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Development of sustainable and circular criteria in supplier selection

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ABSTRACT

Sustainability and circular economy are becoming leading concepts in the context of contemporary industrialization due to global warming, economic implication, and social consciousness. This has encouraged the implementation of sustainable circular supply chain management (SCSCM). Supplier Selection, as it is known, plays the foremost basic part within the circle of the supply chain under the organization's position. Therefore, this study proposed a sustainable circular supplier selection model using Fuzzy-Decision Making Trial and Evaluation Laboratory (FDEMATEL) technique to support SCSCM. FDEMATEL was used to determine the interrelationships between the criteria. In this regard, 22 criteria were identified under 4 dimensions (Economic, Environment, Social and Circular), and evaluated by 20 experts using pairwise comparison. The results indicate that the criteria (Environmental Management System) is the most important. While (Financial Stability) and (Green Technology) are the most influential criteria over the other criteria, however (Cost) is mostly influenced by other factors. Moreover, limitations of the study and recommendation for further work highlighted

Keywords: Sustainability, Circular Economy, and Supplier Selection.

1. INTRODUCTION

Recently, the importance of sustainable supply chain management (SSCM) has increased due to the global population growth, resource controls, consumption activities, and the increasing levels of waste and pollution(Tseng *et al.*, 2022). Accordingly, especially with the competitive global market, most of the business organizations need their supply chains to be more sustainable in the direction of the economic, environment, and social aspect (Gaziulusoy and Brezet, 2015; Ottomano Palmisano *et al.*, 2016; Nosratabadi *et al.*, 2019). The world, at its current level of utilization, will exhaust many 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). Nevertheless, global forms of production, consumption, and trade still remain severely unsustainable (Farooque *et al.*, 2019). Hence, to tackle these issues, one important philosophy that may bring about this change which is shifting towards more sustainable mode of production in the supply chain (SC) by following the concept of circular economy (CE) (Lahane *et al.*, 2020). As a result, an increasing awareness has encouraged the incorporation of sustainability and CE thinking in SC paradigms (Chain and Zanin, 2019; Pieroniet *al.,* 2019).

The CE philosophy is developing into a powerful driving force behind sustainability and it has started to be distinguished as a great potential to assist organizations to accomplish a breakthrough in sustainability execution (Lahane *et al.*, 2020). Accordingly, sustainability advances have empowered business firms to implement CE practices in a more efficient way

(Awan, 2022). Despite that the CE eliminates precious material from waste stream by highlighting product reuse and repair and forming restorative industrial systems (Ruggieri *et al.*, 2016), these actions offer advantages for the firms' supply chains in terms of sustainability and improve the firms' sustainable performance (Govindan *et al.*, 2020; Khan *et al.*, 2021). Consequently, CE is expected to be beneficial for achieving the sustainable development goals (SDGs) such as SDG 12 "sustainable production and consumption patterns" (Dantas *et al.*, 2021). Hence, an increasing awareness has encouraged the incorporation of sustainability and CE thinking in supply chain paradigms (Chain and Zanin, 2019; Pieroniet *al.,* 2019).Therefore, recently, gathering the CE and sustainability is becoming progressively more and gaining more attention from practitioners and academics (Nikolaou and Tsagarakis, 2021).

As it is known that suppliers are at the first level of the supply chain network, their actions have an essential effect on the efficacy of the entire network (Mani *et al.,* 2018). Consequently, selecting the right suppliers improves the firms' sustainability and circularity performance, as they can diminish environmental destruction and costs and lead to circularity of used materials (Yu *et al.*, 2019; Govindan *et al.*, 2020; Hendiani *et al.*, 2020). In this context, a new perspective of supplier selection problem had been recently appeared, which is sustainable circular supplier selection (Kannan *et al.*, 2020a).

