1964 and employs more than 40,000 staff. The company currently consists of 16 businesses engaged in commercial, industrial and service operations, as well as four industrial complexes with 26 factories, all of which are furnished with the most modern production technology available. The portfolio of Company A includes 14 international brands across 25 product categories in the consumer electronics and home appliances sector. More than 60 countries throughout the world are recipients of the company's products. The company has certified management systems according to ISO 9001 (Quality Management System), ISO 14001 (environmental management system), ISO 18001 (Occupational Health and Safety Assessment) and ISO 50001 (Energy Management System). Different phases of the action research of the case Company (A) will be explained in detail below.

- ***Phase 1: Data gathering of Company (A):***

  Interviews were conducted with the Supply Chain Manager and Quality Head, both involved in the procurement process at the company. The supply chain manager is an expert in the field of supply chain management for 17 years and is responsible for local and foreign purchasing and sourcing, planning management and inventory control. The Quality Head is an expert in the field of quality management for 15 years and is responsible for monitoring all the operations that affect quality, reviewing current ISO standards and policies, managing waste in production and assessing and reviewing all materials purchases from the suppliers to ensure the overall quality and production standards.

The interviewees were asked to reveal, from their own viewpoint, how the company manages the process of supplier selection and evaluation. They were also asked to share the documents related to the supplier selection and evaluation. Based on the information collected, the current supplier selection process of Company A is shown in **Figure 6.1**. Subsequently, this map was presented to the interviewees for validation regarding its accuracy and representation of the process.

Figure 6.1: Current Supplier Selection Process of Company (A):

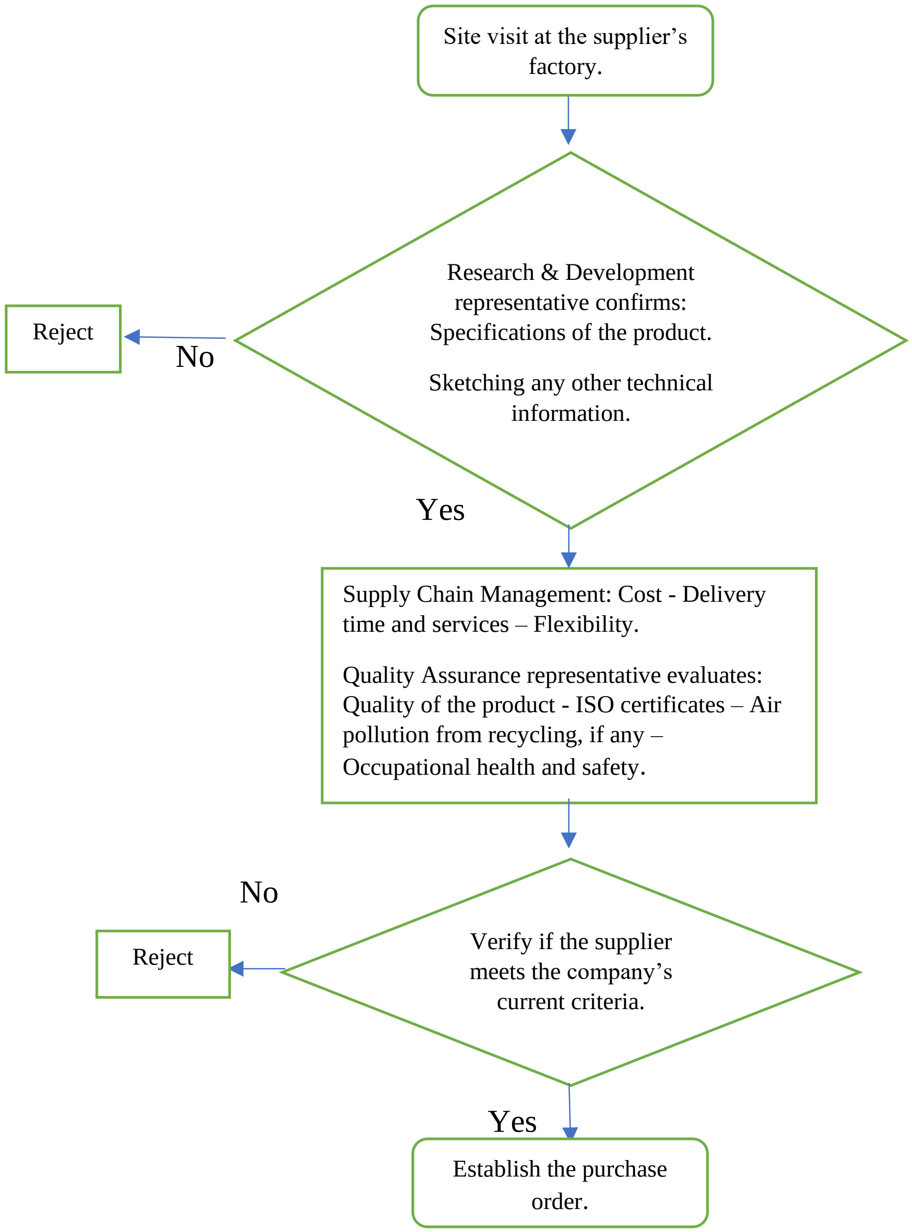


Figure 6.1 shows that the supplier selection process of Company A operates under three main departments: Supply Chain Management, Research & Development and Quality Management. The selection process varies depending on the size of the supplier's enterprise. In the case of dealing with Large Enterprise Supplier and well known to the market, such as steel suppliers, the company follows the following procedures (either local or international): three representatives, one from each of the three different departments of the company, visit the site of the supplier. Each

of the three representatives evaluates the supplier according to his/her department's perspective. The process begins when Research and Development reviews the specification of the product required. After confirming the Research and Development, the Supply Chain Management and Quality Assurance representatives evaluate the supplier according to their perspectives, as shown in **Table 6.2**. A supplier-buyer agreement is formed after the representatives accept the evaluation perspectives according to the evaluation process in **Table 6.3.**

Table 6.2 Supply Chain Management and Quality Assurance representative's supplier evaluation criteria of Company A:

Supply Chain Management Representative	Quality Assurance Representative
- Cost (price of the product and its packaging). - Flexibility (the quantity the supplier can offer). - Delivery time and services (the lead time and the services offered such as packaging the material with appropriate materials and in a manner suitable for transportation).	- The ISO certificates related to the quality (such as ISO 9001 and ISO 14001), - Quality of the material through inspection. - Occupational health and safety at the plant (ISO 18001). - Eco-friendly raw materials. - If recycling process occurs: The air pollution comes from the recycling process.

Table 6.3 Supplier selection criteria of Company (A):

The criteria	Included in the proposed SCSS Model	Dimension	Description	Assessment measures		
Cost	√	Economic	Price of the product and its packaging.	Accepted	Not accepted	
Flexibility	√	Economic	Find out if the supplier has the ability and capacity to meet the company's needs and to provide the right products now and in the future.	Sufficient	In-sufficient	
Delivery time and services	√	Economic	Ask about the lead time (the amount of time taken from the placing the order placed until it delivered), and the services offered such as packaging with appropriate materials and in a manner suitable for transportation.	Accepted	Not accepted	
Quality	√	Economic	Find out if the supplier is ISO 9001 and ISO 14001 certified. If (Yes), it must be specified to what extent the supplier is implementing the quality systems: fully or partially.	Yes, fully implemented.	Yes, partially implemented.	No
			Inspect the quality of the material	Accepted	Not accepted	
Occupational health and safety	√	Social	Find out if the supplier is ISO 18001 certified.	Yes	No	
Eco-friendly raw materials	√	Circular	Find out if the supplier is using eco-friendly raw materials.	Yes	No	
Air pollution comes from the recycling process.	√	Circular	Find out if the supplier has control over the air pollution coming from the recycling process of waste and unusable products.	Yes	No	

- ***Phase (2): Data feedback of Company (A):***

Upon analysing the data related to **Company (A)**'s current supplier selection process, the table above demonstrates that the Economic criteria of the proposed SCSS Model, including Cost, Quality, Delivery time, services and Flexibility, are currently being utilised. In terms of Environmental criteria, the only commonality between the proposed and current criteria is the Environmental Management System (ISO 14001). Concerning the Social criteria, the only similarity between the proposed criteria and **Company (A)**'s criteria is occupational health & safety systems. Lastly, for the Circular criteria, it is evident that **Company (A)** follows two criteria that align with the proposed criteria, which are eco-friendly raw materials and air pollution resulting from the recycling process.

- ***Phase (3): Data analysis of Company (A):***

Table 6.4 reports how the proposed SCSS Model could enhance the current supplier selection process of **Company (A).** These potential improvements aim to enhance the supplier selection process in the direction of sustainability and CE contexts.

Table 6.4 Potential improvements for Company (A):

Shortcomings of the Current Supplier Selection Process of Company (A).	Proposed SCSS Model.
Only three sustainability and circular criteria are included (although the company is ISO 14001)	A list of sustainable circular supplier selection criteria including four dimensions (Economic, Environmental, Social, and Circular) is considered.
Criteria are not differentiated from each other and their correlation is overlooked.	Relative weightings of the criteria and interdependency among criteria are addressed.
Assessment measures of some criteria involve subjective judgement.	Fuzzy TOPSIS utilises fuzzy sets to capture uncertain or ambiguous information, rendering it more appropriate for decision-making scenarios where criteria or assessments vary subjectively. It permits the allocation of weights to criteria according to their FUZZY-DEMATEL assigned weights, guaranteeing that the decision-making process corresponds with the organisation's priorities.

- ***<u>Phase (4): Action plan of Company (A):</u>***

In this stage, the key questions for the action plan, mentioned in Chapter 3, must be addressed to pinpoint the necessary changes for executing the proposed **SCSS Model** within the company.

(1) What changes are necessary?

The process of supplier selection needs to be improved towards sustainable and CE contexts.

(2) Which parts of the organisation require these changes?

The departments that are primarily responsible for selecting and evaluating suppliers, such as Supply Chain Management, Research & Development, and Quality Management.

(3) What kind of changes are needed?

- New supplier selection criteria, as included in the proposed SCSS Model.
- Changes in the prioritization of the supplier selection criteria, according to the FUZZY-DEMATEL analysis.
- Changes in the way of selecting suppliers as alternatives using FUZZY-TOPSIS.

(4) Whose assistance is crucial?

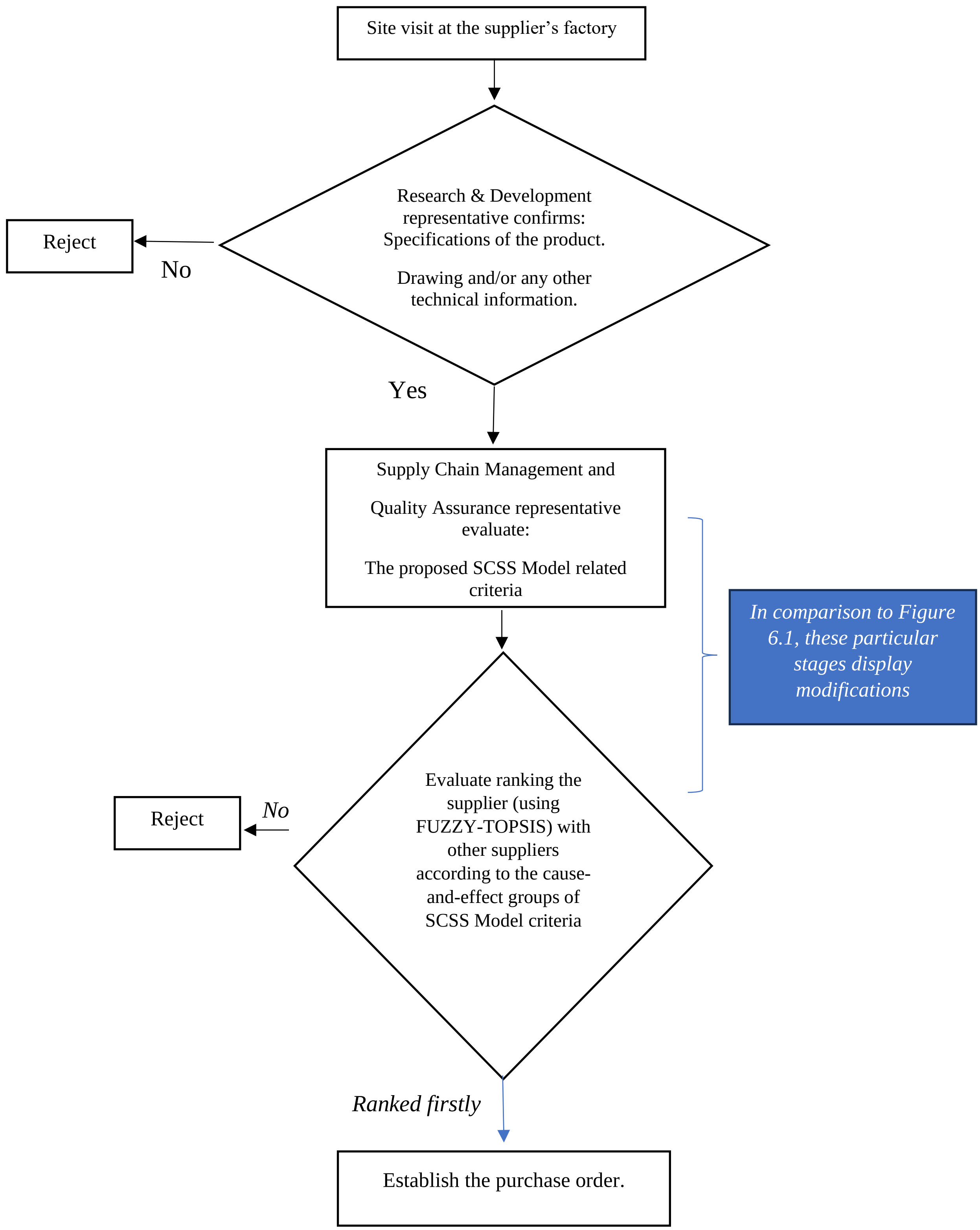
The key stakeholders that are responsible for supplier selection, such as the procurement team within the supply chain management department, the research & development team, and the quality management team.

(5) How can commitment be fostered?

The researcher provides a detailed explanation to the key stakeholders in charge of supplier selection on how they will use the proposed SCSS Model to assess suppliers. **Figure 6.3** illustrates the allocation of commitments, and the duration required.

According to the research aim, the researcher of the study modified the current supplier selection process of "Company A" to include the proposed criteria of the proposed **SCSS Model** of the study to improve its supplier selection process towards sustainability and CE contexts. The modifications mainly were improving the evaluation criteria employed by the Supply Chain Management department and Quality Assurance department to involve the criteria of the proposed SCSS Model, in addition to ranking the supplier (using FUZZY-TOPSIS) according to the cause-and-effect groups of SCSS Model criteria. The modification will be shown in **Figure 6.2** highlighted in green.

Figure 6.2: The modified Supplier Selection Process of "Company A":



After modifying the current supplier selection process of **Company (A)** (as shown in **Figure 6.2**), the working principles of the proposed **SCSS Model** were presented to Company **(A)**. In order to ensure effective implementation of the SCSS model, four key steps were adopted as reported in **Figure 6.3.**

Figure 6.3: The steps of implementation of the proposed SCSS Model at Company (A)

STEP #1

The researcher explained the 22 criteria and their measurements to the decision makers who were the supply chain manager and quality head.

STEP #2

The researcher provided the decision makers with "supplier's rating documents", to rate the suppliers according to the proposed sustainable circular criteria.

(1 – 5 Likert Scale)

STEP #3

After 25 days, the company contacted the researcher to provide her the results of rating the suppliers.

STEP #4

After collecting the results, the researcher used the rating results as inputs to FUZZY-TOPSIS that indicated the suppliers' ranking results to select the best supplier according to the proposed **SCSS Model**.

As shown in **Figure 6.3**, the researcher initially explained the 22 criteria of the SCSS Model to the heads of supply chain management and quality assurance. Next, they provided a document for rating three suppliers on a 1–5 Likert scale based on the proposed criteria. The decision makers agreed that the evaluation process would take about one month. After 25 days, the researcher collected the rating documents upon their request. Subsequently, the researcher began the selection calculations using the FUZZY-TOPSIS technique.

- ***Phase (5): Implementation Plan of Company (A):***

This phase was about the implementation of the proposed SCSS Model. As outlined in Chapter 3, the SCSS model utilises the FUZZY-TOPSIS method to evaluate suppliers. By implementing the SCSS Model, the organisation was equipped with the capability to evaluate three suppliers of their choice and choose the optimal one, taking into account both sustainability and the CE. These three suppliers were manufacturers of steel that provide "Galvanized Iron." The FUZZY-TOPSIS software was applied to compute the ranking results of all suppliers. The **steps** of computing the suppliers' ranking using FUZZY-TOPSIS technique at Company (A) are described below:

Step 1: Create a decision matrix.

For the case of Company (A), there were 22 selection criteria, and three suppliers were ranked. Table **6.5** shows the weight assigned to each criterion in form of a fuzzy total relation matrix based on the FUZZY-DEMATEL method which is detailed in Chapter 5.

Table 6.5: Criteria Weightings for Company (A):

	Criteria	Weight
1	EC1	(0.003,0.012,0.067)
2	EC2	(0.014,0.046,0.133)
3	EC3	(0.004,0.011,0.054)
4	EC4	(0.003,0.008,0.043)
5	EC5	(0.001,0.003,0.048)
6	ENV1	(0.028,0.074,0.159)
7	ENV2	(0.018,0.052,0.130)
8	ENV3	(0.006,0.020,0.076)
9	ENV4	(0.007,0.024,0.089)
10	ENV5	(0.023,0.062,0.142)
11	ENV6	(0.009,0.030,0.098)
12	SO1	(0.011,0.035,0.104)
13	SO2	(0.004,0.017,0.069)
14	SO3	(0.016,0.047,0.122)
15	SO4	(0.013,0.041,0.121)

16	SO5	(0.007,0.025,0.091)
17	CR1	(0.013,0.038,0.106)
18	CR2	(0.012,0.037,0.108)
19	CR3	(0.018,0.054,0.143)
20	CR4	(0.015,0.046,0.125)
21	CR5	(0.005,0.018,0.075)
22	CR6	(0.008,0.025,0.089)

A linguistic scale for assessing suppliers based on SCSS criteria is presented in the table below, as used by (Kore *et al.*, 2017):

Table 6.6: Fuzzy Scale for Company (A):

Code	Linguistic terms	L	M	U
1	Very low	1	1	3
2	Low	1	3	5
3	Medium	3	5	7
4	High	5	7	9
5	Very high	7	9	9

Note: L is the set of semantic rules, U is the universe of discourse of the base variable and M is a semantic rule which maps each linguistic term to its meaning.

The suppliers were evaluated using various criteria, and the decision matrix results are shown in Appendix XI.

Step 2: Create the normalised decision matrix:

Based on the positive and negative ideal solutions, a normalised decision matrix, as shown in Appendix XII, can be calculated by the following relation:

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \quad ; \quad c_j^* = max_i\, c_{ij} \text{ ; } \textit{Positive ideal solution} \qquad \text{Equation 11.}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \quad ; \quad a_j^- = min_i\, a_{ij} \text{ ; } \textit{Negative ideal solution} \qquad \text{Equation 12.}$$

Step 3: Create the weighted normalised decision matrix:

Considering the different weights of each criterion, the weighted normalised decision matrix, as shown in Appendix XIII, can be calculated by multiplying the weight of each criterion in the normalised fuzzy decision matrix, according to the following formula.

$$\tilde{v}_{ij} = \tilde{r}_{ij}.\tilde{w}_{ij} \qquad \text{Equation 13.}$$

Where $\tilde{w}_{ij}$ represents weight of criterion c_j

Step 4: Determine the fuzzy positive ideal solution (FPIS, A*) and the fuzzy negative ideal solution ($FNIS, A^{-}$)

The FPIS and FNIS of the alternatives (suppliers) can be defined as follows:

$$A^{*} = \{\tilde{v}_1^{*}, \tilde{v}_2^{*}, \ldots, \tilde{v}_n^{*}\} = \left\{\left(\max_j v_{ij} \,|i \in B\right), \left(\min_j v_{ij} \,|i \in C\right)\right\} \qquad \text{Equation 14.}$$

$$A^{-} = \{\tilde{v}_1^{-}, \tilde{v}_2^{-}, \ldots, \tilde{v}_n^{-}\} = \left\{\left(\min_j v_{ij} \,|i \in B\right), \left(\max_j v_{ij} \,|i \in C\right)\right\} \qquad \text{Equation 15.}$$

Where $\tilde{v}_i^{*}$ is the max value of the criterion for all the alternatives and $\tilde{v}_1^{-}$ is the min value of the criterion for all the alternatives. *B* and *C* represent the positive and negative ideal solutions, respectively.

The positive and negative ideal solutions are shown in **Table 6.7**.

Table 6.7: The positive and negative ideal solutions for Company (A):

	Positive ideal	Negative ideal
EC1	(0.002,0.012,0.067)	(0.001,0.007,0.052)
EC2	(0.011,0.046,0.133)	(0.008,0.036,0.133)
EC3	(0.002,0.009,0.054)	(0.001,0.006,0.042)
EC4	(0.002,0.008,0.043)	(0.002,0.006,0.043)
EC5	(0.001,0.003,0.048)	(0.001,0.003,0.048)
ENV1	(0.016,0.058,0.159)	(0.009,0.041,0.124)
ENV2	(0.008,0.037,0.130)	(0.008,0.037,0.130)

ENV3	(0.002,0.007,0.076)	(0.002,0.007,0.076)
ENV4	(0.004,0.019,0.089)	(0.002,0.013,0.069)
ENV5	(0.018,0.062,0.142)	(0.008,0.034,0.110)
ENV6	(0.004,0.021,0.098)	(0.004,0.021,0.098)
SO1	(0.005,0.025,0.104)	(0.002,0.015,0.074)
SO2	(0.002,0.013,0.069)	(0.001,0.009,0.054)
SO3	(0.012,0.047,0.122)	(0.009,0.037,0.122)
SO4	(0.007,0.032,0.121)	(0.001,0.014,0.067)
SO5	(0.005,0.025,0.091)	(0.004,0.019,0.091)
CR1	(0.007,0.030,0.106)	(0.004,0.021,0.082)
CR2	(0.007,0.029,0.108)	(0.004,0.021,0.084)
CR3	(0.010,0.042,0.143)	(0.006,0.030,0.111)
CR4	(0.006,0.033,0.125)	(0.006,0.033,0.125)
CR5	(0.002,0.013,0.075)	(0.001,0.008,0.054)
CR6	(0.003,0.018,0.089)	(0.001,0.011,0.064)

Step 5: Calculate the distance between each alternative (supplier) and the fuzzy positive ideal solution A^*as well as the distance between each alternative and the fuzzy negative ideal solution A^-

The distance between each alternative (suppliers) and FPIS and the distance between each alternative and FNIS can be calculated as follows:

$S_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^*)$ *i=1,2,...,m* Equation 16.

$S_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-)$ *i=1,2,...,m* Equation 17.

d is the distance between two fuzzy numbers, when given two triangular fuzzy numbers (a_1, b_1, c_1) and (a_2, b_2, c_2), e distance between the two can be calculated as follows:

$d_v(\widetilde{M}_1, \widetilde{M}_2) = \sqrt{\frac{1}{3}[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]}$ Equation 18.

Note that $d(\tilde{v}_{ij}, \tilde{v}_j^*)$ and $d(\tilde{v}_{ij}, \tilde{v}_j^-)$ are crisp numbers. **Table 6.8** shows distance from positive and negative ideal solutions for all suppliers.

Table 6.8: **Distance from positive and negative ideal solutions for Company (A):**

Alternatives	Distance from positive ideal	Distance from negative ideal
Supplier 1	0.01	0.22
Supplier 2	0.15	0.085
Supplier 3	0.194	0.036

Step 6: Calculate the closeness coefficient and rank the alternatives (suppliers):

The closeness coefficient of each alternative (supplier) can be calculated as follows:

$$CC_i = \frac{S_i^-}{S_i^+ + S_i^-} \qquad \text{Equation 19.}$$

The best alternative (supplier) is closest to the FPIS and farthest to the FNIS. The closeness coefficient of each alternative and the ranking order of all alternatives (suppliers) are shown in **Table 6.9**.

Table 6.9: Closeness coefficient for Company (A):

Alternatives	Ci	rank
Supplier 1	0.955	1
Supplier 2	0.364	2
Supplier 3	0.158	3

Therefore, it was demonstrated that the SCSS model can help Company (A) to evaluate and select the best supplier, i.e. Supplier (1), which was deemed as the most suitable supplier enhancing both sustainability and CE performance of the company.

- ***<u>Phase (6): Evaluation of Company (A):</u>***

The feedback of supply chain manager and quality head about the model implementation was gathered via a questionnaire. This questionnaire comprises two distinct sections. The first section contains five questions asking about the experts' level of satisfaction concerning the suggested model using 7-point Likert Scale. The second section addresses, from the participants' viewpoint, the constraints of the model and ways of enhancing the model. The questionnaire can be found in Appendix XVII.

- 1st section of the feedback questionnaire of **Company (A)**:

Table 6.10 shows the analysis of the results of the first section of the questionnaire.

Table 6.10 Results of Degree of Satisfaction of Company (A):

Question 1: All the criteria of the model are clear.							
Level	*Extremely Unsatisfied*	*Very Unsatisfied*	*Unsatisfied*	*Neutral*	*Satisfied*	*Very Satisfied*	*Extremely Satisfied*
Results							2
Question 2: The model provides strong structure for measuring the sustainable circular practices of the suppliers.							
Level	*Extremely Unsatisfied*	*Very Unsatisfied*	*Unsatisfied*	*Neutral*	*Satisfied*	*Very Satisfied*	*Extremely Satisfied*
Results							2
Question 3: The model generates reliable results.							
Level	*Extremely Unsatisfied*	*Very Unsatisfied*	*Unsatisfied*	*Neutral*	*Satisfied*	*Very Satisfied*	*Extremely Satisfied*
Results							2
Question 4: The suppliers' rating sheet is easy and understandable.							
Level	*Extremely Unsatisfied*	*Very Unsatisfied*	*Unsatisfied*	*Neutral*	*Satisfied*	*Very Satisfied*	*Extremely Satisfied*
Results						1	1
Question 5: The time consumed for implementing the model							
Level	*Extremely Unsatisfied*	*Very Unsatisfied*	*Unsatisfied*	*Neutral*	*Satisfied*	*Very Satisfied*	*Extremely Satisfied*
Results				1		1	

The findings indicated that the participants expressed satisfaction with the proposed **SCSS Model** and acknowledged its potential utility in enhancing their procurement procedures. As for the final question pertaining to the implementation timeline of the model, one participant displayed a neutral level of satisfaction. To sum up, the outcomes of this section revealed that the participants were content with the suggested **SCSS Model** and recognised its value in improving their procurement practices.

- 2nd Section of the feedback questionnaire of **Company (A)**:

Q1: What are the limitations/challenges that occurred while implementing the model? How to overcome these limitations?

Participants from **Company (A)** noted that in order to implement the proposed SCSS Model successfully, a significant amount of data on supplier sustainability and CE practices was necessary to evaluate the model's criteria. However, delays arose in gathering these data since they are being evaluated for the first time. Furthermore, the participants noted that a supplier seemed reluctant to share certain data regarding sustainability and circular practices, possibly due to being asked for an evaluation for the first time. Additionally, they pointed out that the decision-makers responsible for supplier selection found the SCSS Model to be complex during their first practice, given its numerous criteria that require specific knowledge for effective utilisation. They recommended the following in order to overcome these limitations:

- Engage in discussions with potential suppliers to understand the proposed SCSS Model and its advantages for the entire supply chain. This promotes transparency and motivates them to share relevant information. Simultaneously, this will empower them to enhance their performance in alignment with the SCSS Model selection criteria, increasing their chances of being chosen as suppliers by the company.
- Train staff members who have the responsibility of choosing suppliers to increase their awareness and involvement in effectively utilising the proposed SCSS Model.

Q2: What could be the action plan for executing the proposed SCSS Model instead of your current supplier selection process?

Participants of **Company (A)** stated that they already have a “Product Team”, which consists of Marketing, Sales, Quality, Supply chain, and Research and Development heads. This team is responsible for setting the requirements of the products’ design and specifications, therefore, all of them must meet and review how the requirements of the components or/and raw material supplied from the suppliers would change based on the experience gained from the model implementation , such as the consideration of more selection criteria including green design, eco-friendly material, eco-friendly packaging, etc.

Inspired by the recommendations of the “Product Team”, the three decision makers of the purchasing process (Research and Development, Quality Assurance, and Supply Chain heads) will make a proposal to add a number of new selection criteria in relation to the organisational management, such as environmental management systems, worker’s right, occupational health and safety, respecting environmental standards of recycling process, etc. The proposal must also include the mechanism of changing the purchasing policy with an aim to achieve sustainable and circular practices. Finally, the approval from “Top-Management” will be sought if this proposal is to be executed.

Q3. What does your company need to increase the knowledge of its employees about the proposed model?

Participants of **Company (A)** emphasised the importance of keeping employees in research and development, supply chain, and quality departments informed about sustainable supplier selection and evaluation processes. Additionally, they highlighted the need to share the procurement policy with workers, stakeholders and key suppliers. They also suggested providing guideline criteria that encompass environmental, economic, social, and circular aspects for assessing tenders based on sustainability and CE.

Q4. To what extent do you expect the proposed SCSS Model will improve the current procurement practice?

Participants of **Company (A)** stated that this will benefit their company, as their company already was working hard to comply with the country’s strategic sustainable development directions and its 2030 vision "Egypt 2030 vision" towards sustainable development, by being one of the major entities in the private sector in improving the indicators of the Egyptian economy and protecting the environment. Consequently, with the help of this research, the company would be able to achieve some of the SDGs.

6.3 Action research - case company (B):

Company (B) is one of the largest companies in the world that makes sanitary ware. It also makes a lot of ceramic tiles in Egypt and Lebanon. The Company’s factories are in Alexandria, Egypt. The company has more than 6,000 staff and can make more than 6.2 million pieces of sanitary ware and 24.8 million square meters of tiles every year. **Company (B)** makes a variety of sanitary ware products that are certified internationally and sold in over 50 countries, both under its own brand and by other manufacturers and customers under their own brands. **Company (B)** also makes a wide variety of ceramic floor and wall tiles, which are mostly sold in Egypt and Lebanon.

Over 65.5% of the company's sanitary ware is sold outside of the country. This is done through its trading subsidiaries in the UK and a strong network of well-known distributors, agents and specialised merchants in Europe and the MENA region. The company is also a major maker of sanitary ware for international brands. More than 30% of the sanitary ware that **Company (B)** exports is made for other companies. It is one of the most popular brands of bathroom fixtures in the UK and Ireland. The company applies certified management systems according to ISO 9001 (Quality Management System), ISO 14001 (environmental management system) and ISO 18001 (Occupational Health & Safety Management System). Different phases of the action research of case **Company (B)** will be explained in detail below.

- ***Phase 1: Data gathering of Company (B):***

Interviews were conducted with the Quality Head and the Procurement manager, who are involved in the procurement process at the company. The Quality Head has experience of quality assurance and control for 15 years. She was responsible for ensuring that the company’s operations of the business process and products are in compliance with the ISO standards, as well as managing the improvement of the overall performance of quality assurance activities and process control, inspecting materials for production and support production heads in implementing ISO standards. Regarding the procurement manager, he has experience of procurement field for 14 years. He was responsible for supervision of all activities of the procurement department, preparing plans for purchasing equipment and supplies, following and imposing the company’s procurement procedures and policies, researching and evaluating potential suppliers, maintaining supplier relationships and updating suppliers’ data, such as qualifications, products variety and delivery time.

The interviewees were asked to reveal, from their own viewpoint, how the company is managing the process of supplier selection. They were also asked to share the documents related to the supplier selection and evaluation. Based on the information collected, the current supplier selection process of **Company (B)** is shown in **Figure 6.4**.

Figure 6.4: Current Supplier Selection Process of "Company B":

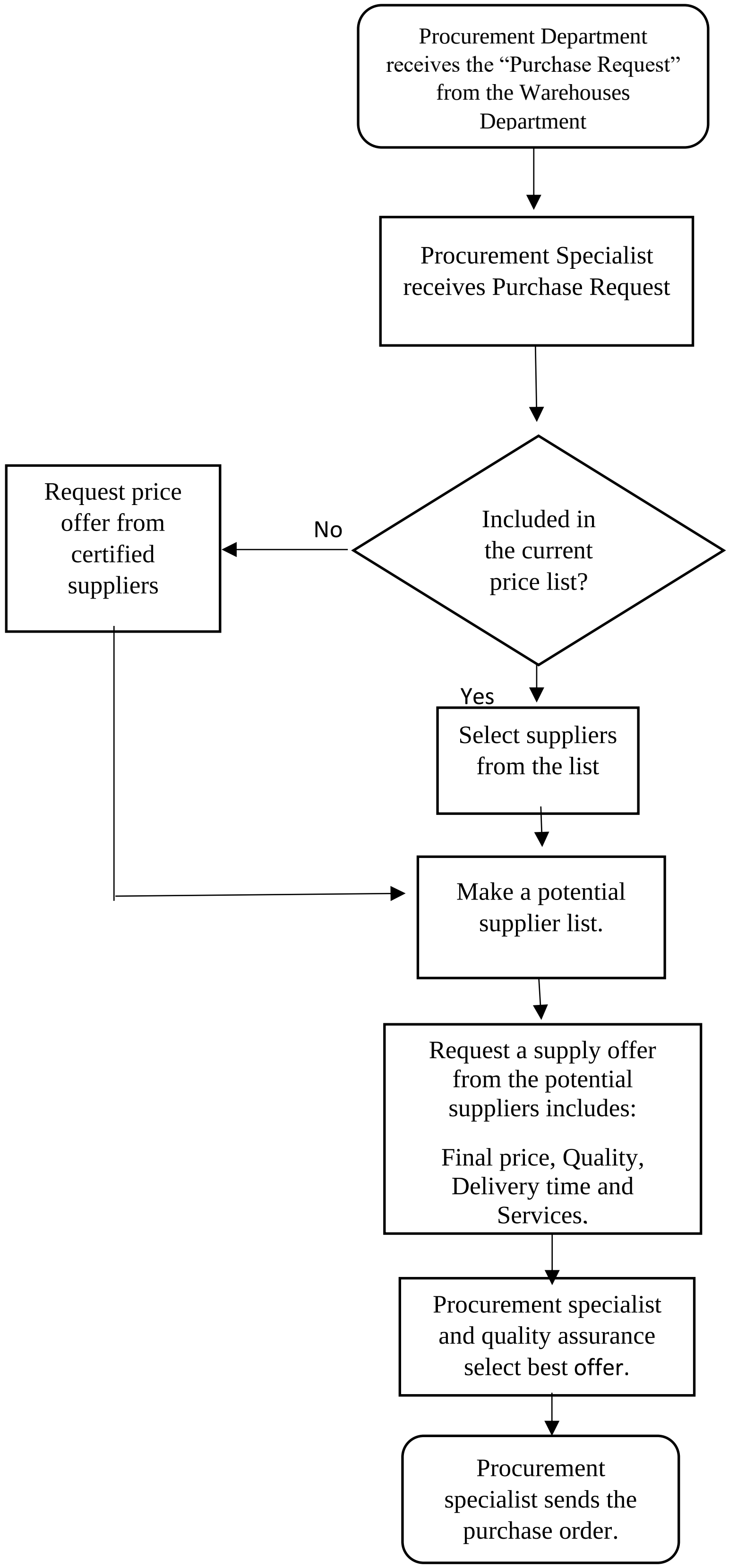


Figure 6.4 shows that the supplier selection process of **Company (B)** is managed by two main departments, which are Procurement Management and Quality Management.

- Purchase requests issued by warehouses reach the procurement department after the general director of the factory gives his approval.
- In cases of repeated or permanent purchases, the procurement specialist reviews the collected price lists in order to indicate the supplier who will be dealt with.
- In the case of items with no historical price list or price lists that are no longer valid due to the expiration of related offers and price differences that are either up, down, or outdated for more than six months, new price requests are prepared and sent to certified suppliers either by hand or by email.
- After selecting the best suppliers according to their prices, the procurement specialist makes a suppliers' list and then asks each supplier to provide him with an offer, considering the following: the final **price,** along with any related services such as payment terms; the **quality,** which includes the specifications of the product and the packaging specifications; the **delivery and services,** which includes the lead time and the minimum order quantity the supplier can offer.
- The procurement specialist and the quality assurance representative review the offers coming from the selected suppliers (suppliers' list) and then select the best one according to Price, Quality, Delivery time, Flexibility of payment terms and the quantity they can provide.

Finally, after selecting the best supplier, the procurement specialist sends a purchase order to the chosen supplier, indicating the required items and their specifications accurately. **Table 6.11** shows how **Company (B)** evaluates its suppliers.

Table 6.11 Supplier selection criteria of Company B:

The criteria	Included in the proposed SCSS Model	Dimension	Description	Assessment measure (100% Total Score)
Quality	√	Economic	It includes the specifications of the product and the packaging specifications.	50 %
Cost	√	Economic	The final price along with any related services such as payment terms	25 %
Delivery time and services	√	Economic	The lead time (the amount of time taken from the placing the order placed until it delivered) and find out the minimum order quantity that could be offered by the supplier.	25%

- ***<u>Phase 2: Data Feedback of Company (B):</u>***

According to the current supplier selection process of **Company (B)**, it has been shown that the company relies on traditional factors like Cost, Quality, Delivery time, and services. However, the conventional method of supplier assessment is no longer effective in today's context. The fusion of environmental and economic strategies has become crucial in recent years, highlighting the increasing significance of a company's global ecological performance in alignment with business goals and environmental regulations. Thus, it is imperative that sustainability and CE requirements are integrated into the weighted evaluation criteria for any new sourcing project.

- ***Phase 3: Data Analysis of Company (B):***

Through the analysis of the current process of supplier selection of **Company (B)**, **Table 6.12** reports how the proposed SCSS Model could enhance the current supplier selection process of **Company (B).** These potential improvements aim to enhance the supplier selection process in the direction of sustainability and CE contexts.

Table 6.12 Potential improvements for Company (B):

Current Supplier Selection Criteria of Company (B)	Proposed SCSS Model Criteria
Includes conventional criteria for selecting suppliers such as cost, quality, delivery time and service are prioritised, despite the company's adherence to ISO 14001 standards, while overlooking any sustainable or circular criteria.	Full view of sustainable circular supplier selection criteria including four dimensions (Economic, Environmental, Social, and Circular)
Individual weights to the traditional criteria, apart from reflecting the complex interdependency relationship among criteria.	FUZZY-DEMATEL is employed for the purpose of determining the relative importance assigned to the criteria that represent the most influential factors impacting other criteria.
Traditional rating scales, expressed as percentages, exhibit deficiencies in effectively managing uncertainty related to supplier performance. Additionally, this method of evaluation, reliant on human judgment, has the potential to introduce inconsistencies in the outcomes.	The rating scale of FUZZY TOPSIS is employed for the assessment of suppliers according to the weightage results from FUZZY-DEMATEL, thus offering a precise and enhanced approach through the integration of FUZZY logic.

- ***Phase (4): Action plan of Company (B):***

In this stage, the key questions for the action plan, mentioned in Chapter 3, must be addressed to pinpoint the necessary changes for executing the proposed **SCSS Model** within the company.

(6) What changes are necessary?

The process of supplier selection needs to be improved towards sustainable and CE contexts.

(7) Which parts of the organization require these changes?

The Departments that are primarily responsible for selecting and evaluating suppliers, such as the Procurement Department and Quality Management Department.

(8) What kind of changes are needed?

- New supplier selection criteria, as included in the proposed SCSS Model.
- Changes in the prioritization of the supplier selection criteria, according to the FUZZY-DEMATEL analysis.
- Changes in the way of selecting suppliers as alternatives using FUZZY-TOPSIS.

(9) Whose assistance is crucial?

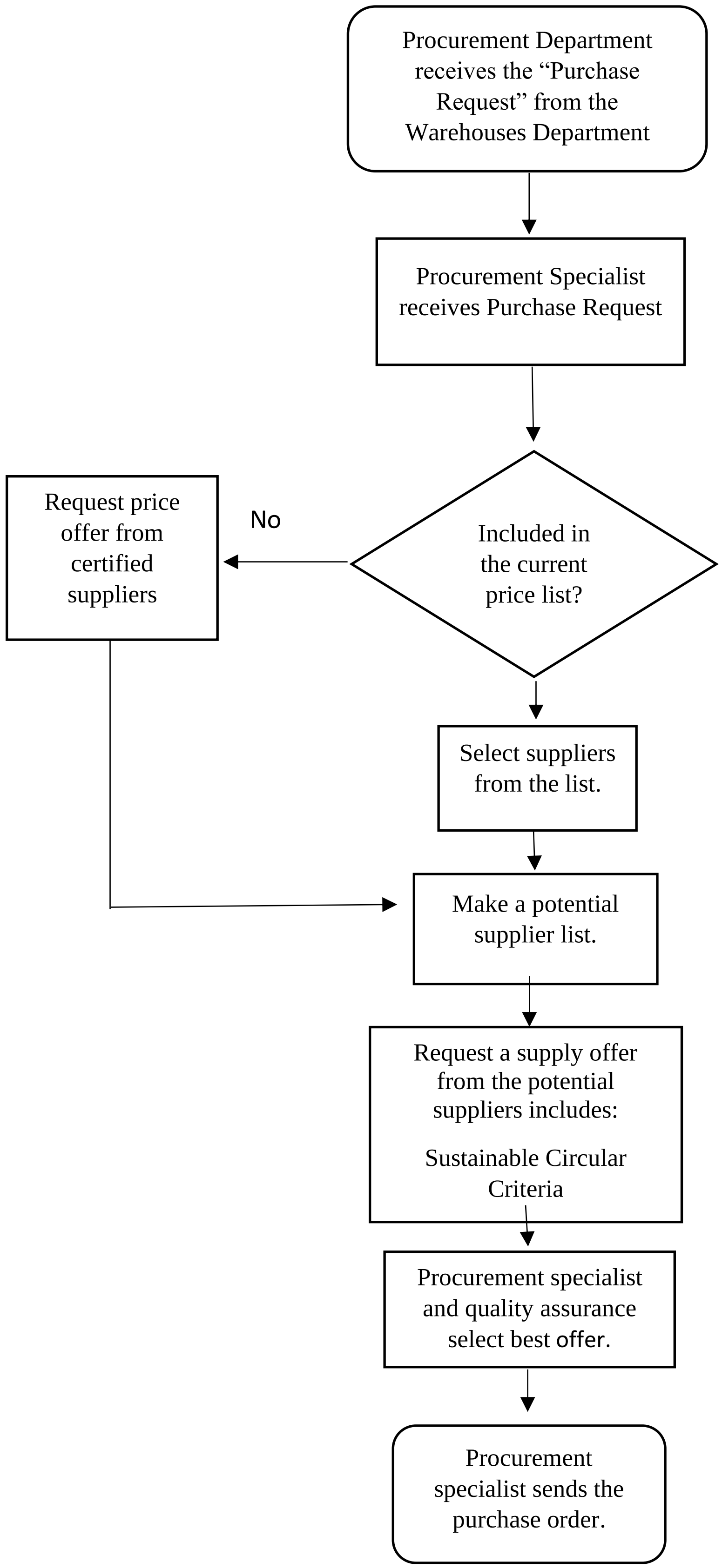
The key stakeholders that are responsible for supplier selection, such as the procurement specialist from the procurement management department, and the quality assurance representative from the quality management department.

(10) How can commitment be fostered?

The researcher provides a detailed explanation to the key stakeholders in charge of supplier selection on how they will use the proposed SCSS Model to assess suppliers. **Figure 6.5** illustrates the allocation of commitments, and the duration required.

According to the research aim, the researcher of the study modified the current supplier selection process of "Company B" to include the proposed criteria of the proposed **SCSS Model** of the study to improve its supplier selection process towards sustainability and CE contexts. The modifications mainly were improving the evaluation criteria employed by the Procurement Management and Quality Management departments to be involved the criteria of the proposed SCSS Model, as well as ranking the supplier (using FUZZY-TOPSIS) according to the cause-and-effect groups of SCSS Model criteria. The modification will be shown in **Figure 6.5** highlighted in green.

Figure 6.5: The modified Supplier Selection Process of "Company B":



After modifying the current supplier selection process of **Company (B)** (as shown in **Figure 6.5**), the working principles of the proposed **SCSS Model** were presented to the participants of **Company (B)** to ensure effective implementation of the SCSS model. Four key steps were adopted as reported in **Figure 6.6.**

Figure 6.6: The steps of implementation of the proposed SCSS Model at Company (B):

STEP #1

The researcher explained the 22 criteria and their measurements to the decision makers, who were the procurement specialist and quality head.

STEP #2

The researcher provided the decision makers with "supplier's rating documents", to rate the suppliers according to the proposed sustainable circular criteria.

(1 – 5 Likert Scale)

STEP #3

After 20 days, the company contacted the researcher to provide her with the results of rating the suppliers.

STEP #4

After collecting the results, the researcher used the rating results as input to FUZZ-TOPSIS that indicated the results to select the best supplier according to the proposed **SCSS Model**.

As shown in **Figure 6. 6**, the researcher initially explained the 22 criteria of the SCSS Model to the procurement specialist and the quality head. Next, they provided a document for rating three suppliers on a 1–5 Likert scale based on the proposed criteria. The decision makers agreed that the evaluation process would take about one month. After 20 days, the researcher collected the rating documents upon their request. Subsequently, the researcher began the selection calculations using the FUZZY-TOPSIS technique.

- ***Phase (5): Implementation of Company (B):***

This phase was about the implementation of the proposed **SCSS Model**. As outlined in Chapter 3, the SCSS model utilises the FUZZY-TOPSIS method to evaluate suppliers. By implementing the SCSS Model, the organisation was equipped with the capability to evaluate two suppliers of their choice and choose the optimal one, taking into account both sustainability and the CE. These two suppliers were for supplying "Flush Valve". The FUZZY-TOPSIS software was applied to compute the ranking results of all suppliers. The **steps** of computing the suppliers' ranking using FUZZY-TOPSIS technique at **Company (B)** are described below:

Step 1: Create a decision matrix:

For the case of **Company (B)**, there were 22 selection criteria, and two suppliers were ranked. Table **6.13** shows the weight assigned to each criterion in form of a fuzzy total relation matrix using the FUZZY TOPSIS method, which is detailed in Chapter 5.

Table 6.13. Criteria Weightings for Company (B):

	Criteria	Weight
1	EC1	(0.003,0.012,0.067)
2	EC2	(0.014,0.046,0.133)
3	EC3	(0.004,0.011,0.054)
4	EC4	(0.003,0.008,0.043)
5	EC5	(0.001,0.003,0.048)
6	ENV1	(0.028,0.074,0.159)
7	ENV2	(0.018,0.052,0.130)
8	ENV3	(0.006,0.020,0.076)
9	ENV4	(0.007,0.024,0.089)
10	ENV5	(0.023,0.062,0.142)
11	ENV6	(0.009,0.030,0.098)
12	SO1	(0.011,0.035,0.104)
13	SO2	(0.004,0.017,0.069)
14	SO3	(0.016,0.047,0.122)

15	SO4	(0.013,0.041,0.121)
16	SO5	(0.007,0.025,0.091)
17	CR1	(0.013,0.038,0.106)
18	CR2	(0.012,0.037,0.108)
19	CR3	(0.018,0.054,0.143)
20	CR4	(0.015,0.046,0.125)
21	CR5	(0.005,0.018,0.075)
22	CR6	(0.008,0.025,0.089)

A linguistic scale for assessing suppliers based on SCSS criteria is presented in the table below, as used by (Kore *et al.*, 2017):

Table 6.14: Fuzzy Scale for Company (B):

Code	Linguistic terms	L	M	U
1	Very low	1	1	3
2	Low	1	3	5
3	Medium	3	5	7
4	High	5	7	9
5	Very high	7	9	9

The suppliers were then evaluated using various criteria, and the decision matrix results are shown in Appendix XIV.

Step 2: Create the normalized decision matrix:

Based on the positive and negative ideal solutions, a normalised decision matrix can be calculated by the following relation, based on Equation 11 and Equation 12. The normalised decision matrix is shown in Appendix XV.

Step 3: Create the weighted normalized decision matrix:

Considering the different weights of each criterion, the weighted normalized decision matrix, as shown in Appendix XVI, can be calculated by multiplying the weight of each criterion in the normalised fuzzy decision matrix, according to Equation 13.

Step 4: Determine the fuzzy positive ideal solution (FPIS, A*) and the fuzzy negative ideal solution ($FNIS, A^{-}$)

The FPIS and FNIS of the alternatives (suppliers) can be defined according to Equation 14 and 15.

Table 6.15: The positive and negative ideal solutions for Company (B):

Criteia	Positive ideal	Negative ideal
EC1	(0.002,0.012,0.067)	(0.001,0.007,0.052)
EC2	(0.011,0.046,0.133)	(0.011,0.046,0.133)
EC3	(0.003,0.011,0.054)	(0.002,0.009,0.054)
EC4	(0.002,0.006,0.043)	(0.002,0.006,0.043)
EC5	(0.001,0.003,0.048)	(0.001,0.003,0.048)
ENV1	(0.022,0.074,0.159)	(0.016,0.058,0.159)
ENV2	(0.010,0.040,0.130)	(0.010,0.040,0.130)
ENV3	(0.001,0.012,0.076)	(0.001,0.012,0.076)
ENV4	(0.004,0.019,0.089)	(0.002,0.013,0.069)
ENV5	(0.018,0.062,0.142)	(0.008,0.034,0.110)
ENV6	(0.005,0.023,0.098)	(0.001,0.010,0.054)
SO1	(0.006,0.027,0.104)	(0.004,0.019,0.081)
SO2	(0.002,0.013,0.069)	(0.002,0.013,0.069)
SO3	(0.012,0.047,0.122)	(0.009,0.037,0.122)
SO4	(0.007,0.032,0.121)	(0.004,0.023,0.094)
SO5	(0.004,0.019,0.091)	(0.004,0.019,0.091)
CR1	(0.010,0.038,0.106)	(0.004,0.021,0.082)
CR2	(0.007,0.029,0.108)	(0.004,0.021,0.084)

CR3	(0.010,0.042,0.143)	(0.006,0.030,0.111)
CR4	(0.008,0.036,0.125)	(0.005,0.026,0.097)
CR5	(0.003,0.014,0.075)	(0.003,0.014,0.075)
CR6	(0.003,0.018,0.089)	(0.003,0.018,0.089)

Step 5: Calculate the distance between each alternative and the fuzzy positive ideal solution A^* as well as the distance between each alternative and the fuzzy negative ideal solution A^-

The distance between each alternative and FPIS and the distance between each alternative and FNIS can be calculated according to Equation 16, Equation 17 and Equation 18. **Table 6.16** shows distance from positive and negative ideal solutions for all suppliers.

Table 6.16 Distance from positive and negative ideal solutions for Company (B):

Alternatives (Suppliers)	Distance from positive ideal	Distance from negative ideal
Supplier 1	0.181	0.009
Supplier 2	0.009	0.181

Step 6: Calculate the closeness coefficient and rank the alternatives:

The closeness coefficient of each alternative can be calculated according to Equation 19.

The best alternative is closest to FPIS and farthest to the FNIS. The closeness coefficient of each alternative and the ranking order of all suppliers are shown in **Table 6.17**.

Table 6.17 Closeness coefficient:

Alternatives (Suppliers)	Ci	rank
Supplier 1	0.048	2
Suppliers 2	0.952	1

Therefore, it was demonstrated the SCSS model can help **Company (B)** to evaluate and select the best supplier, i.e. Supplier (2), which was deemed as the most suitable supplier enhancing both sustainability and CE performance of the company.

- ***<u>Phase (6): Evaluation of Company (B):</u>***

The feedback of the participants about the model implementation was gathered via a questionnaire. Consistent with the evaluation phase of Company (A), the first section contains five questions asking about the experts' level of satisfaction concerning the suggested model, using 7-point Likert Scale. The second section addresses, from the participants' viewpoint, the constraints of the model and ways of enhancing the model.

- 1st section of the feedback questionnaire of **Company (B)**: **Table 6.18** shows the analysis of the results of 1st section of the questionnaire.

Table 6.18 Results of Degree of Satisfaction of Company (B):

Question 1: All the criteria of the model are clear.							
Level	*Extremely Unsatisfied*	*Very Unsatisfied*	*Unsatisfied*	*Neutral*	*Satisfied*	*Very Satisfied*	*Extremely Satisfied*
Results						1	1
Question 2: The model provides strong structure for measuring the sustainable circular practices of the suppliers.							
Level	*Extremely Unsatisfied*	*Very Unsatisfied*	*Unsatisfied*	*Neutral*	*Satisfied*	*Very Satisfied*	*Extremely Satisfied*
Results							2
Question 3: The model generates reliable results.							
Level	*Extremely Unsatisfied*	*Very Unsatisfied*	*Unsatisfied*	*Neutral*	*Satisfied*	*Very Satisfied*	*Extremely Satisfied*
Results							2
Question 4: The suppliers' rating sheet is easy and understandable.							
Level	*Extremely Unsatisfied*	*Very Unsatisfied*	*Unsatisfied*	*Neutral*	*Satisfied*	*Very Satisfied*	*Extremely Satisfied*
Results							2
Question 5: The time consumed for implementing the model							
Level	*Extremely Unsatisfied*	*Very Unsatisfied*	*Unsatisfied*	*Neutral*	*Satisfied*	*Very Satisfied*	*Extremely Satisfied*
Results				1		1	

The results showed that the participants were happy with the proposed **SCSS Model** and recognised its potential to improve their procurement processes. Regarding the final question about their satisfaction with the implementation timeline, one participant showed a neutral level of contentment. In conclusion, the findings in this section indicated that the participants approved of the suggested **SCSS Model** and understood its importance in enhancing their procurement procedures.

- 2nd section of the feedback questionnaire of **Company (B):**

Q1: What are the limitations/challenges that occurred while implementing the model? How to overcome these limitations?

Participants of **Company (B)** stated that collecting the data from the suppliers in order to rate them according to all criteria was quite challenging and consumed time when providing them with the related information and evidence. This is because most of the proposed criteria were applied for the first time to rate the suppliers. They recommended the following in order to overcome this limitation:

- Build a long-term relationship with the suppliers that had been selected so that there will be no need to re-collect at least the criteria related to their organisation environment, such as occupational health and safety, workers' rights, social responsibility and respecting environmental standards for recycling.
- Raise awareness of key suppliers about the new criteria, by sending them the proposed criteria along with their descriptions before the selection process.

Q2: What could be the action plan for executing the proposed model, which is the sustainable supplier selection model, instead of the current supplier selection process?

Participants of **Company (B)** stated that the supply chain department is the department which is responsible for setting the procurement policy. Therefore, the supply chain director will make a proposal for the "Top-Management" in order to explain the proposed model and define its criteria and explain how it could improve the company's procurement practices and supply chain management. If the "Top-Management" approves the changing process of selecting and evaluating suppliers, then the supply chain director will approve the changing process, and accordingly the supply chain team and quality team will amend the procedures, and the documents related to the supplier selection process management.

Q3. What does your company need to increase the knowledge of its employees about the proposed model?