To select the proper supplier, different criteria have to be considered and evaluated with regard to the supplier's attribute (Khan *et al.*, 2018). Consequently, the supplier selection is considered as a multicriteria decision making (MCDM) problem (Memari *et al.*, 2019). Although that there are numerous MCDM methods have been conducted in sustainable supplier selection such as 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), there is a few studies had been conducted for MCDM methods in the context of SCSS (Kannan *et al.*, 2020b; Alavi, Tavana and Mina, 2021).

In this viewpoint, this study introduces for the first time, a structural model of criteria for sustainable circular supplier selection including the four dimensions (economic, environmental, social, and circular) through the well-known MCDM method, Fuzzy- Decision-Making Trial and Evaluation Laboratory (FDEMATEL). The FDEMATEL method is used in this study for analyzing the interdependencies between the criteria.

The remainder of the paper is arranged as follows: **Section 2** discusses the literature in relation to three main topics including (1) Sustainable Supply Chain Management and CE are presented, (2) Approaches and methods of supplier selection regarding sustainability and CE, (3) Criteria for supplier selection. **Section 3** explains the research methodology including data collection. **Section 4** presents main findings of the FDEMATEL. **Section 5** concludes this paper together with future research direction and the research limitation.

2. LITERATURE REVIEW

A significant number of research studies been conducted on supplier selection problem with various criteria and methods. In this section, based on the research purpose, only the criteria and approaches/methods used in selecting suppliers from a sustainable and CE perspectives are reviewed. The reviewed papers are classified into three categories depending on their focus: (1) SSS methods, (2) SSS in the context of CE, and (3) Addressing the SSS criteria comprising CE criteria.

- **Sustainable Supplier Selection (SSS) methods**

Supplier selection problem is a critical and strategic decision-making process. Selecting suppliers became more intensified and complex in the context of sustainability which fundamentally increases the number of selection criteria and the trade-offs between sustainability-related criteria (e.g. environmental considerations) and others such as cost of the product, quality of products, delivery lead-time, flexibility , etc. (Trapp and Sarkis, 2016; Khan *et al.*, 2018). This imposes a major challenge on purchasing managers when evaluating and selecting suppliers given the impact of sustainability (Amindoust *et al.*, 2012). Moreover, supplier evaluation towards sustainability aspects helps organizations in achieving other benefits such as; improved financial performance, fairness to the suppliers and customers, positive corporate reputation, social change, good human relations, and inter-organizational learning (Baskaran, Nachiappan and Rahman, 2012).

Therefore, a considerable number of studies had been conducted on the supplier selection problems with numerous evaluated criteria and methods related to the sustainability concept. Ghadimi and Heavey (2014) gathered the most important criteria of SSS in medical device industry and categorized it to the three dimensions of sustainability using an efficient Fuzzy Inference System (FIS). Additionally, Mani, Agrawal and Sharma (2014) presented a methodology that focused on socially SSS through social parameters using analytic hierarchy process (AHP) technique. Azadi *et al.* (2015) developed an integrated DEA enhanced Russell measure (ERM) model in fuzzy context to select the best sustainable suppliers. Another research done by Orji and Wei (2015) presented a novel modeling approach of integrating information on supplier behavior in fuzzy environment with system dynamics simulation modeling technique which results in a more reliable and responsible decision support system. Also, Lin *et al.* (2015) applied analytic network process (ANP) in supplier selection problem at Taiwanese Electronics Company under sustainability. Likewise, Gold and Awasthi (2015) proposed a two-step fuzzy AHP approach for sustainable global supplier selection problem that considers sustainability risks from sub-suppliers.