Participants of **Company (B)** noticed that:

- It is important to make sure that all of the employees in the supply chain and quality departments know about the proposed model and how suppliers will be rated based on the criteria of the proposed SCSS Model.
- Consider any training needs for sustainable procurement. This should consider if existing staff members need specialised training, as well as training for new employees who will perform a significant role in procurement decisions.
- Amend the related documents, which include the selection and evaluation criteria, to match the sustainable circular proposed criteria.

Q4. To what extent do you expect the proposed SCSS Model will improve the current procurement practice?

Participants of **Company (B)** stated that this will benefit their company's performance, especially that their company is in the planning phase for transition from ISO 18001 to ISO 45001 (Occupational Health and Safety), which require the organisation to create and maintain policies to control the procurement of goods and services to accomplish the desired results of occupational health and safety. Moreover, they stated that the idea of determining the case-and-effect groups of the criteria was helpful, which assisted them to notify the suppliers to recognise what to improve in their performance according to the causal criteria, in which these criteria will influence their overall performance.

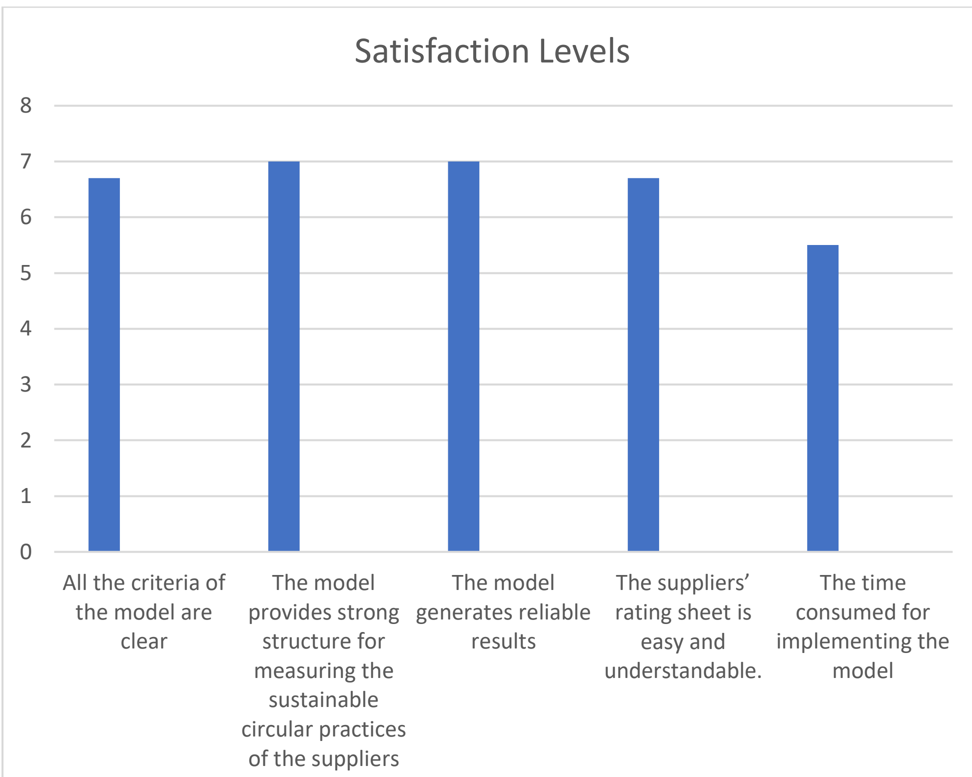
6.4 Chapter Summary:

This chapter presented an action research methodology to test the usefulness of the proposed **SCSS Model** within two case companies. The chapter outlined the key steps of the action research cycle within the two companies, encompassing Data gathering, Data feedback, Data analysis, Action Planning, and Evaluation.

Some key findings of the model test were presented. This test examined the level of participants' contentment to the implementation of the proposed **SCSS Model**, in addition to the factors driving and hindering its adoption. Based on the participants' feedback, as shown in **Figure 6.7**, some main findings are summarised below:

- The mean satisfaction level score of the SCSS model was 6.75 (between "very satisfied" and "extremely satisfied") indicating that all selection criteria were clear.
- The model was deemed to have a strong structure of measuring the sustainable and circular practices of the suppliers, as indicated by the mean satisfaction level score,7 (the maximum).
- The mean satisfaction score over the model reliability was 7 (the maximum).
- The mean satisfaction core regarding the rating mechanism's simplicity was 6.75.
- The participants were found to be less satisfied with the time consumed for implementing the model, as the mean satisfaction level was only 5.

Figure 6.7 The participants' satisfaction levels:



On the other hand, regarding the challenges associated with the implementation of the model, most participants commented that the process of measuring all selection criteria and ranking the suppliers was tedious. While acknowledging this challenge, some recommendations were suggested to overcome these challenges by: (1) Increasing the awareness of suppliers about the selection criteria especially those new ones, by providing the criteria description and rationale behind, and (2) Building a long-term relationship with the suppliers to increase their commitment towards the model and reduce their effort in data collection.

Based on the collected feedback, a 6-month action plan was established to indicate the tasks and timeline through a "Gantt Chart" as shown in **Figure 6.8** which will help to increase the feasibility of the recommendations. All estimated times for each activity of all main tasks were determined by consulting with the participants (Appendix XVIII).

Figure 6.8 Gantt Chart for implementing the proposed SCSS Model:

#	TASK	Activity	1 Month	2 Months	3 Months	4 Months	5 Months	6 Months
1	**Approval of the new method of selecting suppliers (proposed SCSS Model)**	Formulating a proposal to discern the SCSS Model and its significance for corporate sustainability.	■					
		Submitting the proposal to Top Management for approval.		■				
2	**Internal Organizational Management**	Employee awareness about sustainable circular procurement practices			■			
		Training on sustainable circular procurement for decision makers and their teams is necessary.			■	■		
3	**Documentation**	Revise the appropriate procurement documentation.				■		
4	**External management**	Distribute the procurement policy to primary suppliers.					■	■
		Distribute the guideline criteria for the participants of the tenders.					■	■

In conclusion, testing the implementation results indicated that the SCSS model was considered useful and feasible to improve the supplier selection process of the two case companies and both companies have shown a good level of confidence towards the adoption of the action plan over a period of 6 months.

CHAPTER 7
CONCLUSION

7.1 Introduction

This final chapter offers an overview of the research, a conclusion, novelty and contribution, research limitations and recommendations for follow-up research. The chapter is, hence, divided into four sections. Section 7.2 presents the overall research problem and design and highlights how research aim, and objectives are achieved. Section 7.3 displays the research novelty and contribution. Section 7.4 discusses the research limitations. Finally, section 7.5 concludes the whole research with some recommendations for future work.

7.2 Research Problem and Design:

This study aims to improve the knowledge base for supplier selection area towards sustainability and circular economy (CE) contexts. Nowadays, supplier selection processes encounter problems over selecting suitable suppliers to improve companies' sustainable and circular supply chains management. Most of the current studies focused on developing sustainable supplier selection problems, determining the three pillars/dimensions of sustainability (economic, environment, and social). However, the literature review findings revealed that although engaging CE into sustainability has become crucial to improve sustainable circular supply chain management, the problem of supplier selection considering both sustainability and circularity has not been sufficiently addressed. Given this knowledge gap, the Sustainable Circular Supplier Selection (SCSS) Model was developed to provide a structured approach of evaluating and selecting suppliers.

Moreover, the SCSS Model is capable of considering the interdependence between the criteria over four dimensions and identifying the most influential criterion/criteria in the process of supplier selection towards sustainability and CE. In particular, the reverse logistics is, for the first time, being explicitly defined and considered in this research, offering a more holistic approach to supplier selection.

To bridge the knowledge gap, this study aimed to develop the SCSS Model, using FUZZY-DEMATEL technique with a number of key objectives as follows:

- To develop a list of supplier selection criteria for sustainability and CE with four dimensions (Economic, Environmental, Social, Circular), with a particular focus on the application in the MENA region.
- To find out the importance and applicability levels of criteria for supplier selection that refer to sustainability and CE, particularly within the context of the MENA region's specific circumstances.
- To develop a **SCSS Model** using the FUZZY-DEMATEL technique to measure the interdependency relationship among the proposed criteria.
- To test the proposed SCSS Model within a practical setting through the implementation of an action research pilot.

To achieve these objectives and answer their related research questions, the research methodology was structured in four phases (as shown in **Figure 1.1** in Chapter 1) as follows:
Phase 1, known as the “Identification of Supplier Selection Criteria for sustainability and CE”, aimed to achieve research objective 1 (**RO1):**

During this stage, a review of the literature was conducted to determine the existing research on supplier selection issues and to identify areas requiring further investigation within sustainable and CE contexts. Following the literature analysis, a detailed list of 24 criteria for sustainable circular supplier selection was conducted, categorised into four primary dimensions: economic, environmental, social and circular. Subsequently, the researcher carried out thorough semi-structured interviews with five distinct manufacturing companies to explore their current supplier selection methodologies and to uncover any additional pertinent criteria that could enhance the comprehensive list, guided by the recommendations of the experts. The experts suggested incorporating 2 additional criteria into the proposed model: Financial Stability and Reverse Logistics Agreement. This phase was instrumental in aiding the researcher in the formation of an initial **SCSS Model** aimed at selecting suppliers within sustainability and CE frameworks, incorporating the newly identified criteria "Reverse Logistics Agreement" under the circular dimension. An initial list of 26 criteria for supplier selection was conducted in this phase.

Phase 2, known as the "Validation of the practical need of the proposed list of criteria of the SCSS Model" aimed to achieve Research Objective 2 **(RO2)**:

In this phase, the initial list of the 26 sustainable circular criteria was assessed to ensure their importance and practical necessity to decide which ones should be incorporated into the SCSS Model. This assessment was conducted using a 5-point Likert scale questionnaire designed to evaluate the importance and applicability of the suggested criteria with 52 industry experts. The Relative Importance Index (RII) and Mann Witney-U test statistical tools were utilised for analysing the results of the questionnaire. The results from the questionnaire indicated that only 22 criteria were deemed suitable for inclusion in the proposed SCSS Model based on the RII and Mann Witney-U test, after excluding four criteria based on their low RII and Mann Witney-U test values.

Phase 3, Known as the **"**Developing a **SCSS Model** using FUZZY-DEMATEL MCDM" aimed to achieve Research Objective 3 **(RO3)**:

In this phase, the SCSS Model was developed using FUZZY-DEMATEL technique. The development was conducted through pairwise comparison between the 22 criteria by 20 experts within the MENA region. The FUZZY-DEMATEL technique provided "cause-and-effect" diagram categorised the 22 criteria into 4 quarters according to their prominence and relation levels. The results showed that 8 cause criteria were listed in the 1st quarter, which is considered as the core influential criteria that affect other sustainable circular supplier selection criteria. It means that suppliers should prioritize improving these criteria. These criteria were Environmental Management Systems (ENV1), GHG emissions (ENV5), Air pollution resulting from recycling process (CR3), Clean technology for recycling (CR4), Occupational Health & Safety (SO3), Respecting environmental standards and regulations in the process of recycling (CR2), Training Related Carbon (SO1). Regarding the 2nd quarter, which represented the driving criteria, possessing a low degree of prominence but a strong relation, only two cause criteria were listed in this quarter i.e. "Information Disclosure (SO5)" and "Financial Stability (EC5)". Concerning the 3rd quarter, it involved seven criteria, which are considered as independent criteria that can be improved independently as they have low values of interactions with the other criteria. These criteria were seven effect criteria i.e. Reverse Logistics Agreement (CR6), Green Transportation (ENV3), Eco-friendly packaging (CR5), Cost (EC1), Worker's Rights (SO2), Delivery and services (EC3), and Flexibility (EC4). The final quarter was the 4th quarter and represented the impacted criteria which cannot be directly improved, as their improvements depend on other criteria within the cause group. Five effect criteria were listed in this quarter i.e. Green Design (ENV2), Quality (EC2), Society's Rights/ Social responsibilities (SO4), Eco-friendly raw materials (CR1), and Carbon Disclosure Report (ENV6). The findings of this phase provided recommendations for organisations in their process of supplier selection, focusing on both sustainability and CE contexts based on the criteria weights and the analysis of the causal relationship derived from FUZZY-DEMATEL. Additionally, these findings can help suppliers refine their development criteria and boost their competitiveness by utilizing the criteria weights and the analysis of the causal relationships obtained from FUZZY-DEMATEL.

Phase 4, known as "Testing the proposed SCSS Model in practical setting", aimed to achieve Research Objective 4 (RO4):

Finally, the proposed SCSS Model efficacy was assessed through an action research pilot conducted in two specific case companies. The action research study aimed to improve the process of supplier selection with a focus on sustainability and CE contexts. Coughlan and Coghlan (2002) action research cycle framework was utilized due to its focused approach towards addressing action research within the field of management studies. By utilising action research cycle, the proposed SCSS Model was successfully implemented by the two case companies to rank suppliers using FUZZY-TOPSIS technique. The findings of the evaluation of implementing the SCSS Model identified the time-consuming process of measuring all selection criteria and ranking suppliers as a primary challenge. To address the challenges related to the implementation of the SCSS Model, the study suggests: (1) Enhancing supplier awareness: Offering detailed explanations and justifications for the selection criteria, particularly the new ones, can assist suppliers in grasping their significance and adjusting their practices accordingly, (2) Nurturing Long-Term Relationships: Refining strong connections with suppliers can promote trust, commitment, and alleviate the burden of data collection. In conclusion, the implementation of the proposed SCSS Model could enhance the sustainability and performance of CE practices for both companies by ensuring that their suppliers conform to their sustainable and CE goals. By addressing the identified challenges and implementing the recommended strategies, companies can create more sustainable supply chain and circular supply chain management.

7.3 Research novelty and contribution:

The novel of this study is developing a comprehensive SCSS Model for evaluating suppliers across four key dimensions: economic, environmental, social and circular. The model explicitly incorporates CE principles, which are increasingly important for sustainable and circular supply chain management. The research employed a unique combination of FUZZY-DEMATEL and FUZZY-TOPSIS, providing a strong and efficient approach for analyzing the interdependencies among criteria and ranking suppliers. This study uniquely tackles the context of the MENA region, marking the first time this problem has been addressed within that region.

This study contributes to knowledge by developing for the first time SCSS Model for evaluating suppliers across four key dimensions: economic, environmental, social and circular incorporating new criterion under the circular dimension i.e. "Revers Logistics Agreement". The study utilises FUZZY-DEMATEL technique which identifies the interdependency among criteria of the proposed SCSS Model.

Moreover, the study contributes to practice, because the proposed SCSS Model assists the decision-makers in selecting suppliers that align with their sustainability and CE goals. As a result, by adopting the SCSS Model, organisations can enhance the sustainability and circularity performance of their supply chains.

The study supports SDG 8 (decent work and economic growth) and SDG 12 (responsible consumption and production). The SCSS Model promotes ethical labor and safe working conditions, enhancing decent work under "SDG 8". Moreover, CE principles like repair and reuse create job opportunities. Furthermore, the utilisation of the SCSS Model will encourage suppliers to focus on resource efficiency and waste reduction leads to better operations, lower costs, increased productivity, and enhanced economic competitiveness. The study promotes "SDG 12" in many areas, as the integration of CE principles within the SCSS Model encourages suppliers to improve resource efficiency, recycle materials, and reduce waste. Moreover, CE principles promote the development of longer-lasting products, enhancing sustainability. Additionally, choosing suppliers based on their environmental practices reduces pollution and conserves energy and water.

7.4 Research limitations

This research provides good academic and industrial values to the field of supplier selection, but it also suffers from some limitations. These limitations provide some areas for improvement and offer useful basis for future research in sustainable circular supplier selection in particular as well as sustainable circular supply chain in general:

- The study focused exclusively on the MENA region. Although the results might be relevant to additional regions, additional investigation is required to confirm the generalisability of the proposed SCSS Model.
- Due to the accessibility of the researcher, the proposed SCSS Model was testing only at two industrial companies located in Egypt by utilising action research cycle. Although it offers important insights based on the evaluation phase of the action research cycle, it may not encompass the complete range of variations and complexities present in varied industries and situations.

7.5 Recommendations for future work

To enhance the effectiveness of the proposed SCSS Model, it is essential to investigate methods for integrating this SCSS Model with current enterprise resource planning (ERP) systems within organisations or sustainability management software to facilitate its implementation.

To implement the suggested SCSS Model in practical scenarios, a strategic plan, illustrated in Chapter 6 (Figure 6.8), is provided to assist manufacturing firms in adapting their procurement strategies to incorporate the proposed SCSS Model in the future, moving away from their existing supplier selection practices.

To facilitate effective data gathering from suppliers in line with the SCSS Model criteria, purchasing firms must leverage technological solutions, such as data analytics software, to optimise both data collection and analysis processes. Moreover, they must establish uniform data collection techniques to guarantee consistency and comparability among various suppliers, especially for the intangible criteria such as the ones under social and circular dimensions. Furthermore, companies must work closely with suppliers to obtain the necessary data and address any concerns or challenges.

Given that the practical application of the proposed SCSS Model was limited to just two industrial companies in the MENA region, additional research involving more case studies across various regions and industries is essential to confirm the generalisability of the results and pinpoint best practices. Another path for future research involves conducting longitudinal studies to assess the long-term effects of implementing the SCSS Model on company performance, sustainability outcomes, and supply chain resilience.

References

Abdulkader, M., Bhatt, S. K. and El-Mekkawy, T. (2015) 'Reverse Supply Chain: Literature Review and Models', *Journal of Supply Chain Management Systems*, 4(1and2). doi: 10.21863/jscms/2015.4.1and2.007.

Abualigah, L. *et al.* (2023a) 'Revolutionizing sustainable supply chain management: A review of metaheuristics', *Engineering Applications of Artificial Intelligence*, 126. doi: 10.1016/j.engappai.2023.106839.

Abualigah, L. *et al.* (2023b) 'Revolutionizing sustainable supply chain management: A review of metaheuristics', *Engineering Applications of Artificial Intelligence*, 126(PA), p. 106839. doi: 10.1016/j.engappai.2023.106839.

ACTED (2022) 'Circularity as a lifeline for MENA economies in distress'. Available at: https://www.acted.org/wp-content/uploads/2021/03/circularity-as-a-lifeline-for-mena-economies-in-distress-v3.pdf.

Adebanjo, D. *et al.* (2013) 'A case study of supplier selection in developing economies: A perspective on institutional theory and corporate social responsibility', *Supply Chain Management*, 18(5), pp. 553–566. doi: 10.1108/SCM-08-2012-0272.

Akal, A. Y. and Kineber, A. F. (2022) 'A Phase-Based Roadmap for Proliferating BIM within the Construction Sector Using DEMATEL Technique : Perspectives from Egyptian Practitioners', *Buildings*, 12(1805), pp. 1–29. doi: https://doi.org/10.3390/buildings12111805.

Akyuz, E. and Celik, E. (2015) 'A fuzzy DEMATEL method to evaluate critical operational hazards during gas freeing process in crude oil tankers', *Journal of Loss Prevention in the Process Industries*, 38, pp. 243–253. doi: 10.1016/j.jlp.2015.10.006.

Alaei, S. *et al.* (2023) 'Unveiling the role of sustainable supply chain drivers toward knowledge-based economy via a novel permutation approach: implications from an emerging economy', *Operations Management Research*, 16(3), pp. 1231–1250. doi: 10.1007/s12063-023-00380-1.

Alavi, B., Tavana, M. and Mina, H. (2021) 'A Dynamic Decision Support System for Sustainable Supplier Selection in Circular Economy', *Sustainable Production and Consumption*, 27, pp. 905–920. doi: 10.1016/j.spc.2021.02.015.

Ali, H., Zhang, J. and Shoaib, M. (2023) *A hybrid approach for sustainable-circular supplier selection based on industry 4.0 framework to make the supply chain smart and eco-friendly*, *Environment, Development and Sustainability*. Springer Netherlands. doi: 10.1007/s10668-023-03567-5.

Alidrisi, H. (2014) 'An ANP-based multi criteria decision making model for supplier selection', *IEEE International Conference on Industrial Engineering and Engineering Management*, 2015-Janua, pp. 585–588. doi: 10.1109/IEEM.2014.7058705.

Alikhani, R., Torabi, S. A. and Altay, N. (2019) 'Strategic supplier selection under sustainability and risk criteria', *International Journal of Production Economics*, 208(October 2018), pp. 69–82. doi: 10.1016/j.ijpe.2018.11.018.

Alzawawi, M. (2013) 'Drivers and Obstacles for Creating Sustainable Supply Chain Management and Operations', *Journal of Engineering Education (JEE)*, pp. 1–8.

Amindoust, A. *et al.* (2012) 'Sustainable supplier selection: A ranking model based on fuzzy inference system', *Applied Soft Computing Journal*, 12(6), pp. 1668–1677. doi: 10.1016/j.asoc.2012.01.023.

Ansari, Zulfiquar N and Kant, R. (2017) 'A state-of-art literature review reflecting 15 years of focus on sustainable supply chain management', *Journal of Cleaner Production*, 142, pp. 2524–2543. doi: 10.1016/j.jclepro.2016.11.023.

Ansari, Zulfiquar N. and Kant, R. (2017) 'A state-of-art literature review reflecting 15 years of focus on sustainable supply chain management', *Journal of Cleaner Production*, 142, pp. 2524–2543. doi: 10.1016/j.jclepro.2016.11.023.

Arabsheybani, A., Paydar, M. M. and Safaei, A. S. (2018) 'An integrated fuzzy MOORA method and FMEA technique for sustainable supplier selection considering quantity discounts and supplier's risk', *Journal of Cleaner Production*, 190, pp. 577–591. doi: 10.1016/j.jclepro.2018.04.167.

Armoh, M. B. *et al.* (2023) 'Effect of supplier appraisal on firm performance in Ghana: Views of employees of selected manufacturing firms', *Scientific African*, 21(July), p. e01829. doi: 10.1016/j.sciaf.2023.e01829.

Asadi, S. *et al.* (2022) 'Drivers and barriers of electric vehicle usage in Malaysia: A DEMATEL approach', *Resources, Conservation and Recycling*, 177(January 2020), p. 105965. doi: 10.1016/j.resconrec.2021.105965.

Ashraf, S. *et al.* (2020) 'Diverging Mysterious in Green Supply Chain Management', *Oriental journal of computer science and technology*, 13(1), pp. 22–28. doi: 10.13005/ojcst13.01.02.

Asthana, N. and Gupta, M. (2015) 'Supplier selection using artificial neural network and genetic algorithm', *International Journal of Indian Culture and Business Management*, 11(4), p. 457. doi: 10.1504/ijicbm.2015.072428.

Awasthi, A., Govindan, K. and Gold, S. (2018) 'Multi-tier sustainable global supplier selection using a fuzzy AHP-VIKOR based approach', *International Journal of Production Economics*, 195, pp. 106–117. doi: 10.1016/j.ijpe.2017.10.013.

Aydin, F. and Gümüş, B. (2022) 'Comparative analysis of multi-criteria decision making methods for the assessment of optimal SVC location', *Bulletin of the Polish Academy of Sciences: Technical Sciences*, 70(2). doi: 10.24425/bpasts.2022.140555.

Azadi, M. *et al.* (2015) 'A new fuzzy DEA model for evaluation of efficiency and effectiveness of suppliers in sustainable supply chain management context', *Computers and Operations Research*, 54, pp. 274–285. doi: 10.1016/j.cor.2014.03.002.

Azadnia, A. H. *et al.* (2013) *An integrated approach for sustainable supplier selection using fuzzy logic and fuzzy AHP*, *Applied Mechanics and Materials*. doi: 10.4028/www.scientific.net/AMM.315.206.

Bai, C. and Sarkis, J. (2010) 'Integrating sustainability into supplier selection with grey system and rough set methodologies', *International Journal of Production Economics*, 124(1), pp. 252–

264. doi: 10.1016/j.ijpe.2009.11.023.

Bai, C. and Sarkis, J. (2014) ‘Determining and applying sustainable supplier key performance indicators’, *Supply Chain Management*, 19(3), pp. 275–291. doi: 10.1108/SCM-12-2013-0441.

Bai, C. and Sarkis, J. (2020) ‘A supply chain transparency and sustainability technology appraisal model for blockchain technology’, *International Journal of Production Research*, 58(7), pp. 2142–2162. doi: 10.1080/00207543.2019.1708989.

Bakås, O., Tveit, S. S. and Thomassen, M. K. (2022) *Reverse Logistics for Improved Circularity in Mass Customization Supply Chains, Lecture Notes in Mechanical Engineering*. Springer International Publishing. doi: 10.1007/978-3-030-90700-6_118.

Bansal, P. and Mcknight, B. (2009) ‘Looking forward, pushing back and peering sideways: Analyzing the sustainability of industrial symbiosis’, *Journal of Supply Chain Management*, 45(4), pp. 26–37. doi: 10.1111/j.1745-493X.2009.03174.x.

Baskaran, V., Nachiappan, S. and Rahman, S. (2012) ‘Indian textile suppliers sustainability evaluation using the grey approach’, *International Journal of Production Economics*, 135(2), pp. 647–658. doi: 10.1016/j.ijpe.2011.06.012.

Benediktsson, H. *et al.* (1992) ‘Ultrasound guided needle biopsy of brain tumors using an automatic sampling instrument’, *Acta Radiologica*, 33(6), pp. 512–517. doi: 10.1177/028418519203300602.

Bernon, M., Tjahjono, B. and Ripanti, E. F. (2018) ‘Aligning retail reverse logistics practice with circular economy values: an exploratory framework’, *Production Planning and Control*, 29(6), pp. 483–497. doi: 10.1080/09537287.2018.1449266.

Bhanot, N., Rao, P. V. and Deshmukh, S. G. (2017) ‘An integrated approach for analysing the enablers and barriers of sustainable manufacturing’, *Journal of Cleaner Production*, 142, pp. 4412–4439. doi: 10.1016/j.jclepro.2016.11.123.

Bhaskar, R. and Danermark, B. (2006) ‘Metatheory, interdisciplinarity and disability research: A critical realist perspective’, *Scandinavian Journal of Disability Research*, 8(4), pp. 278–297. doi: 10.1080/15017410600914329.

Biancolin, M., Capoani, L. and Rotaris, L. (2023) ‘Reverse logistics and circular economy: A literature review’, *European Transport - Trasporti Europei*, (94), pp. 1–19. doi: 10.48295/ET.2023.94.7.

Blum, N. U., Haupt, M. and Bening, C. R. (2020) ‘Why “Circular” doesn’t always mean “Sustainable”’, *Resources, Conservation and Recycling*, 162(July), p. 105042. doi: 10.1016/j.resconrec.2020.105042.

Bohdanowicz, P., Zientara, P. and Novotna, E. (2006) ‘Journal of Sustainable Tourism International hotel chains and environmental protection: an analysis of Hilton’s we care! programme (Europe, 2006-2008)’, *Journal of Sustainable Tourism*, 19(7), pp. 797–816. doi: 10.1080/09669582.2010.549566.

Boix, M. *et al.* (2015) ‘Optimization methods applied to the design of eco-industrial parks: A literature review’, *Journal of Cleaner Production*, 87(1), pp. 303–317. doi:

10.1016/j.jclepro.2014.09.032.

El Boudali, J., Qbadou, M. and Mansouri, K. (2022) ‘Designing of the reverse logistics network for returnable packaging’, *2022 IEEE 14th International Conference of Logistics and Supply Chain Management, LOGISTIQUA 2022*, pp. 1–6. doi: 10.1109/LOGISTIQUA55056.2022.9938079.

Bougie, R. and Uma, S. (2020) *Research methods for business: a skill building approach*. 8th edn. John Wiley And Sons.

Bowen, F. E. *et al.* (2001) ‘The role of supply management capabilities in green supply’, *Production and Operations Management*, 10(2), pp. 174–189. doi: 10.1111/j.1937-5956.2001.tb00077.x.

Burke, H., Zhang, A. and Wang, J. X. (2023) ‘Integrating product design and supply chain management for a circular economy’, *Production Planning and Control*, 34(11), pp. 1097–1113. doi: 10.1080/09537287.2021.1983063.

Burns, R. B. (2000) *Introduction to research methods*. 4th edn. Sage Publications.

Büyüközkan, G. and Çifçi, G. (2011) ‘A novel fuzzy multi-criteria decision framework for sustainable supplier selection with incomplete information’, *Computers in Industry*, 62(2), pp. 164–174. doi: 10.1016/j.compind.2010.10.009.

de Campos, E. A. R. *et al.* (2017) ‘Reverse logistics for the end-of-life and end-of-use products in the pharmaceutical industry: a systematic literature review’, *Supply Chain Management*, 22(4), pp. 375–392. doi: 10.1108/SCM-01-2017-0040.

Carter, C. R. and Rogers, D. S. (2008) ‘A framework of sustainable supply chain management: Moving toward new theory’, *International Journal of Physical Distribution and Logistics Management*, 38(5), pp. 360–387. doi: 10.1108/09600030810882816.

Chan, C. K. *et al.* (2020) ‘Supply chain coordination with reverse logistics: A vendor/recycler-buyer synchronized cycles model’, *Omega (United Kingdom)*, 95. doi: 10.1016/j.omega.2019.07.006.

Chang, P. C., Liu, C. H. and Lai, R. K. (2008) ‘A fuzzy case-based reasoning model for sales forecasting in print circuit board industries’, *Expert Systems with Applications*, 34(3), pp. 2049–2058. doi: 10.1016/j.eswa.2007.02.011.

Chauhan, C., Parida, V. and Dhir, A. (2022) ‘Linking circular economy and digitalisation technologies: A systematic literature review of past achievements and future promises’, *Technological Forecasting and Social Change*, 177(January), p. 121508. doi: 10.1016/j.techfore.2022.121508.

Chen, C. Y. and Huang, J. J. (2022) ‘A Novel DEMATEL Approach by Considering Normalization and Invertibility’, *Symmetry*, 14(6). doi: 10.3390/sym14061109.

Chen, G. *et al.* (2005) ‘Is China’s securities regulatory agency a toothless tiger? Evidence from enforcement actions’, *Journal of Accounting and Public Policy*, 24(6), pp. 451–488. doi: 10.1016/j.jaccpubpol.2005.10.002.

Chen, W. *et al.* (2015) 'Supply chain design for unlocking the value of remanufacturing under uncertainty', *European Journal of Operational Research*, 247(3), pp. 804–819. doi: 10.1016/j.ejor.2015.06.062.

Chen, Y. *et al.* (2018) 'Socially responsible supplier selection and sustainable supply chain development: A combined approach of total interpretive structural modeling and fuzzy analytic network process', *Business Strategy and the Environment*, 27(8), pp. 1708–1719. doi: 10.1002/bse.2236.

Chen, Y., Okudan, G. E. and Riley, D. R. (2010) 'Sustainable performance criteria for construction method selection in concrete buildings', *Automation in Construction*, 19(2), pp. 235–244. doi: 10.1016/j.autcon.2009.10.004.

Chen, Y. W. *et al.* (2017) 'A particle swarm approach for optimizing a multi-stage closed loop supply chain for the solar cell industry', *Robotics and Computer-Integrated Manufacturing*, 43, pp. 111–123. doi: 10.1016/j.rcim.2015.10.006.

Chen, Z. and Wang, X. (2020) 'Specific investment, supplier vulnerability and profit risks', *Journal of Business Finance and Accounting*, 47(9–10), pp. 1215–1237. doi: 10.1111/jbfa.12450.

Cheraghalipour, A. and Farsad, S. (2018) 'A bi-objective sustainable supplier selection and order allocation considering quantity discounts under disruption risks: A case study in plastic industry', *Computers and Industrial Engineering*, 118(March), pp. 237–250. doi: 10.1016/j.cie.2018.02.041.

Chiou, C. Y., Hsu, C. W. and Chen, H. C. (2011) 'Using DEMATEL to explore a casual and effect model of sustainable supplier selection', in *APBITM 2011 - Proceedings2011 IEEE International Summer Conference of Asia Pacific Business Innovation and Technology Management*, pp. 240–244. doi: 10.1109/APBITM.2011.5996331.

Costa, F. *et al.* (2019) 'Understanding Relative Importance of Barriers to Improving the Customer–Supplier Relationship within Construction Supply Chains Using DEMATEL Technique', *Journal of Management in Engineering*, 35(3), pp. 1–13. doi: 10.1061/(asce)me.1943-5479.0000680.

Coughlan, P. and Coghlan, D. (2002) 'Action research for operations management', *International Journal of Operations and Production Management*, 22(2), pp. 220–240. doi: 10.1108/01443570210417515.

Creswell, J. W. (2003) *Research design: Qualitative, quantitative, mixed methods approaches*. 2nd edn. Sage Publications.

Cristini, G., Zerbini, C. and Salvietti, G. (2021) 'Sustainable Supply Chain Management: A Literature Review', *Micro and Macro Marketing*, 30(1), pp. 19–42. doi: 10.1431/100335.

Cui, H. and Sošić, G. (2019) 'Recycling common materials: Effectiveness, optimal decisions, and coordination mechanisms', *European Journal of Operational Research*, 274(3), pp. 1055–1068. doi: 10.1016/j.ejor.2018.11.010.

Dai, J. and Blackhurst, J. (2012) 'A four-phase AHP-QFD approach for supplier assessment: A sustainability perspective', *International Journal of Production Research*, 50(19), pp. 5474–5490. doi: 10.1080/00207543.2011.639396.

Debacker, W. *et al.* (2020) 'Circular economy and design for change within the built environment:

preparing the transition', *International HISER Conference on Advances in Recycling and Management of Construction and Demolition Waste*, (June), pp. 114–117. Available at: https://www.bamb2020.eu/wp-content/uploads/2017/07/Circular-economy-and-design-for-change-within-the-built-environment_prep....pdf.

Dev, N. K., Shankar, R. and Qaiser, F. H. (2020) 'Industry 4.0 and circular economy: Operational excellence for sustainable reverse supply chain performance', *Resources, Conservation and Recycling*, 153(January 2019), p. 104583. doi: 10.1016/j.resconrec.2019.104583.

Dong, B. and Wilkinson, S. (2007) 'Practitioner perceptions of sustainability in the Building Code of Australia', *International Conference Adelaide Australia*, pp. 272–288. Available at: http://www.aibs.com.au/aibs_docs/conferences/Session_T1_Wilkinson.pdf.

Dubey, R. *et al.* (2017) 'Sustainable supply chain management: framework and further research directions', *Journal of Cleaner Production*, 142, pp. 1119–1130. doi: 10.1016/j.jclepro.2016.03.117.

Dudovskiy, J. (2022) *Positivism Research Philosophy*, *Business Research Methodology*. Available at: https://research-methodology.net/research-philosophy/positivism/#:~:text=Positivism depends on quantifiable observations,knowledge stems from human experience.

Ecer, F. and Torkayesh, A. (2022) 'A Stratified Fuzzy Decision-Making Approach for Sustainable Circular Supplier Selection', *IEEE Transactions on Engineering Management*, (Mcdm), pp. 1–15. doi: 10.1109/TEM.2022.3151491.

Echefaj, K. *et al.* (2023) 'Sustainable and resilient supplier selection in the context of circular economy: an ontology-based model', *Management of Environmental Quality: An International Journal*, 34(5), pp. 1461–1489. doi: 10.1108/MEQ-02-2023-0037.

Echefaj, K., Charkaoui, A. and Cherrafi, A. (2022) 'Sustainable and Resilient Supplier Selection in Circular Economy Framwork: Trends and Perspectives', *2022 IEEE 14th International Conference of Logistics and Supply Chain Management, LOGISTIQUA 2022*, pp. 1–6. doi: 10.1109/LOGISTIQUA55056.2022.9938112.

Eden, C. and Ackermann, F. (2018) 'Theory into practice, practice to theory: Action research in method development', *European Journal of Operational Research*, 271(3), pp. 1145–1155. doi: 10.1016/j.ejor.2018.05.061.

Edwards, J. B., McKinnon, A. C. and Cullinane, S. L. (2010) 'Comparative analysis of the carbon footprints of conventional and online retailing: A "last mile" perspective', *International Journal of Physical Distribution and Logistics Management*, 40(1–2), pp. 103–123. doi: 10.1108/09600031011018055.

Eide, A. E., Saether, E. A. and Aspelund, A. (2020) 'An investigation of leaders' motivation, intellectual leadership, and sustainability strategy in relation to Norwegian manufacturers' performance', *Journal of Cleaner Production*, 254, p. 120053. doi: 10.1016/j.jclepro.2020.120053.

Emamisaleh, K. and Rahmani, K. (2017) 'Sustainable supply chain in food industries: Drivers and strategic sustainability orientation', *Cogent Business and Management*, 4(1). doi: 10.1080/23311975.2017.1345296.

Emamisaleh, K. and Taimouri, A. (2021) 'Sustainable supply chain management drivers and outcomes: an emphasis on strategic sustainability orientation in the food industries', *Independent Journal of Management & Production*, 12(1), pp. 282–309. doi: 10.14807/ijmp.v12i1.1238.

Emovon, I. (2020) 'A Fuzzy Multi-Criteria Decision-Making Approach for Power Generation Problem Analysis', *Journal of Engineering Sciences*, 7(2), pp. E26–E31. doi: 10.21272/jes.2020.7(2).e5.

van Engelenhoven, T., Kassahun, A. and Tekinerdogan, B. (2023) 'Systematic Analysis of the Supply Chain Operations Reference Model for Supporting Circular Economy', *Circular Economy and Sustainability*, 3(2), pp. 811–834. doi: 10.1007/s43615-022-00221-6.

Erol, I. *et al.* (2010) 'Exploring reverse supply chain management practices in Turkey', *Supply Chain Management*, 15(1), pp. 43–54. doi: 10.1108/13598541011018111.

Fallahpour, A. *et al.* (2017) 'A decision support model for sustainable supplier selection in sustainable supply chain management', *Computers and Industrial Engineering*, 105, pp. 391–410. doi: 10.1016/j.cie.2017.01.005.

Farhangpour, Y. and Abdolsalami, A. (2016) 'The Philosophy of Postmodernism, Its Scholars and Its Impact on Art Designing a Database for Oriental Textiles in Medieval Period View project', (February). Available at: https://www.researchgate.net/publication/330971771.

Farooque, M. *et al.* (2019) 'Circular supply chain management: A definition and structured literature review', *Journal of Cleaner Production*. Elsevier Ltd, pp. 882–900. doi: 10.1016/j.jclepro.2019.04.303.

Farooque, M. *et al.* (2020) 'Fuzzy DEMATEL analysis of barriers to Blockchain-based life cycle assessment in China', *Computers and Industrial Engineering*, 147(July), p. 106684. doi: 10.1016/j.cie.2020.106684.

Farooque, M. *et al.* (2022) 'Circular supply chain management: Performance outcomes and the role of eco-industrial parks in China', *Transportation Research Part E: Logistics and Transportation Review*, 157(December 2021), p. 102596. doi: 10.1016/j.tre.2021.102596.

Farooque, M., Zhang, A. and Liu, Y. (2019) 'Barriers to circular food supply chains in China', *Supply Chain Management*, 24(5), pp. 677–696. doi: 10.1108/SCM-10-2018-0345.

Fernando, Y., Shaharudin, M. S. and Abideen, A. Z. (2023) 'Circular economy-based reverse logistics: dynamic interplay between sustainable resource commitment and financial performance', *European Journal of Management and Business Economics*, 32(1), pp. 91–112. doi: 10.1108/EJMBE-08-2020-0254.

Fleetwood, S. (2005) 'Ontology in organization and management studies: A critical realist perspective', *Organization*, 12(2), pp. 197–222. doi: 10.1177/1350508405051188.

Foddy, W. (1993) *Reducing question threat', in Constructing Questions for Interviews and Questionnaires: Theory and Practice in Social Research*. Cambridge University Press. doi: https://doi.org/10.1017/CBO9780511518201.010.

Fraenkel, J. R. and Wallen, N. E. (2007) *How to Design and Evaluate and Research in Education.* Boston: McGraw Hill. Available at: http://journal.umsurabaya.ac.id/index.php/JKM/article/view/2203.

Freise, M. and Seuring, S. (2015) ‘Social and environmental risk management in supply chains: a survey in the clothing industry’, *Logistics Research*, 8(1), pp. 1–12. doi: 10.1007/s12159-015-0121-8.

Frota Neto, J. Q. *et al.* (2008) ‘Designing and evaluating sustainable logistics networks’, *International Journal of Production Economics*, 111(2), pp. 195–208. doi: 10.1016/j.ijpe.2006.10.014.

Gao, D., Zhao, Y. and Ma, J. (2023) ‘How Does Supply Chain Information Disclosure Relate to Corporate Investment Efficiency? Evidence from Chinese-Listed Companies’, *Sustainability (Switzerland)*, 15(8). doi: 10.3390/su15086479.

García-Barragán, J. F., Eyckmans, J. and Rousseau, S. (2019) ‘Defining and Measuring the Circular Economy: A Mathematical Approach’, *Ecological Economics*, 157(October 2018), pp. 369–372. doi: 10.1016/j.ecolecon.2018.12.003.

Gaziulusoy, A. I. and Brezet, H. (2015) ‘Design for system innovations and transitions: A conceptual framework integrating insights from sustainablity science and theories of system innovations and transitions’, *Journal of Cleaner Production*, 108, pp. 558–568. doi: 10.1016/j.jclepro.2015.06.066.

Genovese, A., Acquaye, Adolf A, *et al.* (2017) ‘Sustainable supply chain management and the transition towards a circular economy : Evidence and some applications $’, *Omega*, 66, pp. 344–357. doi: 10.1016/j.omega.2015.05.015.

Genovese, A., Acquaye, Adolf A., *et al.* (2017) ‘Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications’, *Omega (United Kingdom)*, 66, pp. 344–357. doi: 10.1016/j.omega.2015.05.015.

Ghadimi, P. and Heavey, C. (2014) ‘Sustainable supplier selection in medical device industry: Toward sustainable manufacturing’, *Procedia CIRP*, 15, pp. 165–170. doi: 10.1016/j.procir.2014.06.096.

Ghisellini, P., Cialani, C. and Ulgiati, S. (2016) ‘A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems’, *Journal of Cleaner Production*, 114, pp. 11–32. doi: 10.1016/j.jclepro.2015.09.007.

Giannakis, M. and Papadopoulos, T. (2016) ‘Supply chain sustainability: A risk management approach’, *International Journal of Production Economics*, 171, pp. 455–470. doi: 10.1016/j.ijpe.2015.06.032.

Giri, B. C., Molla, M. U. and Biswas, P. (2022) ‘Pythagorean fuzzy DEMATEL method for supplier selection in sustainable supply chain management’, *Expert Systems with Applications*, 193(January), p. 116396. doi: 10.1016/j.eswa.2021.116396.

Giunipero, L. C., Hooker, R. E. and Denslow, D. (2012) ‘Purchasing and supply management sustainability: Drivers and barriers’, *Journal of Purchasing and Supply Management*, 18(4), pp. 258–269. doi: 10.1016/j.pursup.2012.06.003.

Gold, S. and Awasthi, A. (2015) ‘Sustainable global supplier selection extended towards sustainability risks from (1+n)th tier suppliers using fuzzy AHP based approach', *IFAC-PapersOnLine*, 28(3), pp. 966–971. doi: 10.1016/j.ifacol.2015.06.208.

Göll, E., Uhl, A. and Zwiers, J. (2019) 'Sustainable Development in the Mena Region', *MENARA Future Notes*, (20), pp. 1–8. Available at: https://www.iai.it/en/pubblicazioni/sustainable-development-mena-region.

Gouda, S. K. and Saranga, H. (2018) 'Sustainable supply chains for supply chain sustainability: impact of sustainability efforts on supply chain risk', *International Journal of Production Research*, 56(17), pp. 5820–5835. doi: 10.1080/00207543.2018.1456695.

Govindan, K. *et al.* (2016) 'Accelerating the transition towards sustainability dynamics into supply chain relationship management and governance structures', *Journal of Cleaner Production*, 112, pp. 1813–1823. doi: 10.1016/j.jclepro.2015.11.084.

Govindan, K. *et al.* (2020) 'An Integrated Hybrid Approach for Circular supplier selection and Closed loop Supply Chain Network Design under Uncertainty', *Journal of Cleaner Production*, 242, p. 118317. doi: 10.1016/j.jclepro.2019.118317.

Govindan, K., Khodaverdi, R. and Jafarian, A. (2013) 'A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach', *Journal of Cleaner Production*, 47, pp. 345–354. doi: 10.1016/j.jclepro.2012.04.014.

Guarnieri, P., Cerqueira-Streit, J. A. and Batista, L. C. (2020) 'Reverse logistics and the sectoral agreement of packaging industry in Brazil towards a transition to circular economy', *Resources, Conservation and Recycling*, 153(October 2019), p. 104541. doi: 10.1016/j.resconrec.2019.104541.

Gupta, H. and Barua, M. K. (2017) 'Supplier selection among SMEs on the basis of their green innovation ability using BWM and fuzzy TOPSIS', *Journal of Cleaner Production*, 152, pp. 242–258. doi: 10.1016/j.jclepro.2017.03.125.

Haleem, A. *et al.* (2021) 'Supplier evaluation in the context of circular economy: A forward step for resilient business and environment concern', *Business Strategy and the Environment*, 30(4), pp. 2119–2146. doi: 10.1002/bse.2736.

Halldórsson, Á. and Kovács, G. (2010) 'The sustainable agenda and energy efficiency: Logistics solutions and supply chains in times of climate change', *International Journal of Physical Distribution & Logistics Management*, 40(1–2), pp. 5–13. doi: 10.1108/09600031011018019.

Handfield, R. B. *et al.* (2015) 'How Can Supply Management Really Improve Performance? A Knowledge-Based Model of Alignment Capabilities', *Journal of Supply Chain Management*, 51(3), pp. 3–17. doi: 10.1111/jscm.12066.

Harymawan, I. *et al.* (2020) 'Insights into research on carbon disclosure', *Journal of Security and Sustainability Issues*, 9(4), pp. 1157–1164. doi: 10.9770/jssi.2020.9.4(3).

Hashemkhani Zolfani, S., Chatterjee, P. and Yazdani, M. (2019) 'A structured framework for sustainable supplier selection using a combined BWM-CoCoSo model', (May). doi: 10.3846/cibmee.2019.081.

Hashmi, N., Jalil, S. A. and Javaid, S. (2021) 'Carbon footprint based multi-objective supplier selection problem with uncertain parameters and fuzzy linguistic preferences', *Sustainable Operations and Computers*, 2(November 2020), pp. 20–29. doi: 10.1016/j.susoc.2021.03.001.

Hassini, E., Surti, C. and Searcy, C. (2012) 'A literature review and a case study of sustainable supply chains with a focus on metrics', *International Journal of Production Economics*, 140(1), pp. 69–82. doi: 10.1016/j.ijpe.2012.01.042.

Hazen, B. T., Mollenkopf, D. A. and Wang, Y. (2017) 'Remanufacturing for the Circular Economy: An Examination of Consumer Switching Behavior', *Business Strategy and the Environment*, 26(4), pp. 451–464. doi: 10.1002/bse.1929.

Hendiani, S., Mahmoudi, A. and Liao, H. (2020) 'A multi-stage multi-criteria hierarchical decision-making approach for sustainable supplier selection', *Applied Soft Computing Journal*, 94, p. 106456. doi: 10.1016/j.asoc.2020.106456.

Heras-Saizarbitoria, I., Boiral, O. and Testa, F. (2023) 'Circular economy at the company level: An empirical study based on sustainability reports', *Sustainable Development*, (January), pp. 2307–2317. doi: 10.1002/sd.2507.

Herren, A., Hadley, J. and Klein, E. (2010) *Barriers to Environmental Sustainability Facing Small Businesses in Durham , NC*. Nicholas School of the Environment of Duke University.

Hervani, A. A. *et al.* (2022) 'A performance measurement framework for socially sustainable and resilient supply chains using environmental goods valuation methods', *Sustainable Production and Consumption*, 30, pp. 31–52. doi: 10.1016/j.spc.2021.11.026.

Hsu, C. C. *et al.* (2013) 'Supply chain drivers that foster the development of green initiatives in an emerging economy', *International Journal of Operations and Production Management*, 33(6), pp. 656–688. doi: 10.1108/IJOPM-10-2011-0401.

Hsu, C. W. *et al.* (2013) 'Using DEMATEL to develop a carbon management model of supplier selection in green supply chain management', *Journal of Cleaner Production*, 56, pp. 164–172. doi: 10.1016/j.jclepro.2011.09.012.

Hussain, M. and Malik, M. (2020) 'Organizational enablers for circular economy in the context of sustainable supply chain management', *Journal of Cleaner Production*, 256, p. 120375. doi: 10.1016/j.jclepro.2020.120375.

Hwang, B. N., Huang, C. Y. and Wu, C. H. (2016) 'A TOE approach to establish a green supply chain adoption decision model in the semiconductor industry', *Sustainability (Switzerland)*, 8(2). doi: 10.3390/su8020168.

Hwang, C. L. (1979) 'Optimal Scheduled-Maintenance Policy Based on', *IEEE Transactions on Reliability*, R-28(5), pp. 394–399.

Ismail, A; Bujang, AA; Anthony, W. R.; and Jaaf, W. R. (2015) 'Factor Affecting the Housing Financing of Bumiputera in Iskandar Malaysia', *Journal of Economics, Business and Management*, 3(11), pp. 1031–1036. doi: 10.7763/joebm.2015.v3.329.

Jabbour, C. J. C. *et al.* (2019) 'Unlocking the circular economy through new business models based on large-scale data: An integrative framework and research agenda', *Technological Forecasting and Social Change*, 144(September 2017), pp. 546–552. doi: 10.1016/j.techfore.2017.09.010.

Jackson, E. (2013) ‘Choosing a Methodology: Philosophical Underpinning’, *Practitioner Research in Higher Education Journal*, 7(71), pp. 49–62.

Jauhar, S. K. and Pant, M. (2017) ‘Integrating DEA with DE and MODE for sustainable supplier selection’, *Journal of Computational Science*, 21, pp. 299–306. doi: 10.1016/j.jocs.2017.02.011.

Jensen, F., Schäfer, D. and Stephan, A. (2019) ‘Financial constraints of firms with environmental innovation’, *Vierteljahrshefte zur Wirtschaftsforschung*, 88(3), pp. 43–65. doi: 10.3790/vjh.88.3.43.

Jira, C. and Toffel, M. W. (2013) ‘Engaging supply chains in climate change’, *Manufacturing and Service Operations Management*, 15(4), pp. 559–577. doi: 10.1287/msom.1120.0420.

Jörg H. Grimm, Joerg S. Hofstetter, J. S. (2014) ‘JCP_SubSupplierMgmt_Manuscript_141019_revised’, *The Journal of Cleaner Production*.

Kalverkamp, M. and Young, S. B. (2019) ‘In support of open-loop supply chains: Expanding the scope of environmental sustainability in reverse supply chains’, *Journal of Cleaner Production*, 214, pp. 573–582. doi: 10.1016/j.jclepro.2019.01.006.

Kambanou, M. L. (2020) ‘Life cycle costing: Understanding how it is practised and its relationship to life cycle management-A case study’, *Sustainability (Switzerland)*, 12(8), p. 3252. doi: 10.3390/SU12083252.

Kannan, D. (2018) ‘Role of multiple stakeholders and the critical success factor theory for the sustainable supplier selection process’, *International Journal of Production Economics*, 195(December 2014), pp. 391–418. doi: 10.1016/j.ijpe.2017.02.020.

Kannan, D. *et al.* (2020a) ‘Sustainable circular supplier selection: A novel hybrid approach’, *Science of the Total Environment*, 722, p. 137936. doi: 10.1016/j.scitotenv.2020.137936.

Kannan, D. *et al.* (2020b) ‘Sustainable circular supplier selection: A novel hybrid approach’, *Science of the Total Environment*, 722, p. 137936. doi: 10.1016/j.scitotenv.2020.137936.

Karmaker, C. L. *et al.* (2021) ‘Improving supply chain sustainability in the context of COVID-19 pandemic in an emerging economy: Exploring drivers using an integrated model’, *Sustainable Production and Consumption*, 26, pp. 411–427. doi: 10.1016/j.spc.2020.09.019.

Khan, M. M. *et al.* (2023) ‘Resilient and sustainable supplier selection: an integration of SCOR 4.0 and machine learning approach’, *Sustainable and Resilient Infrastructure*, 8(5), pp. 453–469. doi: 10.1080/23789689.2023.2165782.

Khan, S. A. *et al.* (2018) ‘Supplier sustainability performance evaluation and selection: A framework and methodology’, *Journal of Cleaner Production*, 205, pp. 964–979. doi: 10.1016/j.jclepro.2018.09.144.

Khan, S. A. R. *et al.* (2020) ‘Measuring the impact of renewable energy, public health expenditure, logistics, and environmental performance on sustainable economic growth’, *Sustainable Development*, 28(4), pp. 833–843. doi: 10.1002/sd.2034.

Khan, S. A. R., Yu, Z., *et al.* (2021) ‘A state-of-the-art review and meta-analysis on sustainable supply chain management: Future research directions’, *Journal of Cleaner Production*, 278, p.

123357. doi: 10.1016/j.jclepro.2020.123357.

Khan, S. A. R., Razzaq, A., *et al.* (2021) 'Industry 4.0 and circular economy practices: A new era business strategies for environmental sustainability', *Business Strategy and the Environment*, 30(8), pp. 4001–4014. doi: 10.1002/bse.2853.

Koho, M., Torvinen, S. and Romiguer, A. T. (2011) 'Objectives, enablers and challenges of sustainable development and sustainable manufacturing: Views and opinions of Spanish companies', *Proceedings - 2011 IEEE International Symposium on Assembly and Manufacturing, ISAM 2011*, pp. 1–6. doi: 10.1109/ISAM.2011.5942343.

Köksal, D. *et al.* (2017) 'Social sustainable supply chain management in the textile and apparel industry-a literature review', *Sustainability (Switzerland)*, 9(1), pp. 1–32. doi: 10.3390/su9010100.

Kore, N. B., Ravi, P. K. and Patil, A. P. S. B. (2017) '" A Simplified Description of FUZZY TOPSIS Method for Multi Criteria Decision Making "', *nternational Research Journal of Engineering and Technology*, pp. 1–4.

Kulatunga, A. K. and Jayatilaka, P. R. Jayawickrama, M. (2013) 'Drivers and barriers to implement sustainable manufacturing concepts in Sri Lankan manufacturing sector', *11th Global Conference on Sustainable Manufacturing*, (September), pp. 171–176. doi: 10.13140/2.1.2952.1927.

Kumar, A. *et al.* (2023) 'Sustainable Supply Chain Management, Performance Measurement, and Management: A Review', *Sustainability (Switzerland)*, 15(6), pp. 1–25. doi: 10.3390/su15065290.

Kumar, A. and Dixit, G. (2018) 'An analysis of barriers affecting the implementation of e-waste management practices in India: A novel ISM-DEMATEL approach', *Sustainable Production and Consumption*, 14, pp. 36–52. doi: 10.1016/j.spc.2018.01.002.

Kumar, N. *et al.* (2019) 'Integrating sustainable supply chain practices with operational performance: an exploratory study of Chinese SMEs', *Production Planning and Control*, 30(5–6), pp. 464–478. doi: 10.1080/09537287.2018.1501816.

Kusi-Sarpong, S. *et al.* (2021) 'Sustainable supplier selection based on industry 4.0 initiatives within the context of circular economy implementation in supply chain operations', *Production Planning and Control*, 0(0), pp. 1–21. doi: 10.1080/09537287.2021.1980906.