More work done by Sarkis and Dhavale (2015) recognized 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. Moreover, Su *et al.* (2016) proposed a hierarchical grey decision-making trial and evaluation laboratory method to identify and analyze criteria and alternatives in incomplete information in sustainable supply chain management context. Luthra *et al.* (2017) proposed a framework to evaluate by using an integrated Analytical Hierarchy Process (AHP), ViseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), a multi-criteria optimization and compromise solution approach with 22 SSS criteria and three dimensions of criteria (economic, environmental, and social) have been identified through literature and experts' opinions, although that this study very close to the research novelty, it wasn't engage to the carbon management criteria in its framework as well. Song, Xu and Liu (2017) summarized the SSS criteria drawing the greatest attention in previous literature, they did a novel integrated method based on pairwise comparison method, DEMATEL, and rough set theory has been proposed. Vahidi, Torabi and Ramezankhani (2018) proposed a novel bi-objective two-stage mixed possibilistic-stochastic programming model to address SSS and order allocation problem under operational and disruption risks.

2.1.1 Sustainable Supplier Selection (SSS) methods in the context of Circular Economy (CE)

Implementing CE in supply chains enforces suppliers to provide raw materials that are technically restorative, recoverable, and would not have negative effects on the environment (Genovese *et al.*, 2017). Hence, circular supplier selection can have substantial effect on the waste reduction of the supply chains (Kannan *et al.*, 2020a).

To-date, to the best authors' knowledge, there are few previous studies that addressed the context of circular economy in supplier selection process. Kusi-Sarpong *et al.* (2019) proposed a decision framework based on industry 4.0 initiatives within circular economy implementation to evaluate and select sustainable suppliers. They used a multi-criteria decision-making support tool composed of the 'best-worst method' (BWM) and VIKOR was applied to aid in the evaluation and selection of a sustainable supplier in Pakistan's textile manufacturing company. Regarding the criteria of selecting suppliers, they categorized the criteria into 4 main categories with 17 sub-categories. The four main categories were Organizational, Regulatory, and Institutional, Technological, and Infrastructural, and Supply Chain collaboration. It was also expected that the criteria presented by them would be considered in the three categories of economic, social, and environmental/circular criteria, but this was not the case (Kannan *et al.*, 2020b). Moreover, Govindan *et al.* (2020) proposed a strategic operational level hybrid approach based on Fuzzy-DEMATEL, FANP, and mathematical programming for circular supplier evaluation, selection and order allocation. They categorized their main criteria for 3 criteria; (1) Circular, (2) Quality, and (On time deliver) with 13 sub-criteria. However, they did a valuable approach in weighting criteria and selecting suppliers, they did not consider all the sustainability dimensions in their work with its main criteria. Furthermore, Kannan *et al.* (2020) combined the fuzzy BWM and the interval VIKOR technique to evaluate and prioritize sustainable suppliers in circular supply chains. The evaluation criteria were classified into three categories of economic, social, and circular factors. Even Though they have used a proper evaluation approach based on two useful methods, they developed only the criteria related to the Economic and Social dimensions and ignored any other Environmental criteria in their approach rather than circular economy ones. This affected the achievement of the full viewpoint of sustainability in the context of circular economy.

2.2.3 Sustainable Circular Supplier Selection (SCSS) Criteria:

As mentioned earlier, some authors addressed the criteria under sustainability concept, and circular economy. According to the research objectives, by considering previous literatures, criteria are classified into four main dimensions; Economic, Environmental, Social, and CE to achieve the full view of evaluating and selecting suppliers' performance towards sustainable circular, as shown in **Table 1.**

Table 1. Sustainable Circular Supplier Selection Criteria

ECONOMIC	
Cost	The factors that show all expenditures and price of purchased material (Fallahpour, 2016).
	(Bai and Sarkis, 2010; Büyüközkan and Çifçi, 2011; Amindoust et al., 2012; Dai and Blackhurst, 2012; Govindan, Khodaverdi and Jafarian, 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, 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)
Quality	The degree of excellence of supplied material (Fallahpour, 2016).
	(Bai and Sarkis, 2010; Büyüközkan and Çifçi, 2011; Amindoust et al., 2012; Dai and Blackhurst, 2012; Govindan, Khodaverdi and Jafarian, 2013; Azadnia 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, Xu and Liu, 2017; Fallahpour et al., 2017; Awasthi, Govindan and Gold, 2018; Cheraghalipour and Farsad, 2018; Alikhani, Torabi and Altay, 2019; Memari et al., 2019; El Mariouli and Abouabdellah, 2019)
Delivery time and services	The effort of supplier in delivering the material and solving its related problems to the customer (Fallahpour, 2016).
	(Bai and Sarkis, 2010; Büyüközkan and Çifçi, 2011; Amindoust et al., 2012; Dai and Blackhurst, 2012; Govindan, Khodaverdi and Jafarian, 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, Govindan and Gold, 2018; Vahidi, Torabi and Ramezankhani, 2018; Cheraghalipour and Farsad, 2018; El Mariouli and Abouabdellah, 2019)
Flexibility	The level of flexibility of supplier in supplying material and price of material (Fallahpour, 2016).
	(Bai and Sarkis, 2010; Büyüközkan and Çifçi, 2011; Amindoust *et al.*, 2012; 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 based on the information about the annual turn-over of the supplier and their financial structure based on the past history (Chan *et al.*, 2008).
	(Amindoust *et al.*, 2012; Alidrisi, 2014; Suraraksa and Shin, 2019)
ENVIRONMENTAL	
Environmental Management System (ISO 14001)	Efforts of supplier in environmental management and the certification related environmental management systems (Fallahpour, 2016).
	(Bai and Sarkis, 2010; Amindoust et al., 2012; Govindan, Khodaverdi and Jafarian, 2013; Orji and Wei, 2015; Sarkis and Dhavale, 2015; Su et al., 2016; Fallahpour et al., 2017; Luthra et al., 2017; Song, Xu and Liu, 2017; Vahidi, Torabi and Ramezankhani, 2018; Cheraghalipour and Farsad, 2018; Alikhani, Torabi and Altay, 2019)
Green Products/Design	To what extend the supplier produce green products (Fallahpour, 2016)
	(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	Minimizing the environmental pollution when transporting the needed order (Fallahpour, 2016)
	(Fallahpour et al., 2017)
Green technology	The technology used to provide producing green products.(Fallahpour, 2016)
	(Fallahpour et al., 2017)(Vahidi, Torabi and Ramezankhani, 2018)
GHG emissions/effect	Gases and substances emitted from the manufacture and transport the products. (El Mariouli and Abouabdellah, 2019)
	Gold, 2018; Cheraghalipour and Farsad, 2018; El Mariouli and Abouabdellah, 2019)
Carbon Disclosure Report	Reports regarding GHG emissions. (Hsu et al., 2013)
	(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)
	(Hsu *et al.*, 2013)
Workers' rights	The supplier's respect of its worker's rights; employment insurance, standard working hours, employments compensations (Fallahpour, 2016).
	(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	Efforts of supplier to provide health and safety for employees at work; medical insurance, training for safety at work, providing appropriate equipment. (Fallahpour, 2016)
	(Bai and Sarkis, 2010; Amindoust *et al.*, 2012; Dai and Blackhurst, 2012; Azadnia *et al.*, 2013; Govindan, Khodaverdi and Jafarian, 2013; Mani, Agrawal and Sharma, 2014; Ghadimi and Heavey, 2014; Orji and Wei, 2015; Gold and Awasthi, 2015; Luthra *et al.*, 2017; Song, Xu and Liu, 2017;