Kusmaryono, I., Wijayanti, D. and Maharani, H. R. (2022) 'Number of Response Options, Reliability, Validity, and Potential Bias in the Use of the Likert Scale Education and Social Science Research: A Literature Review', *International Journal of Educational Methodology*, 8(4), pp. 625–637. doi: 10.12973/ijem.8.4.625.

Lahane, S., Kant, R. and Shankar, R. (2020) 'Circular supply chain management: A state-of-art review and future opportunities', *Journal of Cleaner Production*. Elsevier Ltd, p. 120859. doi: 10.1016/j.jclepro.2020.120859.

Law, M. M. S., Hills, P. and Hau, B. C. H. (2017) 'Engaging Employees in Sustainable Development – a Case Study of Environmental Education and Awareness Training in Hong Kong', *Business Strategy and the Environment*, 26(1), pp. 84–97. doi: 10.1002/bse.1903.

Li, J., Fang, H. and Song, W. (2019) 'Sustainable supplier selection based on SSCM practices: A rough cloud TOPSIS approach', *Journal of Cleaner Production*, 222, pp. 606–621. doi: 10.1016/j.jclepro.2019.03.070.

Li, W., Lai, Y. and Zhong, Y. (2024) 'The closer the better: Supplier geographic proximity and corporate information disclosure violation', *North American Journal of Economics and Finance*, 69(PA), p. 102024. doi: 10.1016/j.najef.2023.102024.

Lieder, M. and Rashid, A. (2016) 'Towards circular economy implementation: A comprehensive review in context of manufacturing industry', *Journal of Cleaner Production*, 115, pp. 36–51. doi: 10.1016/j.jclepro.2015.12.042.

Lima, F. R. and Carpinetti, L. C. R. (2016) 'Evaluating supply chain performance based on SCOR® model and fuzzy-TOPSIS', *2016 IEEE International Conference on Fuzzy Systems, FUZZ-IEEE 2016*, (December), pp. 2075–2082. doi: 10.1109/FUZZ-IEEE.2016.7737947.

Lin, C. *et al.* (2015) 'Developing an assessment framework for managing sustainability programs: A Analytic Network Process approach', *Expert Systems with Applications*, 42(5), pp. 2488–2501. doi: 10.1016/j.eswa.2014.09.025.

Liu, C., Rani, P. and Pachori, K. (2022) 'Sustainable circular supplier selection and evaluation in the manufacturing sector using Pythagorean fuzzy EDAS approach', *Journal of Enterprise Information Management*, 35(4–5), pp. 1040–1066. doi: 10.1108/JEIM-04-2021-0187.

Liu, Y. *et al.* (2021) 'Barriers to sustainable food consumption and production in China: A fuzzy DEMATEL analysis from a circular economy perspective', *Sustainable Production and Consumption*, 28(July), pp. 1114–1129. doi: 10.1016/j.spc.2021.07.028.

Lombardi, D. R. and Laybourn, P. (2012) 'Redefining Industrial Symbiosis: Crossing Academic-Practitioner Boundaries', *Journal of Industrial Ecology*, 16(1), pp. 28–37. doi: 10.1111/j.1530-9290.2011.00444.x.

Lorino, P. (2018) *Pragmatism and Organization Studies: Chapter 7*. Oxford University.

Lüdeke-Freund, F., Gold, S. and Bocken, N. M. P. (2019) 'A Review and Typology of Circular Economy Business Model Patterns', *Journal of Industrial Ecology*, 23(1), pp. 36–61. doi: 10.1111/jiec.12763.

Luthra, S. *et al.* (2017) 'An integrated framework for sustainable supplier selection and evaluation in supply chains', *Journal of Cleaner Production*, 140, pp. 1686–1698. doi: 10.1016/j.jclepro.2016.09.078.

Maestrini, V. *et al.* (2016) 'The action research cycle reloaded: Conducting action research across buyer-supplier relationships', *Journal of Purchasing and Supply Management*, 22(4), pp. 289–298. doi: 10.1016/j.pursup.2016.06.002.

Makaleng, M. S. M. and Lambert, K. R. (2021) 'Evaluation of reverse logistics in challenges within the manufacturing pharmaceutical companies', *Emerging Science Journal*, 5(4), pp. 486–496. doi: 10.28991/esj-2021-01291.

Mallick, P. K. *et al.* (2023) 'Closing the loop: Establishing reverse logistics for a circular economy, a systematic review', *Journal of Environmental Management*, 328(December 2022), p. 117017. doi: 10.1016/j.jenvman.2022.117017.

Mangla, S. K. *et al.* (2018) 'Barriers to effective circular supply chain management in a developing country context', *Production Planning and Control*, 29(6), pp. 551–569. doi: 10.1080/09537287.2018.1449265.

Mani, V., Agrawal, R. and Sharma, V. (2014) 'Supplier selection using social sustainability: AHP based approach in India', *International Strategic Management Review*, 2(2), pp. 98–112. doi: 10.1016/j.ism.2014.10.003.

Mann, H. B. and Whitney, D. R. (1947) 'On a Test of Whether one of Two Random Variables is Stochastically Larger than the Other', *The Annals of Mathematical Statistics*, 18(1), pp. 50–60. doi: 10.1214/aoms/1177730491.

Marculetiu, A., Ataseven, C. and Mackelprang, A. W. (2023) 'A review of how pressures and their sources drive sustainable supply chain management practices', *Journal of Business Logistics*, 44(2), pp. 257–288. doi: 10.1111/jbl.12332.

El Mariouli, O. and Abouabdellah, A. (2019) 'A new model of supplier's selection for sustainable supply chain management', *Advances in Science, Technology and Engineering Systems*, 4(2), pp. 251–259. doi: 10.25046/aj040233.

Markaki, O. and Askounis, D. (2021) 'Assessing the operational and economic efficiency benefits of dynamic manufacturing networks through fuzzy cognitive maps: a case study', *Operational Research*, 21(2), pp. 925–950. doi: 10.1007/s12351-019-00488-y.

Markey, R., McIvor, J. and Wright, C. F. (2016) 'Employee participation and carbon emissions reduction in Australian workplaces', *International Journal of Human Resource Management*, 27(2), pp. 173–191. doi: 10.1080/09585192.2015.1045009.

Marquis, C., Toffel, M. W. and Zhou, Y. (2016) 'Scrutiny, norms, and selective disclosure: A global study of greenwashing', *Organization Science*, 27(2), pp. 483–504. doi: 10.1287/orsc.2015.1039.

Marzouk, M. and Sabbah, M. (2021) 'AHP-TOPSIS social sustainability approach for selecting supplier in construction supply chain', *Cleaner Environmental Systems*, 2(March), p. 100034. doi: 10.1016/j.cesys.2021.100034.

Mavi, R. K. and Shahabi, H. (2015) 'Using fuzzy DEMATEL for evaluating supplier selection criteria in manufacturing industries', *International Journal of Logistics Systems and Management*, 22(1), pp. 15–42. doi: 10.1504/IJLSM.2015.070889.

Memari, A. *et al.* (2019) 'Sustainable supplier selection: A multi-criteria intuitionistic fuzzy TOPSIS method', *Journal of Manufacturing Systems*, 50(September 2018), pp. 9–24. doi: 10.1016/j.jmsy.2018.11.002.

Min, H. and Galle, W. P. (2001) 'Green purchasing practices of US firms', *International Journal of Operations and Production Management*, 21(9), pp. 1222–1238. doi: 10.1108/EUM0000000005923.

Min, S., Zacharia, Z. G. and Smith, C. D. (2019) 'Defining Supply Chain Management: In the Past, Present, and Future', *Journal of Business Logistics*, 40(1), pp. 44–55. doi: 10.1111/jbl.12201.

Mir, J. El, Elgendy, K. and Khamlichi, H. (2021) 'Circular Economy in Cities of the MENA

Region: Prospects and Challenges for Material Circularity', (December).

Mishra, A. *et al.* (2023) 'A review of reverse logistics and closed-loop supply chains in the perspective of circular economy', *Benchmarking*, 30(3), pp. 975–1020. doi: 10.1108/BIJ-11-2021-0669.

Moktadir, M. A. *et al.* (2018) 'Modeling the interrelationships among barriers to sustainable supply chain management in leather industry', *Journal of Cleaner Production*, 181, pp. 631–651. doi: 10.1016/j.jclepro.2018.01.245.

Montag, L. and Pettau, T. (2022) 'Process performance measurement framework for circular supply chain: An updated SCOR perspective', *Circular Economy*, 1(1), pp. 1–12. doi: 10.55845/kaiz3670.

Moradian, M., Modanloo, V. and Aghaiee, S. (2019) 'Comparative analysis of multi criteria decision making techniques for material selection of brake booster valve body', *Journal of Traffic and Transportation Engineering (English Edition)*, 6(5), pp. 526–534. doi: 10.1016/j.jtte.2018.02.001.

Muhammad, M. N. and Cavus, N. (2017) 'Fuzzy DEMATEL method for identifying LMS evaluation criteria', *Procedia Computer Science*, 120, pp. 742–749. doi: 10.1016/j.procs.2017.11.304.

Münch, C., Benz, L. A. and Hartmann, E. (2022) 'Exploring the circular economy paradigm: A natural resource-based view on supplier selection criteria', *Journal of Purchasing and Supply Management*, 28(4), p. 100793. doi: 10.1016/j.pursup.2022.100793.

Nachar, N. (2008) 'The Mann-Whitney U: A Test for Assessing Whether Two Independent Samples Come from the Same Distribution', *Tutorials in Quantitative Methods for Psychology*, 4(1), pp. 13–20. doi: 10.20982/tqmp.04.1.p013.

Naffin, J., Klewitz, J. and Schaltegger, S. (2023) 'Sustainable development of supplier performance . An empirical analysis of relationship characteristics in the automotive sector', *Corporate Social Responsibility and Environmental Management*, (December 2022), pp. 1753–1769. doi: 10.1002/csr.2452.

Namdar, R., Karami, E. and Keshavarz, M. (2021) 'Climate change and vulnerability: The case of mena countries', *ISPRS International Journal of Geo-Information*, 10(11). doi: 10.3390/ijgi10110794.

Narayanan, A. and Ishfaq, R. (2022) 'Impact of metric-alignment on supply chain performance: a behavioral study', *International Journal of Logistics Management*, 33(1), pp. 365–384. doi: 10.1108/IJLM-01-2021-0061.

Narimissa, O., Kangarani-Farahani, A. and Molla-Alizadeh-Zavardehi, S. (2020) 'Drivers and barriers for implementation and improvement of Sustainable Supply Chain Management', *Sustainable Development*, 28(1), pp. 247–258. doi: 10.1002/sd.1998.

Näslund, D., Kale, R. and Paulraj, A. (2010) 'Action Research in Supply Chain Management—a Framework for Relevant and Rigorous Research', *Journal of Business Logistics*, 31(2), pp. 331–355. doi: 10.1002/j.2158-1592.2010.tb00155.x.

Nikolaou, I. E., Evangelinos, K. I. and Allan, S. (2013) 'A reverse logistics social responsibility evaluation framework based on the triple bottom line approach', *Journal of Cleaner Production*, 56, pp. 173–184. doi: 10.1016/j.jclepro.2011.12.009.

Nikolaou, I. E., Jones, N. and Stefanakis, A. (2021) 'Circular Economy and Sustainability: the Past, the Present and the Future Directions', *Circular Economy and Sustainability*, 1(1), pp. 1–20. doi: 10.1007/s43615-021-00030-3.

Nyimbili, P. H., Erden, T. and Mwanaumo, E. M. (2023) 'A DEMATEL-based approach of multi-criteria evaluation for urban fire and emergency facilities', *Frontiers in Environmental Economics*, 2. doi: 10.3389/frevc.2023.1198541.

Oelze, N. (2017) 'Sustainable supply chain management implementation-enablers and barriers in the textile industry', *Sustainability (Switzerland)*, 9(8). doi: 10.3390/su9081435.

Ojijo, A. D. (2023) 'Effect of Sustainable Supplier Selection on Procurement Performance of Chartered Public Universities in Kenya', *International Journal of Management, Accounting and Economics*, 10(7), pp. 447–467. doi: 10.5281/zenodo.8265343.

Ong, T. S., Magsi, H. B. and Burgess, T. F. (2019) 'Organisational culture, environmental management control systems, environmental performance of Pakistani manufacturing industry', *International Journal of Productivity and Performance Management*, 68(7), pp. 1293–1322. doi: 10.1108/IJPPM-05-2018-0187.

Opricovic, S. and Tzeng, G. H. (2003) 'Defuzzification within a multicriteria decision model', *International Journal of Uncertainty, Fuzziness and Knowlege-Based Systems*, 11(5), pp. 635–652. doi: 10.1142/S0218488503002387.

Orji, I. J. and Wei, S. (2015) 'An innovative integration of fuzzy-logic and systems dynamics in sustainable supplier selection: A case on manufacturing industry', *Computers and Industrial Engineering*, 88, pp. 1–12. doi: 10.1016/j.cie.2015.06.019.

Ott, C., Schiemann, F. and Günther, T. (2017) 'Disentangling the determinants of the response and the publication decisions: The case of the Carbon Disclosure Project', *Journal of Accounting and Public Policy*, 36(1), pp. 14–33. doi: 10.1016/j.jaccpubpol.2016.11.003.

Oyewole, K. A. *et al.* (2023) 'Carbon dioxide emission, mitigation and storage technologies pathways', *Sustainable Environment*, 9(1). doi: 10.1080/27658511.2023.2188760.

Ozbiltekin-Pala, M., Koçak, A. and Kazancoglu, Y. (2023) 'A proposed circular-SCOR model for supply chain performance measurement in manufacturing industry during COVID-19', *International Journal of Quality and Reliability Management*, 40(5), pp. 1203–1232. doi: 10.1108/IJQRM-03-2022-0101.

Özdemirci, F. *et al.* (2023) 'An assessment of alternative social banking systems using T-Spherical fuzzy TOP-DEMATEL approach', *Decision Analytics Journal*, 6(January), p. 100184. doi: 10.1016/j.dajour.2023.100184.

Ozusaglam, S., Robin, S. and Wong, C. Y. (2018) *Early and late adopters of ISO 14001-type standards: revisiting the role of firm characteristics and capabilities*, *Journal of Technology Transfer*. doi: 10.1007/s10961-017-9560-5.

Parsa, M., Nookabadi, A. S. and Atan, Z. (2020) *A joint economic lot-size model for sustainable industries of recycled content products, International Journal of Production Research*. doi: 10.1080/00207543.2020.1802078.

Pattnaik, Susmita and Pattnaik, Subhra (2019) 'Relationships between green supply chain drivers, triple bottom line sustainability and operational performance: An empirical investigation in the UK manufacturing supply chain', *Operations and Supply Chain Management*, 12(4), pp. 198–211. doi: 10.31387/oscm0390243.

Perçin, S. (2022) *Circular supplier selection using interval-valued intuitionistic fuzzy sets, Environment, Development and Sustainability*. Springer Netherlands. doi: 10.1007/s10668-021-01671-y.

Pisano, U., Lange, L. K. and Berger, G. (2015) *Agenda for Sustainable Development: Governance for SD principles, approaches and examples in Europe. European Sustainable Development Network (ESDN) View project*. Available at: www.sd-network.eu.

Prahinski, C. and Kocabasoglu, C. (2006) 'Empirical research opportunities in reverse supply chains', *Omega*, 34(6), pp. 519–532. doi: 10.1016/j.omega.2005.01.003.

Preuss, L. (2009) 'Addressing sustainable development through public procurement: The case of local government', *Supply Chain Management*, 14(3), pp. 213–223. doi: 10.1108/13598540910954557.

Rashidi, K. and Saen, R. F. (2018) 'Incorporating dynamic concept into gradual efficiency: Improving suppliers in sustainable supplier development', *Journal of Cleaner Production*, 202, pp. 226–243. doi: 10.1016/j.jclepro.2018.08.092.

Raut, R. D. *et al.* (2019) 'To investigate the determinants of cloud computing adoption in the manufacturing micro, small and medium enterprises: A DEMATEL-based approach', *Benchmarking*, 26(3), pp. 990–1019. doi: 10.1108/BIJ-03-2018-0060.

Renyu Kuang and Sanafatema Sumara (2021) *Master Thesis Master ' s Programme in Strategic Entrepreneurship for Internatinal Growth in Strategic Leadership , 60 credits Perception of Leadership In Virtual Teams Strategic Leadership , 15 credits Perception of Leadership In Virtual Teams*. HALMSTAD UNIVERSITY.

Revell, A. (2011) 'Small businesses and the environment: Turning over a new leaf?', *Strategic Direction*, 27(1), pp. 4–17. doi: 10.1108/sd.2011.05627aad.004.

Revell, A. and Blackburn, R. (2007) 'The Business Case for Sustainability ? in the UK ' s Construction and', *Business Strategy and the Environment*, 16(October 2005), pp. 404–420. Available at: http://onlinelibrary.wiley.com/doi/10.1002/bse.499/abstract.

Rogetzer, P., Silbermayr, L. and Jammernegg, W. (2018) 'Sustainable sourcing of strategic raw materials by integrating recycled materials', *Flexible Services and Manufacturing Journal*, 30(3), pp. 421–451. doi: 10.1007/s10696-017-9288-4.

Ronaghi, M., Reed, M. and Saghaian, S. (2020) 'The impact of economic factors and governance on greenhouse gas emission', *Environmental Economics and Policy Studies*, 22(2), pp. 153–172. doi: 10.1007/s10018-019-00250-w.

Rouhani, S., Ashrafi, A. and Afshari, S. (2014) ‘Fuzzy DEMATEL model for evaluation criteria of business intelligence’, *ICEIS 2014 - Proceedings of the 16th International Conference on Enterprise Information Systems*, 1(June), pp. 456–463. doi: 10.5220/0004882404560463.

Roy, T. *et al.* (2022) ‘Redesigning traditional linear supply chains into circular supply chains–A study into its challenges’, *Sustainable Production and Consumption*, 31, pp. 113–126. doi: 10.1016/j.spc.2022.02.004.

Ruggieri, A. *et al.* (2016) ‘A meta-model of inter-organisational cooperation for the transition to a circular economy’, *Sustainability (Switzerland)*, 8(11), pp. 1–17. doi: 10.3390/su8111153.

Saeed, M. A. and Kersten, W. (2019) ‘Drivers of sustainable supply chain management: Identification and classification’, *Sustainability (Switzerland)*, 11(4). doi: 10.3390/su11041137.

Sajjad, A., Eweje, G. and Tappin, D. (2015) ‘Sustainable Supply Chain Management: Motivators and Barriers’, *Business Strategy and the Environment*, 24(7), pp. 643–655. doi: 10.1002/bse.1898.

Sajjad, A., Eweje, G. and Tappin, D. (2020a) ‘Managerial perspectives on drivers for and barriers to sustainable supply chain management implementation : Evidence from New Zealand’, (July 2019), pp. 592–604. doi: 10.1002/bse.2389.

Sajjad, A., Eweje, G. and Tappin, D. (2020b) ‘Managerial perspectives on drivers for and barriers to sustainable supply chain management implementation: Evidence from New Zealand’, *Business Strategy and the Environment*, 29(2), pp. 592–604. doi: 10.1002/bse.2389.

dos Santos, B. M., Godoy, L. P. and Campos, L. M. S. (2019) ‘Performance evaluation of green suppliers using entropy-TOPSIS-F’, *Journal of Cleaner Production*, 207, pp. 498–509. doi: 10.1016/j.jclepro.2018.09.235.

Sarkis, J. and Dhavale, D. G. (2015) ‘Supplier selection for sustainable operations: A triple-bottom-line approach using a Bayesian framework’, *International Journal of Production Economics*, 166, pp. 177–191. doi: 10.1016/j.ijpe.2014.11.007.

Sarkis, J., Helms, M. M. and Hervani, A. A. (2010) ‘Reverse logistics and social sustainability’, *Corporate Social Responsibility and Environmental Management*, 17(6), pp. 337–354. doi: 10.1002/csr.220.

Saunders, M. A., Lewis, P. and Thornhill, A. (2012) *Research Methods for Business Students Eights Edition Research Methods for Business Students, Research Methods for Business Students*. Available at: www.pearson.com/uk%0Ahttps://www.amazon.com/Research-Methods-for-Business-Students/dp/1292208783/ref=sr_1_2?dchild=1&qid=1614706531&refinements=p_27%3AAdrian+Thornhill+%2F+Philip+Lewis+%2F+Mark+N.+K.+Saunders&s=books&sr=1-2&text=Adrian+Thornhill+%2F+Phili.

Saunders, M. N. K., Lewis, P. and Thornhill, A. (2019) *‘Research Methods for Business Students’ Chapter 4: Understanding research philosophy and approaches to theory development*, *Researchgate.Net*. Available at: www.pearson.com/uk%0Awww.pearson.com/uk%0Ahttps://www.researchgate.net/publication/330760964_Research_Methods_for_Business_Students_Chapter_4_Understanding_research_philosophy_and_approaches_to_theory_development.

Saunila, M. *et al.* (2019) 'Why invest in green technologies? Sustainability engagement among small businesses', *Technology Analysis and Strategic Management*, 31(6), pp. 653–666. doi: 10.1080/09537325.2018.1542671.

Schaper, M. (2002) 'The challenge of environmental responsibility and sustainable development: Implications for SME and entrepreneurship academics', *Radical change in the world - will SMEs soar or crash?; Umbruch der Welt - KMU vor Hohenflug oder Absturz?*, (March), pp. 525–534. Available at: http://cob.nmu.edu/amtmann/Lavras Course Materials/challenge of environmental responsibility and sustainable developement Implications for SME and entrepreneuship academics 2002.pdf.

Schrettle, S. *et al.* (2014) 'Turning sustainability into action: Explaining firms' sustainability efforts and their impact on firm performance', *International Journal of Production Economics*, 147(PART A), pp. 73–84. doi: 10.1016/j.ijpe.2013.02.030.

Seker, S. and Zavadskas, E. K. (2017) 'Application of fuzzy DEMATEL method for analyzing occupational risks on construction sites', *Sustainability (Switzerland)*, 9(11). doi: 10.3390/su9112083.

Seuring, S. *et al.* (2008) 'Sustainability and supply chain management - An introduction to the special issue', *Journal of Cleaner Production*. Elsevier, pp. 1545–1551. doi: 10.1016/j.jclepro.2008.02.002.

Seuring, S. *et al.* (2021) 'The application of theory in literature reviews – illustrated with examples from supply chain management', *International Journal of Operations and Production Management*, 41(1), pp. 1–20. doi: 10.1108/IJOPM-04-2020-0247.

Seuring, S. and Müller, M. (2008) 'From a literature review to a conceptual framework for sustainable supply chain management', *Journal of Cleaner Production*, 16(15), pp. 1699–1710. doi: 10.1016/j.jclepro.2008.04.020.

Shang, Z. *et al.* (2022) 'Supplier selection in sustainable supply chains: Using the integrated BWM, fuzzy Shannon entropy, and fuzzy MULTIMOORA methods', *Expert Systems with Applications*, 195(January), p. 116567. doi: 10.1016/j.eswa.2022.116567.

Shani, A. B. and Coghlan, D. (2021) 'Action research in business and management: A reflective review', *Action Research*, 19(3), pp. 518–541. doi: 10.1177/1476750319852147.

Shourkaei, M. M., Taylor, K. M. and Dyck, B. (2024) 'Examining sustainable supply chain management via a social-symbolic work lens: Lessons from Patagonia', *Business Strategy and the Environment*, 33(2), pp. 1477–1496. doi: 10.1002/bse.3552.

Si, S. L. *et al.* (2018) 'DEMATEL Technique: A Systematic Review of the State-of-the-Art Literature on Methodologies and Applications', *Mathematical Problems in Engineering*, 2018(1). doi: 10.1155/2018/3696457.

Silverman, D. (2017) 'How was it for you? The Interview Society and the irresistible rise of the (poorly analyzed) interview', *Qualitative Research*, 17(2), pp. 144–158. doi: 10.1177/1468794116668231.

Singh, A. and Trivedi, A. (2016) 'Sustainable green supply chain management: trends and current practices', *Competitiveness Review*, pp. 265–288. doi: 10.1108/CR-05-2015-0034.

Singh, R. *et al.* (2024) ‘A historical review and analysis on MOORA and its fuzzy extensions for different applications’, *Heliyon*, 10(3), p. e25453. doi: 10.1016/j.heliyon.2024.e25453.

Song, W., Xu, Z. and Liu, H. C. (2017) ‘Developing sustainable supplier selection criteria for solar air-conditioner manufacturer: An integrated approach’, *Renewable and Sustainable Energy Reviews*, 79(December 2016), pp. 1461–1471. doi: 10.1016/j.rser.2017.05.081.

Song, W., Zhu, Y. and Zhao, Q. (2020) ‘Analyzing barriers for adopting sustainable online consumption: A rough hierarchical DEMATEL method’, *Computers and Industrial Engineering*, 140(37), p. 106279. doi: 10.1016/j.cie.2020.106279.

Stanny, E. (2013) ‘Voluntary Disclosures of Emissions by US Firms’, *Business Strategy and the Environment*, 22(3), pp. 145–158. doi: 10.1002/bse.1732.

Stevic, Z. (2017) ‘Criteria for supplier selection : A literature review International Journal of Engineering , Business and Enterprise Applications (IJEBEA) Criteria for supplier selection : A literature review’, *International Journal of Engineering, Business and Enterprise Applications (IJEBEA)*, (February), pp. 17–106.

Su, C. M. *et al.* (2016) ‘Improving sustainable supply chain management using a novel hierarchical grey-DEMATEL approach’, *Journal of Cleaner Production*, 134(Part B), pp. 469–481. doi: 10.1016/j.jclepro.2015.05.080.

Sudusinghe, J. I. and Seuring, S. (2022) ‘Supply chain collaboration and sustainability performance in circular economy: A systematic literature review’, *International Journal of Production Economics*, 245(December 2021), p. 108402. doi: 10.1016/j.ijpe.2021.108402.

Suo, W. L., Feng, B. and Fan, Z. P. (2012) ‘Extension of the DEMATEL method in an uncertain linguistic environment’, *Soft Computing*, 16(3), pp. 471–483. doi: 10.1007/s00500-011-0751-y.

Suraraksa, J. and Shin, K. S. (2019) ‘Comparative analysis of factors for supplier selection and monitoring: The case of the automotive industry in Thailand’, *Sustainability (Switzerland)*, 11(4). doi: 10.3390/su11040981.

Taha Ahmed, M. and Ammar Alam, M. (2019) ‘The Suppliers’ Characteristics affecting the Supply Chain Disruption: A Case Study of RB (Reckitt Benckiser)’, *International Journal of Applied Business and Management Studies*, 4(2), pp. 119–134.

Taherdoost, H. (2019) ‘What Is the Best Response Scale for Survey and Questionnaire Design ; Review of Different Lengths of Rating Scale / Attitude Scale / Likert Scale Hamed Taherdoost To cite this version : HAL Id : hal-02557308 What Is the Best Response Scale for Survey and’, *International Journal of Academic Research in Management (IJARM)*, 8(1), pp. 1–10. Available at: https://hal.archives-ouvertes.fr/hal-02557308.

Taherdoost, H. and Brard, A. (2019) ‘Analyzing the Process of Supplier Selection Criteria and Methods’, *Procedia Manufacturing*, 32, pp. 1024–1034. doi: 10.1016/j.promfg.2019.02.317.

Tang, Y. M. *et al.* (2022) ‘Industry 4.0 technology and circular economy practices: business management strategies for environmental sustainability’, *Environmental Science and Pollution Research*, 29(33), pp. 49752–49769. doi: 10.1007/s11356-022-19081-6.

Tay, H. L. and Aw, H. Sen (2021) ‘Improving logistics supplier selection process using lean six sigma – an action research case study', *Journal of Global Operations and Strategic Sourcing*, 14(2), pp. 336–359. doi: 10.1108/JGOSS-05-2020-0025.