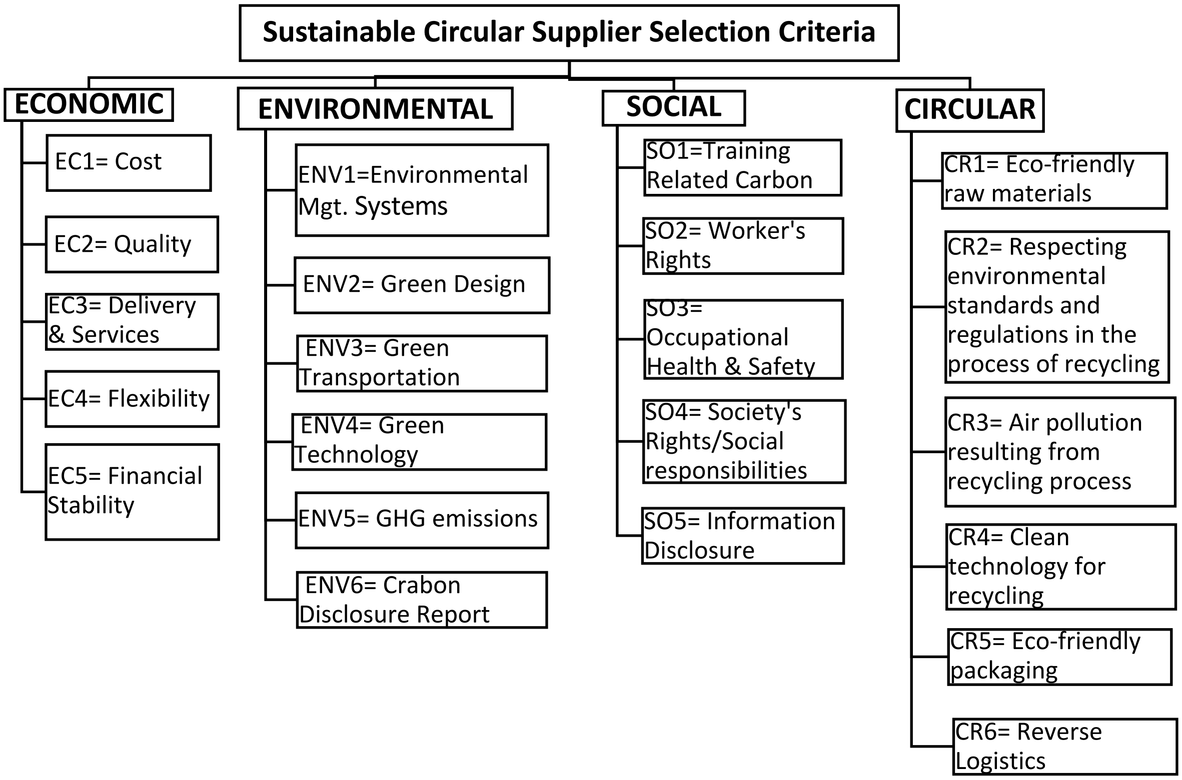
	Fallahpour *et al.*, 2017; Vahidi, Torabi and Ramezankhani, 2018; Cheraghalipour and Farsad, 2018; Memari *et al.*, 2019; El Mariouli and Abouabdellah, 2019)
Society's rights / social responsibilities	Suppliers' competency in improving sustainability, such as; social responsibilities, cleaner environmental/production (Büyüközkan and Çifçi, 2011)
	(Büyüközkan and Çifçi, 2011)(Sarkis and Dhavale, 2015)(Gold and Awasthi, 2015)(Luthra et al., 2017)(Vahidi, Torabi and Ramezankhani, 2018)(Alikhani, Torabi and Altay, 2019)(Cheraghalipour and Farsad, 2018)
Information disclosure	Providing information to the supplier's customer and stakeholders regarding material used, carbon emissions and toxins released during production. (Luthra et al., 2017)
	(Amindoust *et al.*, 2012; Azadnia *et al.*, 2013; Orji and Wei, 2015; Luthra *et al.*, 2017; Yu *et al.*, 2019)
CIRCULAR	
Eco-friendly raw materials	Utilizing recyclable raw materials in producing products (Govindan *et al.*, 2020).
	(Gupta and Barua, 2017; Govindan *et al.*, 2020; Kannan *et al.*, 2020b)
Respecting environmental standards and regulations in the process of recycling	Utilization of the environmental standards in recycling process (Govindan *et al.*, 2020).
	(Rashidi and Saen, 2018; Govindan *et al.*, 2020; Kannan *et al.*, 2020b)
Air pollution resulting from recycling process	Consideration of minimizing air pollution in the operation of recycling the products (Govindan *et al.*, 2020).
	(Rashidi and Saen, 2018; dos Santos, Godoy and Campos, 2019; Govindan *et al.*, 2020; Kannan *et al.*, 2020b)
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.*, 2020b)
Eco-friendly packaging	Using recyclable materials in packaging (Govindan *et al.*, 2020).
	(Govindan *et al.*, 2020; Kannan *et al.*, 2020b)
Reverse Logistics	(Amindoust *et al.*, 2012; Hashemkhani Zolfani, Chatterjee and Yazdani, 2019)

To this end, many authors revealed that selecting the right suppliers affects the firms' sustainability and circularity performance, as they can diminish environmental destruction and costs and lead to circularity of used materials (Yu *et al.*, 2019; Govindan *et al.*, 2020; Hendiani *et al.*, 2020). Moreover, sustainable circular supplier selection will increase the sustainability of the supply chains in addition to waste reduction. Therefore, this study developed a structural model of criteria for sustainable circular supplier selection including the four dimensions (economic, environmental, social, and circular) based on FDEMATEL.

3. RESEARCH METHODOLOGY

As stated before, supplier selection process is multi-criteria evaluation which requires decision makers to provide both quantitative and qualitative evaluations to identify the value of each alternative (supplier) with respect to each criteria, as well as the relative importance of the criteria. Hence, to achieve the purpose of this study, a FDEMATEL technique used to discover the interactives relationships between the proposed sustainable circular supplier selection criteria as shown in Fig. 1, which had been conducted from previous literatures as shown in Table 1 along to their description. The methodology of the FDEMATEL is clarified in the next section.

Fig. (1). Sustainable Circular Supplier Selection Criteria



Fuzzy Decision-Making Trial and Evaluation Laboratory (FDEMATEL)

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) technique introduced in 1973 by the Geneva Research Centre of the Battelle Memorial Institute to visualize 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 as a kind of structural modeling approach, is valuable in analyzing the cause and effect relationships among components of a framework (Si et al., 2018). The advantage of DEMATEL over other MCDM techniques (such as AHP) that it uses structural modelling technique to identify the interdependency among factors through a causal diagram using graphs or matrices which portray the relationships and the strengths of influence between criteria (Wu and Tsai, 2012; Su et al., 2016; Seker and Zavadskas, 2017). DEMATEL method not only converts the interdependence relationships among factors into cause-and-effect group using matrices or graphs, but also finds the critical factors of a complex framework using an influence relation diagram (Mirosław-Świątek et al., 2021).

Although that DEMATEL technique is useful tool for analyzing interdependency among factors using crisp value (Suo, Feng and Fan, 2012), in reality the crisp values are not effective and inadequate due to fuzziness and uncertainty that are commonly involved in judgments of experts (Suo, Feng and Fan, 2012). To overcome this problem in this study, it was decided by the authors to extend the DEMATEL method with fuzzy logic for making superior judgments in fuzzy environments. Fuzzy set theory established by Zadeh (1965) and introduced the membership function concept. Fuzzy theory validates vague and unclear problems, along with unreliable human judgments (Mavi and Shahabi, 2015). In this instance, Akyuz and Celik (2015) stated that a triangular fuzzy number is superior in the evaluation, which is the most generally used fuzzy interpretation and can be classified as a triple called a Triangular Fuzzy Number (TFN).

Fuzzy DEMATEL can convert the relationship between the causes and effects of criteria into intelligible structural model of the system (Rouhani *et al*., 2014).This method is employed in different research areas to solve MCDM problems (Mavi and Shahabi, 2015; Muhammad and Cavus, 2017; Seker and Zavadskas, 2017; Govindan *et al.*, 2020).