Tay, M. Y. *et al.* (2015) 'A Review on Drivers and Barriers towards Sustainable Supply Chain Practices', *International Journal of Social Science and Humanity*, 5(10), pp. 892–897. doi: 10.7763/ijssh.2015.v5.575.

Theeraworawit, M., Suriyankietkaew, S. and Hallinger, P. (2022) 'Sustainable Supply Chain Management in a Circular Economy: A Bibliometric Review', *Sustainability (Switzerland)*, 14(15). doi: 10.3390/su14159304.

Toni, M. (2023) 'Conceptualization Of Circular Economy And Sustainability At The Business Level. Circular Economy And Sustainable Development', *International Journal of Empirical Research Methods*, 1(2), pp. 81–89. doi: 10.59762/ijerm205275791220231205140635.

Trapp, A. C. and Sarkis, J. (2016) 'Identifying Robust portfolios of suppliers: A sustainability selection and development perspective', *Journal of Cleaner Production*, 112, pp. 2088–2100. doi: 10.1016/j.jclepro.2014.09.062.

Turken, N. and Geda, A. (2020) 'Supply chain implications of industrial symbiosis: A review and avenues for future research', *Resources, Conservation and Recycling*, 161(May), p. 104974. doi: 10.1016/j.resconrec.2020.104974.

Vahidi, F., Torabi, S. A. and Ramezankhani, M. J. (2018) 'Sustainable supplier selection and order allocation under operational and disruption risks', *Journal of Cleaner Production*, 174, pp. 1351–1365. doi: 10.1016/j.jclepro.2017.11.012.

Velenturf, A. P. M. and Purnell, P. (2021) 'Principles for a sustainable circular economy', *Sustainable Production and Consumption*, 27, pp. 1437–1457. doi: 10.1016/j.spc.2021.02.018.

Viale, L., Ruel, S. and Zouari, D. (2022) 'A mixed-methods approach to identifying buyers' competencies for enabling innovation', *International Journal of Logistics Research and Applications*. doi: 10.1080/13675567.2021.2020226.

Vijayan, G. *et al.* (2014) 'Sustainability in food retail industry through reverse logistics', *International Journal of Supply Chain Management*, 3(2), pp. 11–23.

Vijfvinkel, S., Bouman, N. and Hessels, J. (2011) *Environmental Sustainability and Financial Performance of SMEs, SCALES, Scientific Analysis of Entrepreneurship and SMEs*. Available at: www.entrepreneurship-sme.eu.

Villanueva-Ponce, R. *et al.* (2015) 'Selección de proveedores verde como un elemento clave en la cadena de suministro: Una revisión de casos de estudio', *DYNA (Colombia)*, 82(194), pp. 36–45. doi: 10.15446/dyna.v82n194.54466.

Villena, V. H. and Dhanorkar, S. (2020) 'How institutional pressures and managerial incentives elicit carbon transparency in global supply chains', *Journal of Operations Management*, 66(6), pp. 697–734. doi: 10.1002/joom.1088.

Walker, A. M. *et al.* (2022) 'What Is the Relation between Circular Economy and Sustainability? Answers from Frontrunner Companies Engaged with Circular Economy Practices', *Circular Economy and Sustainability*, 2(2), pp. 731–758. doi: 10.1007/s43615-021-00064-7.

Walker, H., Di Sisto, L. and McBain, D. (2008) ‘Drivers and barriers to environmental supply chain management practices: Lessons from the public and private sectors’, *Journal of Purchasing and Supply Management*, 14(1), pp. 69–85. doi: 10.1016/j.pursup.2008.01.007.

Wang, H. (2022) ‘Sustainable Circular Supplier Selection in the Power Battery Industry Using a Linguistic T-Spherical Fuzzy MAGDM Model Based on the Improved ARAS Method’, *Sustainability (Switzerland)*, 14(13). doi: 10.3390/su14137816.

Wang, L., Cao, Q. and Zhou, L. (2018) ‘Research on the influencing factors in coal mine production safety based on the combination of DEMATEL and ISM’, *Safety Science*, 103(April 2017), pp. 51–61. doi: 10.1016/j.ssci.2017.11.007.

Wang, X. *et al.* (2023) ‘A Study of the Factors Influencing the Construction Risk of Steel Truss Bridges Based on the Improved DEMATEL–ISM’, *Buildings*, 13(12). doi: 10.3390/buildings13123041.

Wangchen Bhutia, P. (2012) ‘Appication of ahp and topsis method for supplier selection problem’, *IOSR Journal of Engineering*, 02(10), pp. 43–50. doi: 10.9790/3021-021034350.

Weele, V. and Tubergen, V. (2017) *Responsible Purchasing: Moving from Compliance to Value Creation in Supplier Relationships., Springer Series in Supply Chain Management*. Springer, Cham. doi: 10.1007/978-3-031-45565-0_4.

Wetzstein, A. *et al.* (2016) ‘A systematic assessment of supplier selection literature – State-of-the-art and future scope’, *International Journal of Production Economics*, 182, pp. 304–323. doi: 10.1016/j.ijpe.2016.06.022.

Wu, B. *et al.* (2022) ‘Environmental regulations and innovation for sustainability? Moderating effect of political connections’, *Emerging Markets Review*, 50(May 2020), p. 100835. doi: 10.1016/j.ememar.2021.100835.

Wu, C., Lin, Y. and Barnes, D. (2021) ‘An integrated decision-making approach for sustainable supplier selection in the chemical industry’, *Expert Systems with Applications*, 184(May), p. 115553. doi: 10.1016/j.eswa.2021.115553.

Wu, L. and Xu, L. (2022) ‘Bank loans and firm environmental information disclosure: Evidence from China’s heavy polluters’, *Australian Economic Papers*, 61(1), pp. 42–71. doi: 10.1111/1467-8454.12236.

Yahya, N. A., Said, J. and Yusof, A. M. (2021) ‘Students ’ self -regulated learning in open and distance learning for Mathematics course’, *Journal of Science, Mathematics and Technology*, 8(1), pp. 6–10.

Yeşim Yayla, A., Yildiz, A. and Özbek, A. (2012) ‘Fuzzy TOPSIS method in supplier selection and application in the garment industry’, *Fibres and Textiles in Eastern Europe*, 93(4), pp. 20–23.

Yin, R. K. (2016) ‘Robert K. Yin. (2014). Case Study Research Design and Methods (5th ed.). Thousand Oaks, CA: Sage. 282 pages.’, *The Canadian Journal of Program Evaluation*, 30(1), p. 282. doi: 10.3138/CJPE.BR-240.

Yu, C. *et al.* (2019) ‘A group decision making sustainable supplier selection approach using extended TOPSIS under interval-valued Pythagorean fuzzy environment’, *Expert Systems with*

Applications, 121, pp. 1–17. doi: 10.1016/j.eswa.2018.12.010.

Yu, F., Yang, Y. and Chang, D. (2018) ‘Carbon footprint based green supplier selection under dynamic environment’, *Journal of Cleaner Production*, 170, pp. 880–889. doi: 10.1016/j.jclepro.2017.09.165.

Al Zaabi, S., Al Dhaheri, N. and Diabat, A. (2013) ‘Analysis of interaction between the barriers for the implementation of sustainable supply chain management’, *International Journal of Advanced Manufacturing Technology*, 68(1–4), pp. 895–905. doi: 10.1007/s00170-013-4951-8.

Zadeh, L. A. (1965) ‘Fuzzy sets’, *Information and Control*, 8(3), pp. 338–353. doi: 10.1016/S0019-9958(65)90241-X.

Zapletal, F. (2022) ‘Revised PROMETHEE algorithm with reference values’, *Central European Journal of Operations Research*, 30(2), pp. 521–545. doi: 10.1007/s10100-021-00767-0.

Zavadskas, E. K. *et al.* (2016) ‘Hybrid multiple criteria decision-making methods: A review of applications for sustainability issues’, *Economic Research-Ekonomska Istrazivanja* , 29(1), pp. 857–887. doi: 10.1080/1331677X.2016.1237302.

Zeng, H. *et al.* (2017) ‘Institutional pressures, sustainable supply chain management, and circular economy capability: Empirical evidence from Chinese eco-industrial park firms’, *Journal of Cleaner Production*, 155(May 2014), pp. 54–65. doi: 10.1016/j.jclepro.2016.10.093.

Zhang, A. *et al.* (2021) ‘Multi-dimensional circular supply chain management: A comparative review of the state-of-the-art practices and research’, *Transportation Research Part E: Logistics and Transportation Review*, 155(September), p. 102509. doi: 10.1016/j.tre.2021.102509.

Zhang, A. *et al.* (2023) ‘Circular supply chain management: a bibliometric analysis-based literature review’, *International Journal of Logistics Management*, 34(3), pp. 847–872. doi: 10.1108/IJLM-04-2022-0199.

Zhang, C. and Jin, S. (2022) ‘How Does an Environmental Information Disclosure of a Buyer’s Enterprise Affect Green Technological Innovations of Sellers’ Enterprise?’, *International Journal of Environmental Research and Public Health*, 19(22). doi: 10.3390/ijerph192214715.

Zhang, M., Pawar, K. S. and Bhardwaj, S. (2017) ‘Improving supply chain social responsibility through supplier development’, *Production Planning and Control*, 28(6–8), pp. 500–511. doi: 10.1080/09537287.2017.1309717.

Zhang, T. (2023) ‘Critical Realism: A Critical Evaluation’, *Social Epistemology*, 37(1), pp. 15–29. doi: 10.1080/02691728.2022.2080127.

Zhang, X. *et al.* (2023) ‘The Impact of Green Technology Investment Levels on Competitive Supply Chain Integration Decisions’, *Sustainability (Switzerland)*, 15(13), pp. 1–26. doi: 10.3390/su151310386.

Zhang Xumei; Li Zhizhao; Wang Yan (2020) ‘A Review of the Criteria and Methods of Reverse Logistics Supplier Selection’, *Sustainability (Switzerland)*, pp. 1–16. doi: http://dx.doi.org/10.3390/pr8060705.

Zhao, X., Tsuda, T. and Doi, H. (2017) ‘Evaluating the effects of air pollution from a plastic recycling facility on the health of nearby residents', *Acta Medica Okayama*, 71(3), pp. 209–217.

Zimon, D., Madzik, P. and Sroufe, R. (2020) 'The influence of ISO 9001 & ISO 14001 on sustainable supply chain management in the textile industry', *Sustainability (Switzerland)*, 12(10). doi: 10.3390/su12104282.

Zimon, D., Tyan, J. and Sroufe, R. (2019) 'Implementing sustainable supply chain management: Reactive, cooperative, and dynamic models', *Sustainability (Switzerland)*, 11(24). doi: 10.3390/SU11247227.

Zimon, D., Tyan, J. and Sroufe, R. (2020) 'Drivers of sustainable supply chain management: Practices to alignment with un sustainable development goals', *International Journal for Quality Research*, 14(1), pp. 219–236. doi: 10.24874/IJQR14.01-14.

Appendix I

Semi-structured interview of the pilot study

Dear Expert,

Let me first introduce myself, my name Maha Morssi, I am doing my PhD degree at University of Strathclyde, UK. This questionnaire is a part of my research process which aims for improving sustainable supply chain performance within a circular economy context through selecting the right suppliers.

Noted that: The concept of "**Sustainability**" aims for improving three dimensions in the firm's operations, these dimensions are Economic, Environments and Social. While the concept of "**Circular Economy**" is a general term covering all activities that reduce, reuse, and recycle materials in production, distribution, and consumption processes. "**Circular Supply Chain Management"** considers as harmonized forward and reverse supply chains through the incorporation of value creation aspects from products, by-products, and useful waste flows through prolonged life cycle that improves the three dimensions of organizational sustainability.

The results will be used for inclusion in proposing a supplier selection model, that will assist organisations in selecting the best suppliers in the contexts of sustainability and circular economy.

The purpose of this survey is to:

- Discover the drivers and barriers to implementing sustainable supply chain management.
- Investigate how does your company manages the circular economy in its operations.
- Investigate the current supplier selection process at your company.
- Investigate, according to your point of view, any recommended supplier selection criteria for sustainability and the circular economy according to your experience.

The results and contributions are exclusively for the purpose of academic research. Your collaboration is highly respected.

Please read the following questions, and give your answers:

1- What is your company’s activity field?
- Automotive
- Textiles and Apparels
- Metals products
- Construction

- Financial Services
- Energy
- Electronics
- Transportation and Logistic
- Conglomerates
- Telecommunication
- Health care products
- Food and Beverage Products
- Chemicals
- Information Technology
- Public Agencies
- Other:

2- How many people work in your company?
   - Fewer than 250
   - Between 251-400
   - Between 401-600
   - Between 601-900
   - Between 901-1500
   - More than 1500

3- Does your company follow sustainable practices across supply chain activities?
- Yes
- No

Explain the reason behind both situations.
Answer:

4- According to the bellow table, rate to what extent do you agree about the barriers facing your company while managing sustainable supply chain.
Noted that 1 = Strongly Disagree, 2= Disagree, 3= Neutral, 4= Agree, and 5= Strongly Agree.

Barriers					
Higher costs of sustainability and economic condition					
Coordination effort and complexity					
Insufficient communication and sharing information in the supply chain					
Low “eco-literacy”					
Lack of sustainable supplier					

Lack of understanding about environmental management/sustainability					
lack of sustainability standards and appropriate regulations					
Misalignment of short-term and long-term strategic goals					
Lack of effective evaluation measures about sustainability					
Lack of qualified staff, training and education about sustainability					
Complex in design to reduce consumption of resources and energy					
Inadequate facility for adoptions of reverse logistic practices					
Inadequate industrial self-regulation					
Lack of top management commitment to initiate sustainability efforts					
Lack of motivation towards employees (incentives)					
Lack of tools and resources					

5- Does your company consider circular economy practices across supply chain activities?
- Yes
- No

Explain the reason behind both situations.
Answer:

6- How does your company select its suppliers, according to what criteria?
7- According to the table below, according to your point of view, do you recommend any other criteria that can be used while selecting suppliers towards sustainability or circular economy to be applied in the future? If yes, please state the reason behind your recommendation.

Sustainable Circular Supplier Selection Criteria			
Economic	**Environment**	**Social**	**Circular**
- Cost - Quality - Delivery time and services - Flexibility	- Environmental Management System - Green Product - Green Transportation - Life cycle cost management - Involvement in initiatives for carbon management - Carbon accounting and inventory - Green Technology - GHG Emissions - Carbon Disclosure and report	- Training related carbon management - Workers' rights - Occupational Health & Safety - Society's rights/Social responsibilities - Information Disclosure - Supportive Activities	- Eco-friendly raw materials - Respecting environmental standards and regulations in the process of recycling - Air pollution resulting from recycling process - Clean technology for recycling - Eco-friendly packaging

Thank you for your cooperation.

Appendix II

Questionnaire for measuring the importance and applicability of sustainable circular supplier selection criteria.

Dear Expert,

Let me first introduce myself, my name Maha Morssi, I am doing my PhD degree at University of Strathclyde, UK. This questionnaire is a part of my research process which aims for improving sustainable supply chain performance within a circular economy context through selecting the right suppliers.

Noted that: The concept of "**Sustainability**" aims for improving three dimensions in the firm's operations, these dimensions are Economic, Environments and Social. While the concept of "**Circular Economy**” is a general term covering all activities that reduce, reuse, and recycle materials in production, distribution, and consumption processes. "**Circular Supply Chain Management"** considers as harmonized forward and reverse supply chains through the incorporation of value creation aspects from products, by-products, and useful waste flows through prolonged life cycle that improves the three dimensions of organizational sustainability.

The results will be used for inclusion in proposing a supplier selection model, that will assist organisations for selecting the best suppliers in the contexts of sustainability and circular economy.

The purpose of this questionnaire is to measure the significance and extent to which the supplier selection criteria, as shown below, are useful when considering selecting and evaluating suppliers according to their sustainable performance.

The results and contributions are exclusively for the purpose of academic research. Your collaboration is highly respected.

The expected maximum duration of the questionnaire is 30 minutes.

Please read the following questions, and give your answers:

1- What is your company’s activity field?
- Automotive
- Textiles and Apparels
- Metals products
- Construction
- Financial Services
- Energy

- Electronics
- Transportation and Logistic
- Conglomerates
- Telecommunication
- Health care products
- Food and Beverage Products
- Chemicals
- Information Technology
- Public Agencies
- Other:

2- How many people work in your company?
- Fewer than 250
- Between 251-400
- Between 401-600
- Between 601-900
- Between 901-1500
- More than 1500

3- From which region is your company source the raw material?
- Local
- Asia
- Middle East
- Oceania
- Africa
- Europe
- U.S.A

4- Please tick which of these ISO certifications does your company have:
- ISO 9000 (Quality Management)
- ISO 14001 (Environmental Management)
- ISO 26000 (Social Responsibilities)

5- According to the bellow tables, rate to what extent do you agree about importance and applicability levels of the criteria.

Noted that for important levels: 1 = Not at all important, 2= Slightly important, 3= Moderately Important, 4= Very important, and 5= Extremely important.

While for applicability levels: 1 = Not applicable, 2= less applicable, 3= Fairly applicable, 4= Very applicable, and 5= Extremely applicable.

How important is …?	Not at all important	Slightly important	Moderately Important	Very important	Extremely important
Cost:					

The elements that reflect every expense and the cost of the purchased products.					
Quality: The degree of excellence of supplied material					
Delivery time and services: The supplier's efforts to deliver the material and address any issues with it for the customer					
Flexibility: The supplier's degree of flexibility in supplying material and payment.					
Financial Stability: The supplier's financial situation based on the supplier's annual revenue and their financial structure as determined by their prior performance.					
Environmental Management System: Supplier's environmental management efforts and environmental management systems related certification.					
Green Product: How much of the supplier's goods are green.					
Green Transportation: Reducing environmental harm when transporting the required order.					
Green Technology: The technologies employed to produce eco-friendly products.					
GHG Emissions: Chemicals and gases released during product manufacturing.					
Carbon Disclosure and report: Reports on greenhouse gas emissions					
Training related carbon management: To increase environmental awareness among employees, appropriate education and training initiatives must be conducted.					
Workers' rights: Respect for workers' rights by the supplier, including employment insurance, set working hours, and benefits.					
Occupational Health & Safety: Efforts made by the supplier to ensure the health and safety of their workforce, including medical insurance, safety training, and the provision of the necessary tools.					
Society's rights/Social responsibilities:					

Suppliers' capacity to advance sustainability, including social responsibility and cleaner production.					
Information Disclosure: Providing details on the materials used, carbon emissions, and toxins emitted during production to the supplier's customer and other interested parties.					
Eco-friendly raw materials: Making use of recyclable raw materials to produce products					
Respecting environmental standards and regulations in the process of recycling: Using environmental standards during the recycling process.					
Air pollution resulting from recycling process: When recycling the products, take into account reducing air pollution.					
Clean technology for recycling: Using appropriate and environmentally friendly technology to recycle the returned goods.					
Eco-friendly packaging: Using recyclable materials in packaging.					
Reverse Logistics agreement: The suppliers' expertise and abilities in managing reverse logistics operations to ensure product circularity"					

Not applicable, 2= less applicable, 3= Fairly applicable, 4= Very applicable, and 5= Extremely applicable.

To what extent it could be applicable for real-life context?	Not applicable	Less applicable	Fairly applicable	Very applicable	Extremely applicable
Cost: The elements that reflect every expense and the cost of the purchased products.					
Quality: The degree of excellence of supplied material					
Delivery time and services: The supplier's efforts to deliver the material and address any issues with it for the customer					
Flexibility: The supplier's degree of flexibility in supplying material and payment.					
Financial Stability: The supplier's financial situation based on the supplier's annual revenue and					

their financial structure as determined by their prior performance.					
Environmental Management System: Supplier's environmental management efforts and environmental management systems related certification.					
Green Product: How much of the supplier's goods are green.					
Green Transportation: Reducing environmental harm when transporting the required order.					
Green Technology: The technologies employed to produce eco-friendly products.					
GHG Emissions: Chemicals and gases released during product manufacturing.					
Carbon Disclosure and report: Reports on greenhouse gas emissions					
Training related carbon management: To increase environmental awareness among employees, appropriate education and training initiatives must be conducted.					
Workers' rights: Respect for workers' rights by the supplier, including employment insurance, set working hours, and benefits.					
Occupational Health & Safety: Efforts made by the supplier to ensure the health and safety of their workforce, including medical insurance, safety training, and the provision of the necessary tools.					
Society's rights/Social responsibilities: Suppliers' capacity to advance sustainability, including social responsibility and cleaner production.					
Information Disclosure: Providing details on the materials used, carbon emissions, and toxins emitted during production to the supplier's customer and other interested parties.					
Eco-friendly raw materials: Making use of recyclable raw materials to produce products					
Respecting environmental standards and regulations in the process of recycling:					

Using environmental standards during the recycling process.					
Air pollution resulting from recycling process: When recycling the products, take into account reducing air pollution.					
Clean technology for recycling: Using appropriate and environmentally friendly technology to recycle the returned goods.					
Eco-friendly packaging: Using recyclable materials in packaging.					
Reverse Logistics agreement: The suppliers' expertise and abilities in managing reverse logistics operations to ensure product circularity.					

Thank you for your cooperation.

Appendix III

Questionnaire for pair-wise comparison for supplier selection criteria

Dear Expert,

Let me first introduce myself, my name Maha Morssi, I am doing my PhD degree at University of Strathclyde, UK. This questionnaire is a part of my research process which aims for improving sustainable supply chain performance within a circular economy context through selecting the right suppliers. Hence, I am now in a phase of developing a supplier selection model towards sustainability and circular economy contexts.

Noted that: The concept of "**Sustainability**" aims for improving three dimensions in the firm's operations, these dimensions are Economic, Environments and Social. While the concept of "**Circular Economy**” is a general term covering all activities that reduce, reuse, and recycle materials in production, distribution, and consumption processes. "**Circular Supply Chain Management"** considers as harmonized forward and reverse supply chains through the incorporation of value creation aspects from products, by-products, and useful waste flows through prolonged life cycle that improves the three dimensions of organizational sustainability.

The results will be used for inclusion in proposing a supplier selection model, that will assist organisations in selecting the best suppliers in the contexts of sustainability and circular economy.

As a part of my work, I am using a Multi-Criteria Decision-Making Approach called Fuzzy-DEMATEL to weight the criteria towards its significance, and to determine the influential relationship between the criteria to identify causal and effect groups of criteria. The DEMATEL method was first introduced Fonetla and Gabus in 1971and has received widespread recognition since then.

Therefore, a pairwise comparison between the criteria must be developed, which is the purpose of this questionnaire. Pairwise comparisons are fundamental building blocks of the AHP, employing an underlying scale with values from 1 to 5 to rate the influential relation for any two criteria or alternatives.

Table 1 describes the criteria and their codes, while Table 2 will be filled in by you regarding the pairwise comparison.

Table 1:

Dimension	Criteria	Description
Economic	Cost (EC1)	The elements that reflect every expense and the cost of the purchased products.
	Quality (EC2)	The degree of excellence of supplied material
	Delivery time and services (EC3)	The supplier's efforts to deliver the material and address any issues with it for the customer
	Flexibility (EC4)	The supplier's degree of flexibility in supplying material and payment.
	Financial Stability (EC5)	The supplier's financial situation based on the supplier's annual revenue and their financial structure as determined by their prior performance.
Environmental	Environmental Management System (ENV1)	Supplier's environmental management efforts and environmental management systems related certification.
	Green Product (ENV2)	How much of the supplier's goods are green.
	Green Transportation (ENV3)	Reducing environmental harm when transporting the required order.
	Green Technology (ENV4)	The technologies employed to produce eco-friendly products.
	GHG Emissions (ENV5)	Chemicals and gases released during product manufacturing.
	Carbon Disclosure and report (ENV6)	Reports on greenhouse gas emissions
Social	Training related carbon management (SO1)	To increase environmental awareness among employees, appropriate education and training initiatives must be conducted.
	Workers' rights (SO2)	Respect for workers' rights by the supplier, including employment insurance, set working hours, and benefits
	Occupational Health & Safety (SO3)	Efforts made by the supplier to ensure the health and safety of their workforce, including medical insurance, safety training, and the provision of the necessary tools.
	Society's rights/Social responsibilities (SO4)	Suppliers' capacity to advance sustainability, including social responsibility and cleaner production.
	Information Disclosure (SO5)	providing details on the materials used, carbon emissions, and toxins emitted during production to the supplier's customer and other interested parties.
Circular	Eco-friendly raw materials (CR1)	Making use of recyclable raw materials to produce products.
	Respecting environmental standards and regulations in the process of recycling (CR2)	Using environmental standards during the recycling process.
	Air pollution resulting from recycling process (CR3)	When recycling the products, take into account reducing air pollution.
	Clean technology for recycling (CR4)	Using appropriate and environmentally friendly technology to recycle the returned goods
	Eco-friendly packaging (CR5)	Using recyclable materials in packaging.

	Reverse Logistics Agreement (CR6)	Assessing the suppliers' expertise and abilities in managing reverse logistics operations to ensure product circularity.

Table 2: 1= No influence, 2= Influence, 3=Low influence, 4= High influence, and 5= Very high influence.

	EC1	EC2	EC3	EC4	EC5	ENV1	ENV2	ENV3	ENV4	ENV5	ENV6	SO1	SO2	SO3	SO4	SO5	CR1	CR2	CR3	CR4	CR5	CR6
EC1																						
EC2																						
EC3																						
EC4																						
EC5																						
ENV1																						
ENV2																						
ENV3																						
ENV4																						
ENV5																						
ENV6																						
SO1																						
SO2																						
SO3																						
SO4																						
SO5																						
CR1																						
CR2																						
CR3																						
CR4																						
CR5																						
CR6																						

Thank you for your cooperation.

Appendix IV

Action Research Protocol

Dear Expert,

My name Maha Morssi, I am doing my PhD degree at University of Strathclyde, UK. First of all, I want to thank you for giving me a part of your time to support my research. This protocol guarantees the **CONFIDENTIALITY** of your responses as it be used only to the research limits and explains how the case study about your company will be managed.

My research aim is to develop a supplier selection model including criteria that evaluate the suppliers' performance towards sustainability and circular economy in order to improve the supply chains performance regarding sustainability and circular economy as well. The criteria of model are based on four dimensions: Economic, Environment, Social, and Circular.

The model purpose is to assist organisations in selecting the best suppliers in the contexts of sustainability and circular economy.

Noted that: The concept of "**Sustainability**" aims for improving three dimensions in the firm's operations, these dimensions are Economic, Environments and Social. While the concept of "**Circular Economy**" is a general term covering all activities that reduce, reuse, and recycle materials in production, distribution, and consumption processes. "**Circular Supply Chain Management"** considers as harmonized forward and reverse supply chains through the incorporation of value creation aspects from products, by-products, and useful waste flows through prolonged life cycle that improves the three dimensions of organizational sustainability.

However, I already finalised the development of the model, and now in the phase of validating the model through applying it at case study companies.

The past steps of conducting the model were as follows:

1st: The criteria of selecting the suppliers were combined from previous academic researchers and experts,

2nd: Then analysed the importance level of these criteria, and to what extend they are applicable to be used in real life through a survey with 52 experts, 3rd: Then proceeded another questionnaire with 20 experts using an Artificial Intelligence system called (Fuzzy-DEEMATEL) to determine the influential relationship between the criteria to identify the causal and the effect groups of criteria.

The sequence of the conducting the action research will be as follows:

1st Explain your current supplier selection process and criteria you are already using in selecting your suppliers**.**

2nd Nominate some suppliers that are considered as alternatives to each other (at least 2 suppliers).

3rd Rate the same selected suppliers from 1 to 5 according to the proposed criteria which have been done in my research. Noted that I have already identified the importance and influential relationship of the criteria based on previous questionnaire done by some experts.

4th According to your answers, I will use an Artificial Intelligence system called (Fuzzy-TOPSIS) to rank and determine the best supplier.

4th Finally, after rating the suppliers, you will be asked about your **satisfaction level** for my proposed sustainable circular supplier selection model.

Table 1 describes the criteria of the proposed model.

Table 2 demonstrates which criteria are in the cause group, and which criteria are in the effect group.

Table 1: The sustainable circular supplier selection criteria:

Dimension	**Criteria**	**Description**
Economic	Cost	The elements that reflect every expense and the cost of the purchased products.
	Quality	The degree of excellence of supplied material
	Delivery time and services	The supplier's efforts to deliver the material and address any issues with it for the customer
	Flexibility	The supplier's degree of flexibility in supplying material and payment.
	Financial Stability	The supplier's financial situation based on the supplier's annual revenue and their financial structure as determined by their prior performance.
Environmental	Environmental Management System	Supplier's environmental management efforts and environmental management systems related certification.
	Green Product	How much of the supplier's goods are green.
	Green Transportation	Reducing environmental harm when transporting the required order.
	Green Technology	The technologies employed to produce eco-friendly products.
	GHG Emissions	Chemicals and gases released during product manufacturing.
	Carbon Disclosure and report	Reports on greenhouse gas emissions

Social	Training related carbon management	To increase environmental awareness among employees, appropriate education and training initiatives must be conducted.
	Workers' rights	Respect for workers' rights by the supplier, including employment insurance, set working hours, and benefits
	Occupational Health & Safety	Efforts made by the supplier to ensure the health and safety of their workforce, including medical insurance, safety training, and the provision of the necessary tools.
	Society's rights/Social responsibilities	Suppliers' capacity to advance sustainability, including social responsibility and cleaner production.
	Information Disclosure	providing details on the materials used, carbon emissions, and toxins emitted during production to the supplier's customer and other interested parties.
Circular	Eco-friendly raw materials	Making use of recyclable raw materials to produce products.
	Respecting environmental standards and regulations in the process of recycling	Using environmental standards during the recycling process.
	Air pollution resulting from recycling process	When recycling the products, take into account reducing air pollution.
	Clean technology for recycling	Using appropriate and environmentally friendly technology to recycle the returned goods
	Eco-friendly packaging	Using recyclable materials in packaging.
	Reverse Logistics agreement	Assessing the suppliers' expertise and abilities in managing reverse logistics operations to ensure product circularity.

Table 2: The criteria cause and effect groups:

Causal Criteria	Effect Criteria
Environmental Mgt. Systems	Green Design
ENV5- GHG emissions	Society's Rights/ Social responsibilities
Air pollution resulting from recycling process	Eco-friendly raw materials
Clean technology for recycling	Carbon Disclosure Report
Occupational Health & Safety	Reverse Logistics Agreement
Respecting environmental standards and regulations in the process of recycling	Green Transportation
Training Related Carbon	Eco-friendly packaging
Green Technology	Cost
Information Disclosure	Worker's Rights
Financial Stability	Delivery and services
[redacted]	Flexibility
	Green Design

Please indicate whether you accept conducting the validation at your company or not by selecting in of the below options. Best Regards,

- □ Agree
- □ Not agree

Signature

Thank you for your cooperation.

Appendix V

Experts' Profiles for FUZZY-DEMATEL Pairwise Questionnaire

#	Company Field	Title	Years of Experience	ISO Certificates		
				ISO 9000 Quality Management	*ISO14001 Environmental Management Systems*	*ISO 26000 Social Responsibility*
1	Flexible packaging	Procurement Manager	22	√	√	
2	Petrochemicals	SITE MANAGER	20	√	√	
3	Fast Moving Consumer Goods (FMCGs)	Purchasing Manager	10	√	√	
4	Textiles and Apparels	Supply Chain Manager	11	√	√	
5	Textiles and Apparels	Logistics manager	15	√	√	
6	Metals/ Steel products	Production Supervisor	12	√	√	
7	Construction	Ass. Procurement Manager	11	√	√	
8	Textiles and Apparels	Procurement Manager	17	√	√	√
9	Fast Moving Consumer Goods (FMCGs)	Material planner	16	√	√	
10	Electronics	Head of planning and purchasing	20	√	√	√
11	Metals/ Steel products	Procurement Specialist	14	√	√	√
12	Petrochemicals	Section Head of Tendering	15	√	√	√

		& Practices Sector				
13	Petrochemicals	Procurement Specialist, General Department of Material	9	√	√	√
14	Metal products	Purchasing Manager	14	√	√	
15	Metal products	Procurement Specialist	9	√	√	
16	Sanitary Ware and Ceramic Tiles	Head of Quality Department	10	√	√	√
17	Petrochemicals	Purchasing Manager	8	√	√	√
18	Operation and Maintenance Management Company	Procurement Head	20	√	√	
19	Electronics	Procurement Manager	20	√	√	
20	Construction machines manufacturer	Supply Chain Coordinator	14	√	√	

Appendix VI

The Direct Relationship Matrix of FUZZY-DEMATEL

	EC1	EC2	EC3	EC4	EC5	ENV1	ENV2	ENV3	ENV4
EC1	(0.000,0.	(0.738,0.	(0.588,0.	(0.513,0.	(0.150,0.	(0.525,0.	(0.600,0.	(0.625,0.	(0.600,0.
EC2	(0.163,0.	(0.000,0.	(0.413,0.	(0.475,0.	(0.500,0.	(0.613,0.	(0.713,0.	(0.075,0.	(0.725,0.
EC3	(0.275,0.	(0.375,0.	(0.000,0.	(0.675,0.	(0.500,0.	(0.038,0.	(0.038,0.	(0.325,0.	(0.325,0.
EC4	(0.363,0.	(0.213,0.	(0.650,0.	(0.000,0.	(0.488,0.	(0.038,0.	(0.038,0.	(0.000,0.	(0.388,0.
EC5	(0.050,0.	(0.063,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.150,0.
ENV1	(0.063,0.	(0.613,0.	(0.000,0.	(0.000,0.	(0.500,0.	(0.000,0.	(0.663,0.	(0.675,0.	(0.750,1.
ENV2	(0.063,0.	(0.550,0.	(0.125,0.	(0.013,0.	(0.413,0.	(0.750,1.	(0.000,0.	(0.088,0.	(0.688,0.
ENV3	(0.125,0.	(0.050,0.	(0.325,0.	(0.050,0.	(0.400,0.	(0.750,1.	(0.100,0.	(0.000,0.	(0.750,1.
ENV4	(0.063,0.	(0.425,0.	(0.000,0.	(0.000,0.	(0.425,0.	(0.725,0.	(0.038,0.	(0.000,0.	(0.000,0.
ENV5	(0.075,0.	(0.600,0.	(0.000,0.	(0.000,0.	(0.338,0.	(0.713,0.	(0.750,1.	(0.750,1.	(0.688,0.
ENV6	(0.000,0.	(0.525,0.	(0.000,0.	(0.000,0.	(0.275,0.	(0.625,0.	(0.400,0.	(0.325,0.	(0.688,0.
SO1	(0.013,0.	(0.150,0.	(0.000,0.	(0.000,0.	(0.150,0.	(0.675,0.	(0.413,0.	(0.000,0.	(0.563,0.
SO2	(0.000,0.	(0.013,0.	(0.000,0.	(0.000,0.	(0.163,0.	(0.238,0.	(0.063,0.	(0.000,0.	(0.225,0.
SO3	(0.013,0.	(0.138,0.	(0.000,0.	(0.000,0.	(0.375,0.	(0.750,1.	(0.663,0.	(0.288,0.	(0.738,0.
SO4	(0.113,0.	(0.425,0.	(0.000,0.	(0.000,0.	(0.213,0.	(0.525,0.	(0.513,0.	(0.513,0.	(0.538,0.
SO5	(0.013,0.	(0.388,0.	(0.000,0.	(0.000,0.	(0.225,0.	(0.663,0.	(0.063,0.	(0.000,0.	(0.700,0.
CE1	(0.050,0.	(0.625,0.	(0.000,0.	(0.050,0.	(0.125,0.	(0.738,0.	(0.750,1.	(0.000,0.	(0.663,0.
CE2	(0.013,0.	(0.338,0.	(0.000,0.	(0.000,0.	(0.400,0.	(0.675,0.	(0.700,0.	(0.000,0.	(0.750,1.
CE3	(0.013,0.	(0.525,0.	(0.000,0.	(0.000,0.	(0.350,0.	(0.638,0.	(0.650,0.	(0.000,0.	(0.663,0.
CE4	(0.000,0.	(0.438,0.	(0.000,0.	(0.000,0.	(0.500,0.	(0.613,0.	(0.750,1.	(0.138,0.	(0.700,0.
CE5	(0.013,0.	(0.388,0.	(0.050,0.	(0.000,0.	(0.450,0.	(0.688,0.	(0.438,0.	(0.000,0.	(0.750,1.
CE6	(0.163,0. 375,0.625	(0.338,0. 588,0.838	(0.713,0. 963,1.000	(0.625,0. 875,0.988	(0.600,0. 850,0.950	(0.638,0. 888,0.988	(0.513,0. 763,0.925	(0.625,0. 875,0.988	(0.613,0. 863,1.000

CE4	CE3	CE2	CE1	SO5	SO4	SO3	SO2	SO1	ENV6	ENV5
(0.563,0.	(0.538,0.	(0.525,0.	(0.400,0.	(0.000,0.	(0.038,0.	(0.338,0.	(0.000,0.	(0.188,0.	(0.000,0.	(0.513,0.
(0.725,0.	(0.675,0.	(0.700,0.	(0.700,0.	(0.375,0.	(0.063,0.	(0.475,0.	(0.500,0.	(0.363,0.	(0.113,0.	(0.625,0.
(0.075,0.	(0.125,0.	(0.213,0.	(0.350,0.	(0.025,0.	(0.013,0.	(0.050,0.	(0.225,0.	(0.038,0.	(0.000,0.	(0.000,0.
(0.013,0.	(0.075,0.	(0.063,0.	(0.013,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.100,0.	(0.000,0.	(0.000,0.	(0.000,0.
(0.138,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.013,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.000,0.
(0.725,0.	(0.725,0.	(0.675,0.	(0.738,0.	(0.463,0.	(0.238,0.	(0.725,0.	(0.175,0.	(0.700,0.	(0.650,0.	(0.700,0.
(0.700,0.	(0.688,0.	(0.725,0.	(0.463,0.	(0.475,0.	(0.463,0.	(0.613,0.	(0.013,0.	(0.613,0.	(0.150,0.	(0.750,1.
(0.063,0.	(0.613,0.	(0.025,0.	(0.000,0.	(0.463,0.	(0.475,0.	(0.463,0.	(0.000,0.	(0.613,0.	(0.063,0.	(0.550,0.
(0.350,0.	(0.513,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.013,0.	(0.175,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.050,0.
(0.750,1.	(0.638,0.	(0.638,0.	(0.663,0.	(0.500,0.	(0.675,0.	(0.688,0.	(0.175,0.	(0.738,0.	(0.063,0.	(0.000,0.
(0.525,0.	(0.413,0.	(0.338,0.	(0.450,0.	(0.325,0.	(0.550,0.	(0.713,0.	(0.000,0.	(0.613,0.	(0.000,0.	(0.750,1.
(0.000,0.	(0.325,0.	(0.013,0.	(0.000,0.	(0.538,0.	(0.725,0.	(0.625,0.	(0.600,0.	(0.000,0.	(0.413,0.	(0.688,0.
(0.338,0.	(0.038,0.	(0.325,0.	(0.650,0.	(0.038,0.	(0.213,0.	(0.700,0.	(0.000,0.	(0.400,0.	(0.000,0.	(0.600,0.
(0.650,0.	(0.275,0.	(0.425,0.	(0.613,0.	(0.238,0.	(0.225,0.	(0.000,0.	(0.588,0.	(0.663,0.	(0.488,0.	(0.675,0.
(0.488,0.	(0.650,0.	(0.700,0.	(0.625,0.	(0.638,0.	(0.000,0.	(0.425,0.	(0.063,0.	(0.675,0.	(0.488,0.	(0.550,0.
(0.300,0.	(0.313,0.	(0.000,0.	(0.275,0.	(0.000,0.	(0.488,0.	(0.000,0.	(0.063,0.	(0.100,0.	(0.313,0.	(0.725,0.
(0.575,0.	(0.650,0.	(0.738,0.	(0.000,0.	(0.488,0.	(0.288,0.	(0.625,0.	(0.288,0.	(0.725,0.	(0.388,0.	(0.738,0.
(0.600,0.	(0.638,0.	(0.000,0.	(0.000,0.	(0.238,0.	(0.363,0.	(0.625,0.	(0.025,0.	(0.488,0.	(0.250,0.	(0.613,0.
(0.625,0.	(0.000,0.	(0.663,0.	(0.400,0.	(0.350,0.	(0.413,0.	(0.625,0.	(0.113,0.	(0.425,0.	(0.388,0.	(0.738,0.
(0.000,0.	(0.600,0.	(0.413,0.	(0.088,0.	(0.225,0.	(0.363,0.	(0.525,0.	(0.550,0.	(0.425,0.	(0.288,0.	(0.750,1.
(0.750,1.	(0.613,0.	(0.100,0.	(0.025,0.	(0.225,0.	(0.463,0.	(0.100,0.	(0.025,0.	(0.125,0.	(0.150,0.	(0.475,0.
(0.338,0. 588,0.838	(0.575,0. 825,1.000	(0.650,0. 900,1.000	(0.325,0. 488,0.700	(0.088,0. 313,0.563	(0.125,0. 313,0.550	(0.050,0. 250,0.500	(0.000,0. 000,0.250	(0.038,0. 175,0.425	(0.000,0. 000,0.250	(0.088,0. 325,0.575

CE6	CE5
(0.475,0.	(0.613,0.
(0.225,0.	(0.000,0.
(0.488,0.	(0.063,0.
(0.525,0.	(0.000,0.
(0.000,0.	(0.000,0.
(0.700,0.	(0.713,0.
(0.475,0.	(0.063,0.
(0.213,0.	(0.000,0.
(0.000,0.	(0.000,0.
(0.263,0.	(0.138,0.
(0.000,0.	(0.075,0.
(0.000,0.	(0.075,0.
(0.000,0.	(0.000,0.
(0.000,0.	(0.000,0.
(0.075,0.	(0.325,0.
(0.000,0.	(0.238,0.
(0.000,0.	(0.000,0.
(0.000,0.	(0.238,0.
(0.575,0.	(0.313,0.
(0.100,0.	(0.000,0.
(0.388,0.	(0.000,0.
(0.000,0. 000,0.000	(0.413,0. 663,0.900

Appendix VII

The normalized fuzzy direct-relation matrix of FUZZY-DEMATEL

	EC1	EC2	EC3	EC4	EC5	ENV1	ENV2	ENV3	ENV4
EC1	(0.000,0.	(0.038,0.	(0.030,0.	(0.026,0.	(0.008,0.	(0.027,0.	(0.031,0.	(0.032,0.	(0.031,0.
EC2	(0.008,0.	(0.000,0.	(0.021,0.	(0.024,0.	(0.026,0.	(0.031,0.	(0.036,0.	(0.004,0.	(0.037,0.
EC3	(0.014,0.	(0.019,0.	(0.000,0.	(0.035,0.	(0.026,0.	(0.002,0.	(0.002,0.	(0.017,0.	(0.017,0.
EC4	(0.019,0.	(0.011,0.	(0.033,0.	(0.000,0.	(0.025,0.	(0.002,0.	(0.002,0.	(0.000,0.	(0.020,0.
EC5	(0.003,0.	(0.003,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.008,0.
ENV1	(0.003,0.	(0.031,0.	(0.000,0.	(0.000,0.	(0.026,0.	(0.000,0.	(0.034,0.	(0.035,0.	(0.038,0.
ENV2	(0.003,0.	(0.028,0.	(0.006,0.	(0.001,0.	(0.021,0.	(0.038,0.	(0.000,0.	(0.005,0.	(0.035,0.
ENV3	(0.006,0.	(0.003,0.	(0.017,0.	(0.003,0.	(0.020,0.	(0.038,0.	(0.005,0.	(0.000,0.	(0.038,0.
ENV4	(0.003,0.	(0.022,0.	(0.000,0.	(0.000,0.	(0.022,0.	(0.037,0.	(0.002,0.	(0.000,0.	(0.000,0.
ENV5	(0.004,0.	(0.031,0.	(0.000,0.	(0.000,0.	(0.017,0.	(0.036,0.	(0.038,0.	(0.038,0.	(0.035,0.
ENV6	(0.000,0.	(0.027,0.	(0.000,0.	(0.000,0.	(0.014,0.	(0.032,0.	(0.020,0.	(0.017,0.	(0.035,0.
SO1	(0.001,0.	(0.008,0.	(0.000,0.	(0.000,0.	(0.008,0.	(0.035,0.	(0.021,0.	(0.000,0.	(0.029,0.
SO2	(0.000,0.	(0.001,0.	(0.000,0.	(0.000,0.	(0.008,0.	(0.012,0.	(0.003,0.	(0.000,0.	(0.012,0.
SO3	(0.001,0.	(0.007,0.	(0.000,0.	(0.000,0.	(0.019,0.	(0.038,0.	(0.034,0.	(0.015,0.	(0.038,0.
SO4	(0.006,0.	(0.022,0.	(0.000,0.	(0.000,0.	(0.011,0.	(0.027,0.	(0.026,0.	(0.026,0.	(0.028,0.
SO5	(0.001,0.	(0.020,0.	(0.000,0.	(0.000,0.	(0.012,0.	(0.034,0.	(0.003,0.	(0.000,0.	(0.036,0.
CE1	(0.003,0.	(0.032,0.	(0.000,0.	(0.003,0.	(0.006,0.	(0.038,0.	(0.038,0.	(0.000,0.	(0.034,0.
CE2	(0.001,0.	(0.017,0.	(0.000,0.	(0.000,0.	(0.020,0.	(0.035,0.	(0.036,0.	(0.000,0.	(0.038,0.
CE3	(0.001,0.	(0.027,0.	(0.000,0.	(0.000,0.	(0.018,0.	(0.033,0.	(0.033,0.	(0.000,0.	(0.034,0.
CE4	(0.000,0.	(0.022,0.	(0.000,0.	(0.000,0.	(0.026,0.	(0.031,0.	(0.038,0.	(0.007,0.	(0.036,0.
CE5	(0.001,0.	(0.020,0.	(0.003,0.	(0.000,0.	(0.023,0.	(0.035,0.	(0.022,0.	(0.000,0.	(0.038,0.
CE6	(0.008,0.019,0.032	(0.017,0.030,0.043	(0.036,0.049,0.051	(0.032,0.045,0.051	(0.031,0.044,0.049	(0.033,0.045,0.051	(0.026,0.039,0.047	(0.032,0.045,0.051	(0.031,0.044,0.051

CE4	CE3	CE2	CE1	SO5	SO4	SO3	SO2	SO1	ENV6	ENV5
(0.029,0.	(0.028,0.	(0.027,0.	(0.020,0.	(0.000,0.	(0.002,0.	(0.017,0.	(0.000,0.	(0.010,0.	(0.000,0.	(0.026,0.
(0.037,0.	(0.035,0.	(0.036,0.	(0.036,0.	(0.019,0.	(0.003,0.	(0.024,0.	(0.026,0.	(0.019,0.	(0.006,0.	(0.032,0.
(0.004,0.	(0.006,0.	(0.011,0.	(0.018,0.	(0.001,0.	(0.001,0.	(0.003,0.	(0.012,0.	(0.002,0.	(0.000,0.	(0.000,0.
(0.001,0.	(0.004,0.	(0.003,0.	(0.001,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.005,0.	(0.000,0.	(0.000,0.	(0.000,0.
(0.007,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.001,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.000,0.
(0.037,0.	(0.037,0.	(0.035,0.	(0.038,0.	(0.024,0.	(0.012,0.	(0.037,0.	(0.009,0.	(0.036,0.	(0.033,0.	(0.036,0.
(0.036,0.	(0.035,0.	(0.037,0.	(0.024,0.	(0.024,0.	(0.024,0.	(0.031,0.	(0.001,0.	(0.031,0.	(0.008,0.	(0.038,0.
(0.003,0.	(0.031,0.	(0.001,0.	(0.000,0.	(0.024,0.	(0.024,0.	(0.024,0.	(0.000,0.	(0.031,0.	(0.003,0.	(0.028,0.
(0.018,0.	(0.026,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.001,0.	(0.009,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.003,0.
(0.038,0.	(0.033,0.	(0.033,0.	(0.034,0.	(0.026,0.	(0.035,0.	(0.035,0.	(0.009,0.	(0.038,0.	(0.003,0.	(0.000,0.
(0.027,0.	(0.021,0.	(0.017,0.	(0.023,0.	(0.017,0.	(0.028,0.	(0.036,0.	(0.000,0.	(0.031,0.	(0.000,0.	(0.038,0.
(0.000,0.	(0.017,0.	(0.001,0.	(0.000,0.	(0.028,0.	(0.037,0.	(0.032,0.	(0.031,0.	(0.000,0.	(0.021,0.	(0.035,0.
(0.017,0.	(0.002,0.	(0.017,0.	(0.033,0.	(0.002,0.	(0.011,0.	(0.036,0.	(0.000,0.	(0.020,0.	(0.000,0.	(0.031,0.
(0.033,0.	(0.014,0.	(0.022,0.	(0.031,0.	(0.012,0.	(0.012,0.	(0.000,0.	(0.030,0.	(0.034,0.	(0.025,0.	(0.035,0.
(0.025,0.	(0.033,0.	(0.036,0.	(0.032,0.	(0.033,0.	(0.000,0.	(0.022,0.	(0.003,0.	(0.035,0.	(0.025,0.	(0.028,0.
(0.015,0.	(0.016,0.	(0.000,0.	(0.014,0.	(0.000,0.	(0.025,0.	(0.000,0.	(0.003,0.	(0.005,0.	(0.016,0.	(0.037,0.
(0.029,0.	(0.033,0.	(0.038,0.	(0.000,0.	(0.025,0.	(0.015,0.	(0.032,0.	(0.015,0.	(0.037,0.	(0.020,0.	(0.038,0.
(0.031,0.	(0.033,0.	(0.000,0.	(0.000,0.	(0.012,0.	(0.019,0.	(0.032,0.	(0.001,0.	(0.025,0.	(0.013,0.	(0.031,0.
(0.032,0.	(0.000,0.	(0.034,0.	(0.020,0.	(0.018,0.	(0.021,0.	(0.032,0.	(0.006,0.	(0.022,0.	(0.020,0.	(0.038,0.
(0.000,0.	(0.031,0.	(0.021,0.	(0.005,0.	(0.012,0.	(0.019,0.	(0.027,0.	(0.028,0.	(0.022,0.	(0.015,0.	(0.038,0.
(0.038,0.	(0.031,0.	(0.005,0.	(0.001,0.	(0.012,0.	(0.024,0.	(0.005,0.	(0.001,0.	(0.006,0.	(0.008,0.	(0.024,0.
(0.017,0. 030,0.043	(0.029,0. 042,0.051	(0.033,0. 046,0.051	(0.017,0. 025,0.036	(0.005,0. 016,0.029	(0.006,0. 016,0.028	(0.003,0. 013,0.026	(0.000,0. 000,0.013	(0.002,0. 009,0.022	(0.000,0. 000,0.013	(0.005,0. 017,0.029

CE6	CE5
(0.024,0.	(0.031,0.
(0.012,0.	(0.000,0.
(0.025,0.	(0.003,0.
(0.027,0.	(0.000,0.
(0.000,0.	(0.000,0.
(0.036,0.	(0.036,0.
(0.024,0.	(0.003,0.
(0.011,0.	(0.000,0.
(0.000,0.	(0.000,0.
(0.013,0.	(0.007,0.
(0.000,0.	(0.004,0.
(0.000,0.	(0.004,0.
(0.000,0.	(0.000,0.
(0.000,0.	(0.000,0.
(0.004,0.	(0.017,0.
(0.000,0.	(0.012,0.
(0.000,0.	(0.000,0.
(0.000,0.	(0.012,0.
(0.029,0.	(0.016,0.
(0.005,0.	(0.000,0.
(0.020,0.	(0.000,0.
(0.000,0. 000,0.000	(0.021,0. 034,0.046

Appendix VIII

The fuzzy total relation matrix of FUZZY-DEMATEL

	EC1	EC2	EC3	EC4	EC5	ENV1	ENV2	ENV3	ENV4
EC1	(0.003,0.	(0.050,0.	(0.034,0.	(0.030,0.	(0.021,0.	(0.046,0.	(0.046,0.	(0.039,0.	(0.051,0.
EC2	(0.011,0.	(0.014,0.	(0.024,0.	(0.027,0.	(0.038,0.	(0.051,0.	(0.052,0.	(0.011,0.	(0.058,0.
EC3	(0.016,0.	(0.024,0.	(0.004,0.	(0.037,0.	(0.031,0.	(0.010,0.	(0.008,0.	(0.019,0.	(0.025,0.
EC4	(0.020,0.	(0.015,0.	(0.035,0.	(0.003,0.	(0.029,0.	(0.007,0.	(0.005,0.	(0.003,0.	(0.025,0.
EC5	(0.003,0.	(0.004,0.	(0.000,0.	(0.000,0.	(0.001,0.	(0.001,0.	(0.001,0.	(0.000,0.	(0.008,0.
ENV1	(0.006,0.	(0.048,0.	(0.004,0.	(0.003,0.	(0.041,0.	(0.028,0.	(0.054,0.	(0.043,0.	(0.066,0.
ENV2	(0.005,0.	(0.042,0.	(0.009,0.	(0.003,0.	(0.034,0.	(0.059,0.	(0.018,0.	(0.013,0.	(0.057,0.
ENV3	(0.008,0.	(0.012,0.	(0.018,0.	(0.004,0.	(0.029,0.	(0.051,0.	(0.016,0.	(0.006,0.	(0.052,0.
ENV4	(0.004,0.	(0.026,0.	(0.001,0.	(0.001,0.	(0.026,0.	(0.042,0.	(0.008,0.	(0.003,0.	(0.007,0.
ENV5	(0.006,0.	(0.045,0.	(0.003,0.	(0.002,0.	(0.031,0.	(0.060,0.	(0.056,0.	(0.045,0.	(0.060,0.
ENV6	(0.002,0.	(0.039,0.	(0.002,0.	(0.001,0.	(0.025,0.	(0.051,0.	(0.036,0.	(0.023,0.	(0.054,0.
SO1	(0.002,0.	(0.017,0.	(0.001,0.	(0.001,0.	(0.016,0.	(0.048,0.	(0.032,0.	(0.006,0.	(0.043,0.
SO2	(0.001,0.	(0.007,0.	(0.000,0.	(0.000,0.	(0.014,0.	(0.022,0.	(0.012,0.	(0.004,0.	(0.022,0.
SO3	(0.002,0.	(0.020,0.	(0.001,0.	(0.001,0.	(0.030,0.	(0.056,0.	(0.048,0.	(0.021,0.	(0.056,0.
SO4	(0.007,0.	(0.035,0.	(0.002,0.	(0.002,0.	(0.023,0.	(0.048,0.	(0.042,0.	(0.032,0.	(0.049,0.
SO5	(0.002,0.	(0.028,0.	(0.001,0.	(0.001,0.	(0.019,0.	(0.045,0.	(0.013,0.	(0.005,0.	(0.048,0.
CE1	(0.004,0.	(0.045,0.	(0.002,0.	(0.004,0.	(0.019,0.	(0.058,0.	(0.055,0.	(0.007,0.	(0.055,0.
CE2	(0.002,0.	(0.029,0.	(0.001,0.	(0.001,0.	(0.031,0.	(0.051,0.	(0.049,0.	(0.006,0.	(0.055,0.
CE3	(0.003,0.	(0.040,0.	(0.003,0.	(0.002,0.	(0.031,0.	(0.053,0.	(0.050,0.	(0.008,0.	(0.055,0.
CE4	(0.002,0.	(0.034,0.	(0.002,0.	(0.001,0.	(0.036,0.	(0.048,0.	(0.051,0.	(0.013,0.	(0.053,0.
CE5	(0.002,0.	(0.030,0.	(0.005,0.	(0.002,0.	(0.032,0.	(0.049,0.	(0.034,0.	(0.006,0.	(0.053,0.
CE6	(0.011,0.030,0.094	(0.028,0.068,0.164	(0.040,0.061,0.115	(0.035,0.056,0.114	(0.042,0.082,0.170	(0.047,0.093,0.183	(0.037,0.078,0.164	(0.037,0.065,0.133	(0.048,0.096,0.190

CE4	CE3	CE2	CE1	SO5	SO4	SO3	SO2	SO1	ENV6	ENV5
(0.044,0.	(0.044,0.	(0.040,0.	(0.031,0.	(0.010,0.	(0.012,0.	(0.031,0.	(0.006,0.	(0.023,0.	(0.007,0.	(0.042,0.
(0.053,0.	(0.051,0.	(0.050,0.	(0.047,0.	(0.029,0.	(0.014,0.	(0.040,0.	(0.032,0.	(0.033,0.	(0.014,0.	(0.050,0.
(0.010,0.	(0.013,0.	(0.016,0.	(0.022,0.	(0.005,0.	(0.004,0.	(0.008,0.	(0.014,0.	(0.007,0.	(0.002,0.	(0.006,0.
(0.005,0.	(0.008,0.	(0.007,0.	(0.004,0.	(0.001,0.	(0.001,0.	(0.003,0.	(0.006,0.	(0.002,0.	(0.001,0.	(0.003,0.
(0.008,0.	(0.001,0.	(0.001,0.	(0.000,0.	(0.000,0.	(0.001,0.	(0.001,0.	(0.000,0.	(0.000,0.	(0.000,0.	(0.001,0.
(0.058,0.	(0.059,0.	(0.052,0.	(0.051,0.	(0.037,0.	(0.027,0.	(0.056,0.	(0.017,0.	(0.054,0.	(0.043,0.	(0.059,0.
(0.053,0.	(0.053,0.	(0.052,0.	(0.036,0.	(0.035,0.	(0.035,0.	(0.047,0.	(0.008,0.	(0.046,0.	(0.017,0.	(0.057,0.
(0.014,0.	(0.042,0.	(0.011,0.	(0.009,0.	(0.031,0.	(0.032,0.	(0.033,0.	(0.005,0.	(0.040,0.	(0.010,0.	(0.040,0.
(0.024,0.	(0.032,0.	(0.006,0.	(0.005,0.	(0.004,0.	(0.004,0.	(0.014,0.	(0.003,0.	(0.005,0.	(0.003,0.	(0.009,0.
(0.056,0.	(0.052,0.	(0.048,0.	(0.046,0.	(0.038,0.	(0.047,0.	(0.053,0.	(0.017,0.	(0.055,0.	(0.014,0.	(0.023,0.
(0.042,0.	(0.037,0.	(0.030,0.	(0.034,0.	(0.027,0.	(0.038,0.	(0.051,0.	(0.007,0.	(0.045,0.	(0.009,0.	(0.055,0.
(0.013,0.	(0.028,0.	(0.011,0.	(0.011,0.	(0.035,0.	(0.045,0.	(0.043,0.	(0.035,0.	(0.011,0.	(0.027,0.	(0.048,0.
(0.025,0.	(0.010,0.	(0.024,0.	(0.039,0.	(0.008,0.	(0.017,0.	(0.044,0.	(0.004,0.	(0.029,0.	(0.005,0.	(0.040,0.
(0.048,0.	(0.030,0.	(0.034,0.	(0.042,0.	(0.022,0.	(0.022,0.	(0.016,0.	(0.036,0.	(0.048,0.	(0.032,0.	(0.052,0.
(0.042,0.	(0.050,0.	(0.049,0.	(0.043,0.	(0.044,0.	(0.013,0.	(0.038,0.	(0.010,0.	(0.049,0.	(0.034,0.	(0.048,0.
(0.026,0.	(0.027,0.	(0.009,0.	(0.022,0.	(0.007,0.	(0.031,0.	(0.010,0.	(0.007,0.	(0.014,0.	(0.021,0.	(0.047,0.
(0.047,0.	(0.050,0.	(0.052,0.	(0.013,0.	(0.036,0.	(0.027,0.	(0.049,0.	(0.022,0.	(0.052,0.	(0.029,0.	(0.057,0.
(0.045,0.	(0.046,0.	(0.012,0.	(0.010,0.	(0.021,0.	(0.028,0.	(0.045,0.	(0.007,0.	(0.037,0.	(0.020,0.	(0.046,0.
(0.049,0.	(0.018,0.	(0.048,0.	(0.032,0.	(0.029,0.	(0.032,0.	(0.047,0.	(0.013,0.	(0.036,0.	(0.028,0.	(0.056,0.
(0.015,0.	(0.045,0.	(0.033,0.	(0.016,0.	(0.021,0.	(0.028,0.	(0.041,0.	(0.033,0.	(0.035,0.	(0.022,0.	(0.054,0.
(0.050,0.	(0.044,0.	(0.016,0.	(0.010,0.	(0.019,0.	(0.031,0.	(0.016,0.	(0.006,0.	(0.017,0.	(0.014,0.	(0.037,0.
(0.030,0. 072,0.167	(0.042,0. 086,0.180	(0.043,0. 081,0.161	(0.024,0. 053,0.135	(0.012,0. 046,0.137	(0.014,0. 046,0.135	(0.014,0. 051,0.144	(0.004,0. 021,0.099	(0.012,0. 046,0.138	(0.006,0. 024,0.106	(0.018,0. 060,0.154

CE6	CE5
(0.033,0.	(0.036,0.
(0.019,0.	(0.005,0.
(0.028,0.	(0.005,0.
(0.029,0.	(0.002,0.
(0.000,0.	(0.000,0.
(0.043,0.	(0.042,0.
(0.031,0.	(0.009,0.
(0.016,0.	(0.005,0.
(0.003,0.	(0.003,0.
(0.021,0.	(0.013,0.
(0.006,0.	(0.009,0.
(0.005,0.	(0.008,0.
(0.002,0.	(0.002,0.
(0.006,0.	(0.005,0.
(0.010,0.	(0.022,0.
(0.004,0.	(0.016,0.
(0.007,0.	(0.006,0.
(0.006,0.	(0.017,0.
(0.035,0.	(0.021,0.
(0.011,0.	(0.005,0.
(0.025,0.	(0.005,0.
(0.008,0. 025,0.089	(0.025,0. 052,0.124

Appendix IX

The crisp total-relation matrix of FUZZY-DEMATEL

	EC1	EC2	EC3	EC4	EC5	ENV1	ENV2	ENV3	ENV4
EC1	0	0.102	0.066	0	0.073	0.104	0.098	0.078	0.11
EC2	0	0	0	0	0.093	0.109	0.104	0	0.117
EC3	0	0.065	0	0	0.072	0	0	0	0.071
EC4	0	0	0	0	0	0	0	0	0
EC5	0	0	0	0	0	0	0	0	0
ENV1	0	0.105	0	0	0.1	0.084	0.11	0.084	0.128
ENV2	0	0.096	0	0	0.089	0.116	0	0	0.116
ENV3	0	0	0	0	0.075	0.097	0	0	0.099
ENV4	0	0	0	0	0	0.076	0	0	0
ENV5	0	0.1	0	0	0.088	0.119	0.109	0.084	0.12
ENV6	0	0.089	0	0	0.078	0.106	0.088	0	0.11
SO1	0	0	0	0	0	0.095	0.077	0	0.092
SO2	0	0	0	0	0	0.067	0	0	0.069
SO3	0	0.071	0	0	0.081	0.109	0.097	0	0.11
SO4	0	0.09	0	0	0.076	0.108	0.097	0.074	0.111
SO5	0	0.071	0	0	0	0.09	0	0	0.093
CE1	0	0.096	0	0	0.073	0.112	0.104	0	0.112
CE2	0	0.078	0	0	0.08	0.102	0.095	0	0.106
CE3	0	0.094	0	0	0.086	0.111	0.102	0	0.114
CE4	0	0.084	0	0	0.085	0.102	0.098	0	0.107
CE5	0	0.078	0	0	0.081	0.099	0.082	0	0.104
CE6	0	0.08	0.069	0.065	0.091	0.101	0.087	0.074	0.104

CE4	CE3	CE2	CE1	SO5	SO4	SO3	SO2	SO1	ENV6	ENV5
0.099	0.101	0.092	0.078	0	0	0.086	0	0.076	0	0.098
0.107	0.106	0.1	0.093	0.08	0	0.094	0.075	0.088	0	0.105
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0.116	0.118	0.105	0.099	0.092	0.083	0.112	0	0.109	0.09	0.118
0.107	0.108	0.101	0.083	0.086	0.085	0.1	0	0.099	0	0.111
0	0.088	0	0	0.072	0.07	0.078	0	0.083	0	0.085
0	0.066	0	0	0	0	0	0	0	0	0
0.111	0.11	0.1	0.093	0.09	0.097	0.106	0	0.107	0	0.072
0.095	0.092	0.08	0.079	0.076	0.086	0.1	0	0.095	0	0.106
0	0.076	0	0	0.077	0.084	0.086	0.069	0	0.066	0.092
0.068	0	0	0.073	0	0	0.082	0	0.07	0	0.081
0.098	0.085	0.082	0.085	0.072	0.071	0	0.075	0.096	0.075	0.103
0.098	0.107	0.099	0.09	0.094	0	0.094	0	0.102	0.08	0.105
0.072	0.073	0	0	0	0.07	0	0	0	0	0.089
0.1	0.104	0.099	0	0.085	0.076	0.099	0.065	0.101	0.073	0.109
0.094	0.096	0	0	0.068	0.074	0.092	0	0.084	0	0.096
0.104	0.066	0.098	0.076	0.08	0.083	0.099	0	0.09	0.074	0.11
0	0.096	0.078	0	0.069	0.075	0.09	0.072	0.085	0.065	0.103
0.097	0.093	0	0	0.065	0.076	0.066	0	0.066	0	0.087
0.083	0.095	0.09	0.065	0	0	0.065	0	0	0	0.072

CE6	CE5
0.075	0.073
0	0
0	0
0	0
0	0
0	0.082
0.072	0
0	0
0	0
0.064	0
0	0
0	0
0	0
0	0
0	0
0	0
0	0
0	0
0.076	0
0	0
0	0
0	0

Appendix X

Rating suppliers document

Suppling item:

Supplier #1						
Criteria	Cause /Effect	Very Low Dissatisfactory	Dissatisfactory	Neutral	High Satisfactory	Very High Satisfactory
Cost	Effect					
Quality	Effect					
Delivery time and services	Effect					
Flexibility	Effect					
Financial Stability	Cause					
Environmental Management System	Cause					
Green Design	Effect					
Green Transportation	Effect					
Green Technology	Cause					
GHG Emissions	Cause					
Carbon Disclosure and report	Effect					
Training related carbon management	Cause					
Workers' rights	Effect					
Occupational Health & Safety	Cause					
Society's rights/Social responsibilities	Effect					
Information Disclosure	Cause					
Eco-friendly raw materials	Effect					
Respecting environmental standards and regulations in the process of recycling	Cause					
Air pollution resulting from recycling process	Cause					
Clean technology for recycling	Cause					
Eco-friendly packaging	Effect					
Reverse Logistics agreement	Effect					

Appendix XI

Decision matrix results FUZZY-TOPSIS (Company A)

	Supplier 1	Supplier 2	Supplier 3
EC1	(3.000,5.000,7.000)	(5.000,7.000,9.000)	(7.000,9.000,9.000)
EC2	(7.000,9.000,9.000)	(5.000,7.000,9.000)	(5.000,7.000,9.000)
EC3	(5.000,7.000,9.000)	(5.000,7.000,9.000)	(3.000,5.000,7.000)
EC4	(5.000,7.000,9.000)	(7.000,9.000,9.000)	(5.000,7.000,9.000)
EC5	(7.000,9.000,9.000)	(7.000,9.000,9.000)	(7.000,9.000,9.000)
ENV1	(5.000,7.000,9.000)	(5.000,7.000,9.000)	(3.000,5.000,7.000)
ENV2	(3.000,5.000,7.000)	(3.000,5.000,7.000)	(3.000,5.000,7.000)
ENV3	(1.000,1.000,3.000)	(1.000,1.000,3.000)	(1.000,1.000,3.000)
ENV4	(5.000,7.000,9.000)	(3.000,5.000,7.000)	(3.000,5.000,7.000)
ENV5	(7.000,9.000,9.000)	(5.000,7.000,9.000)	(3.000,5.000,7.000)
ENV6	(3.000,5.000,7.000)	(3.000,5.000,7.000)	(3.000,5.000,7.000)
SO1	(3.000,5.000,7.000)	(1.000,3.000,5.000)	(1.000,3.000,5.000)
SO2	(5.000,7.000,9.000)	(5.000,7.000,9.000)	(3.000,5.000,7.000)
SO3	(7.000,9.000,9.000)	(5.000,7.000,9.000)	(5.000,7.000,9.000)
SO4	(5.000,7.000,9.000)	(3.000,5.000,7.000)	(1.000,3.000,5.000)
SO5	(7.000,9.000,9.000)	(5.000,7.000,9.000)	(5.000,7.000,9.000)
CR1	(5.000,7.000,9.000)	(3.000,5.000,7.000)	(5.000,7.000,9.000)
CR2	(5.000,7.000,9.000)	(3.000,5.000,7.000)	(3.000,5.000,7.000)
CR3	(5.000,7.000,9.000)	(3.000,5.000,7.000)	(3.000,5.000,7.000)
CR4	(3.000,5.000,7.000)	(3.000,5.000,7.000)	(3.000,5.000,7.000)
CR5	(3.000,5.000,7.000)	(1.000,3.000,5.000)	(3.000,5.000,7.000)
CR6	(3.000,5.000,7.000)	(1.000,3.000,5.000)	(1.000,3.000,5.000)

Appendix XII

Normalised Decision Matrix FTOBSIS (Company A)

	Supplier 1	Supplier 2	Supplier 3
EC1	(0.333,0.556,0.778)	(0.556,0.778,1.000)	(0.778,1.000,1.000)
EC2	(0.778,1.000,1.000)	(0.556,0.778,1.000)	(0.556,0.778,1.000)
EC3	(0.556,0.778,1.000)	(0.556,0.778,1.000)	(0.333,0.556,0.778)
EC4	(0.556,0.778,1.000)	(0.778,1.000,1.000)	(0.556,0.778,1.000)
EC5	(0.778,1.000,1.000)	(0.778,1.000,1.000)	(0.778,1.000,1.000)
ENV1	(0.556,0.778,1.000)	(0.556,0.778,1.000)	(0.333,0.556,0.778)
ENV2	(0.429,0.714,1.000)	(0.429,0.714,1.000)	(0.429,0.714,1.000)
ENV3	(0.333,0.333,1.000)	(0.333,0.333,1.000)	(0.333,0.333,1.000)
ENV4	(0.556,0.778,1.000)	(0.333,0.556,0.778)	(0.333,0.556,0.778)
ENV5	(0.778,1.000,1.000)	(0.556,0.778,1.000)	(0.333,0.556,0.778)
ENV6	(0.429,0.714,1.000)	(0.429,0.714,1.000)	(0.429,0.714,1.000)
SO1	(0.429,0.714,1.000)	(0.143,0.429,0.714)	(0.143,0.429,0.714)
SO2	(0.556,0.778,1.000)	(0.556,0.778,1.000)	(0.333,0.556,0.778)
SO3	(0.778,1.000,1.000)	(0.556,0.778,1.000)	(0.556,0.778,1.000)
SO4	(0.556,0.778,1.000)	(0.333,0.556,0.778)	(0.111,0.333,0.556)
SO5	(0.778,1.000,1.000)	(0.556,0.778,1.000)	(0.556,0.778,1.000)
CR1	(0.556,0.778,1.000)	(0.333,0.556,0.778)	(0.556,0.778,1.000)
CR2	(0.556,0.778,1.000)	(0.333,0.556,0.778)	(0.333,0.556,0.778)
CR3	(0.556,0.778,1.000)	(0.333,0.556,0.778)	(0.333,0.556,0.778)
CR4	(0.429,0.714,1.000)	(0.429,0.714,1.000)	(0.429,0.714,1.000)
CR5	(0.429,0.714,1.000)	(0.143,0.429,0.714)	(0.429,0.714,1.000)
CR6	(0.429,0.714,1.000)	(0.143,0.429,0.714)	(0.143,0.429,0.714)

Appendix XIII

Weighted normalized decision matrix FUZZY-TOPSIS (Company A)

	Supplier 1	Supplier 2	Supplier 3
EC1	(0.001,0.007,0.052)	(0.002,0.009,0.067)	(0.002,0.012,0.067)
EC2	(0.011,0.046,0.133)	(0.008,0.036,0.133)	(0.008,0.036,0.133)
EC3	(0.002,0.009,0.054)	(0.002,0.009,0.054)	(0.001,0.006,0.042)
EC4	(0.002,0.006,0.043)	(0.002,0.008,0.043)	(0.002,0.006,0.043)
EC5	(0.001,0.003,0.048)	(0.001,0.003,0.048)	(0.001,0.003,0.048)
ENV1	(0.016,0.058,0.159)	(0.016,0.058,0.159)	(0.009,0.041,0.124)
ENV2	(0.008,0.037,0.130)	(0.008,0.037,0.130)	(0.008,0.037,0.130)
ENV3	(0.002,0.007,0.076)	(0.002,0.007,0.076)	(0.002,0.007,0.076)
ENV4	(0.004,0.019,0.089)	(0.002,0.013,0.069)	(0.002,0.013,0.069)
ENV5	(0.018,0.062,0.142)	(0.013,0.048,0.142)	(0.008,0.034,0.110)
ENV6	(0.004,0.021,0.098)	(0.004,0.021,0.098)	(0.004,0.021,0.098)
SO1	(0.005,0.025,0.104)	(0.002,0.015,0.074)	(0.002,0.015,0.074)
SO2	(0.002,0.013,0.069)	(0.002,0.013,0.069)	(0.001,0.009,0.054)
SO3	(0.012,0.047,0.122)	(0.009,0.037,0.122)	(0.009,0.037,0.122)
SO4	(0.007,0.032,0.121)	(0.004,0.023,0.094)	(0.001,0.014,0.067)
SO5	(0.005,0.025,0.091)	(0.004,0.019,0.091)	(0.004,0.019,0.091)
CR1	(0.007,0.030,0.106)	(0.004,0.021,0.082)	(0.007,0.030,0.106)
CR2	(0.007,0.029,0.108)	(0.004,0.021,0.084)	(0.004,0.021,0.084)
CR3	(0.010,0.042,0.143)	(0.006,0.030,0.111)	(0.006,0.030,0.111)
CR4	(0.006,0.033,0.125)	(0.006,0.033,0.125)	(0.006,0.033,0.125)
CR5	(0.002,0.013,0.075)	(0.001,0.008,0.054)	(0.002,0.013,0.075)
CR6	(0.003,0.018,0.089)	(0.001,0.011,0.064)	(0.001,0.011,0.064)

Appendix XIV

Decision matrix results FUZZY-TOPSIS (Company B)

EC1
EC2
EC3
EC4
EC5
ENV1
ENV2
ENV3
ENV4
ENV5
ENV6
SO1
SO2
SO3
SO4
SO5
CR1
CR2
CR3
CR4
CR5
CR6

Supplier 2	Supplier 1
(3.000,5.000,7.000)	(7.000,9.000,9.000)
(7.000,9.000,9.000)	(7.000,9.000,9.000)
(7.000,9.000,9.000)	(5.000,7.000,9.000)
(5.000,7.000,9.000)	(5.000,7.000,9.000)
(7.000,9.000,9.000)	(7.000,9.000,9.000)
(7.000,9.000,9.000)	(5.000,7.000,9.000)
(5.000,7.000,9.000)	(5.000,7.000,9.000)
(1.000,3.000,5.000)	(1.000,3.000,5.000)
(5.000,7.000,9.000)	(3.000,5.000,7.000)
(7.000,9.000,9.000)	(3.000,5.000,7.000)
(5.000,7.000,9.000)	(1.000,3.000,5.000)
(5.000,7.000,9.000)	(3.000,5.000,7.000)
(5.000,7.000,9.000)	(5.000,7.000,9.000)
(7.000,9.000,9.000)	(5.000,7.000,9.000)
(5.000,7.000,9.000)	(3.000,5.000,7.000)
(5.000,7.000,9.000)	(5.000,7.000,9.000)
(7.000,9.000,9.000)	(3.000,5.000,7.000)
(5.000,7.000,9.000)	(3.000,5.000,7.000)
(5.000,7.000,9.000)	(3.000,5.000,7.000)
(5.000,7.000,9.000)	(3.000,5.000,7.000)
(5.000,7.000,9.000)	(5.000,7.000,9.000)
(3.000,5.000,7.000)	(3.000,5.000,7.000)

Appendix XV

Normalised Decision Matrix FTOBSIS (Company A)

EC1
EC2
EC3
EC4
EC5
ENV1
ENV2
ENV3
ENV4
ENV5
ENV6
SO1
SO2
SO3
SO4
SO5
CR1
CR2
CR3
CR4
CR5
CR6

Supplier 1	Supplier 2
(0.778,1.000,1.000)	(0.333,0.556,0.778)
(0.778,1.000,1.000)	(0.778,1.000,1.000)
(0.556,0.778,1.000)	(0.778,1.000,1.000)
(0.556,0.778,1.000)	(0.556,0.778,1.000)
(0.778,1.000,1.000)	(0.778,1.000,1.000)
(0.556,0.778,1.000)	(0.778,1.000,1.000)
(0.556,0.778,1.000)	(0.556,0.778,1.000)
(0.200,0.600,1.000)	(0.200,0.600,1.000)
(0.333,0.556,0.778)	(0.556,0.778,1.000)
(0.333,0.556,0.778)	(0.778,1.000,1.000)
(0.111,0.333,0.556)	(0.556,0.778,1.000)
(0.333,0.556,0.778)	(0.556,0.778,1.000)
(0.556,0.778,1.000)	(0.556,0.778,1.000)
(0.556,0.778,1.000)	(0.778,1.000,1.000)
(0.333,0.556,0.778)	(0.556,0.778,1.000)
(0.556,0.778,1.000)	(0.556,0.778,1.000)
(0.333,0.556,0.778)	(0.778,1.000,1.000)
(0.333,0.556,0.778)	(0.556,0.778,1.000)
(0.333,0.556,0.778)	(0.556,0.778,1.000)
(0.333,0.556,0.778)	(0.556,0.778,1.000)
(0.556,0.778,1.000)	(0.556,0.778,1.000)
(0.429,0.714,1.000)	(0.429,0.714,1.000)

Appendix XVI

Weighted normalized decision matrix FUZZY-TOPSIS (Company A)

Supplier 2	Supplier 1	
(0.001,0.007,0.052)	(0.002,0.012,0.067)	EC1
(0.011,0.046,0.133)	(0.011,0.046,0.133)	EC2
(0.003,0.011,0.054)	(0.002,0.009,0.054)	EC3
(0.002,0.006,0.043)	(0.002,0.006,0.043)	EC4
(0.001,0.003,0.048)	(0.001,0.003,0.048)	EC5
(0.022,0.074,0.159)	(0.016,0.058,0.159)	ENV1
(0.010,0.040,0.130)	(0.010,0.040,0.130)	ENV2
(0.001,0.012,0.076)	(0.001,0.012,0.076)	ENV3
(0.004,0.019,0.089)	(0.002,0.013,0.069)	ENV4
(0.018,0.062,0.142)	(0.008,0.034,0.110)	ENV5
(0.005,0.023,0.098)	(0.001,0.010,0.054)	ENV6
(0.006,0.027,0.104)	(0.004,0.019,0.081)	SO1
(0.002,0.013,0.069)	(0.002,0.013,0.069)	SO2
(0.012,0.047,0.122)	(0.009,0.037,0.122)	SO3
(0.007,0.032,0.121)	(0.004,0.023,0.094)	SO4
(0.004,0.019,0.091)	(0.004,0.019,0.091)	SO5
(0.010,0.038,0.106)	(0.004,0.021,0.082)	CR1
(0.007,0.029,0.108)	(0.004,0.021,0.084)	CR2
(0.010,0.042,0.143)	(0.006,0.030,0.111)	CR3
(0.008,0.036,0.125)	(0.005,0.026,0.097)	CR4
(0.003,0.014,0.075)	(0.003,0.014,0.075)	CR5
(0.003,0.018,0.089)	(0.003,0.018,0.089)	CR6

Appendix XVII

Feedback questionnaire about model implementation

Dear expert,

First of all, I want to thank you for your cooperation and the time you wasted for implementing the supplier selection model at your company. Your engagement is highly appreciated. This questionnaire aims to determine your satisfaction about using the model.

The questionnaire is divided into two sections:

- *Section 1* measures your satisfaction level regarding the proposed approach through five questions that can be measured by quantitative approach (7 points Likert Scale).
- *Section 2* asks about the limitations of the approach, and recommendations for improving the proposed approach.

Section 1: Degree of satisfaction:

Please tick under your preferred answer:

Question 1: All the criteria of the model are clear.							
Level	Extremely Unsatisfied	Very Unsatisfied	Unsatisfied	Neutral	Satisfied	Very Satisfied	Extremely Satisfied
Results							
Question 2: The model provides strong structure for measuring the sustainable circular practices of the suppliers.							
Level	Extremely Unsatisfied	Very Unsatisfied	Unsatisfied	Neutral	Satisfied	Very Satisfied	Extremely Satisfied
Results							
Question 3: The model generates reliable results.							
Level	Extremely Unsatisfied	Very Unsatisfied	Unsatisfied	Neutral	Satisfied	Very Satisfied	Extremely Satisfied
Results							
Question 4: The suppliers' rating sheet is easy and understandable.							
Level	Extremely Unsatisfied	Very Unsatisfied	Unsatisfied	Neutral	Satisfied	Very Satisfied	Extremely Satisfied
Results							
Question 5: The time consumed for implementing the model							
Level	Extremely Unsatisfied	Very Unsatisfied	Unsatisfied	Neutral	Satisfied	Very Satisfied	Extremely Satisfied
Results							

Section 2: Please answer the following questions:

1- What are the limitations/challenges that occurred while implementing the model? How to overcome these limitations?
2- What could be the action plan for executing the proposed model, which is the sustainable supplier selection model, instead of the current supplier selection process?
3- What does your company need to increase the knowledge of its employees about the proposed model?
4- To what extent do you expect the proposed SCSS Model will improve the current procurement practice?

Thank you for your cooperation.

Appendix XVIII

Action plan estimation duration

Dear Expert,

According to your responses in the questionnaire feedback, the researcher concluded these actions, which were common between your responses and other participants' responses of another company case study which has been implemented the proposed model also. Hence, determine the tasks needed to replace your current supplier selection methods by the proposed model of the research.

So please indicate how long each task of the action plan for approving the proposed sustainable supplier selection model at your company.

1- Establishing a proposal for identifying the proposed SCSS Model and its importance towards the company's sustainability performance.
   Expected Duration:
2- Submitting the proposal to the Top Management and getting the approval.
   Expected Duration:
3- Employee awareness about sustainable circular procurement practices.
   Expected Duration:
4- Employee training for sustainable circular procurement for decision makers and their teams
   Expected Duration:
5- Amend the related procurement documents.
   Expected Duration:
6- Share the procurement policy with the key suppliers
   Expected Duration:
7- Provide guideline criteria for tenders
   Expected Duration:

Thank you for your cooperation.