Therefore, the authors of this study decided to propose their approach through combining fuzzy set theory to deal with the vagueness of human thoughts (experts' opinions) and the DEMATEL method to construct impact relation map and determine cause effect groups of criteria. Hence, the fuzzy logic had been combined with DEMATEL method to determine the most significant criteria and develop the ranking of the most valuable criteria in sustainable circular supplier selection problem. The steps of the FDEMATEL used in this study are clarified as follows:

The steps of FDEMATEL methodology:

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

In this step, a panel of experts in manufacturing industries was provided. In addition, key sustainable circular supplier selection criteria were identified from extensive literature review and finalized as selecting/evaluating criteria.

Step 2: To generate the fuzzy direct-relation matrix

After recognizing the selecting/evaluating criteria, in this step a pair-wise comparison was developed. To obtain pair-wise comparison, a five-point fuzzy linguistics scale (1= No influence, 2= Very low influence, 3= Low influence, 4= High influence, and 5= Very high influence) is designed to assist experts evaluate the interrelationships between criteria, as shown in **Table 2**. Arithmetic mean of all experts' opinions is used to generate the direct relation matrix z.

$$z = \begin{bmatrix} 0 & \cdots & \tilde{z}_{n1} \\ \vdots & \ddots & \vdots \\ \tilde{z}_{1n} & \cdots & 0 \end{bmatrix}$$

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 ($x \leq y \leq z$), respectively

Table 2 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 normalize the fuzzy direct-relation matrix

This step for normalizing the fuzzy direct-relation matrix that 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;

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

Step 4: Calculate the fuzzy total-relation matrix

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

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

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 to clear 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:

$$l^n_{ij} = \frac{\left(l^t_{ij} - \min l^t_{ij}\right)}{\Delta^{max}_{min}}$$
$$m^n_{ij} = \frac{(m^t_{ij} - min\ l^t_{ij})}{\Delta^{max}_{min}}$$
$$u^n_{ij} = \frac{(u^t_{ij} - min\ l^t_{ij})}{\Delta^{max}_{min}}$$

So that

$$\Delta^{max}_{min} = \max u^t_{ij} - \min l^t_{ij}$$

Calculating the upper and lower bounds of normalized values:

$$l_{ij}^{s} = {m_{ij}^{n}}\Big/{(1 + m_{ij}^{n} - l_{ij}^{n})}$$
$$u_{ij}^{s} = {u_{ij}^{n}}\Big/{(1 + u_{ij}^{n} - l_{ij}^{n})}$$

The output of the CFCS algorithm is crisp values.

Calculating the total normalized crisp values:

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

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:

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

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

"D" refers to the overall effects of one criteria (i) on the other criteria (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 this final step, the causal-effect diagram is composed using the values of (D+R) and (D-R), in which (D+R) represents the degree of importance, and (D-R) represents the net effects that the criteria contribute to the sustainable circular supplier selection process. If (D-R) value is positive, that criteria relates to the cause group, and if (D-R) value is negative, the criteria relates to the effect group. The values of (D+R) are placed on the horizontal axis and the values of (D-R) on the vertical axis. A flowchart of the steps involved in the FDEMATEL methodology is shown in **Fig. 2**.

Fig. (2). FDEMATEL flowchart of sustainable circular supplier selection criteria

Using Literature and expert's opinion

Defining expert panel and sustainable circular supplier selection criteria

Using experts' opinion and Triangular Fuzzy Number

Constructing pair-wise comparison matrix (obtaining linguistic judgment based upon fuzzy linguistic scale to develop relation matrix)

Obtaining the fuzzy direct relation matrix

Obtaining the normalized fuzzy direct relation matrix

Constructing the fuzzy total relation matrix

Converting the fuzzy numbers into crisp values

Calculating the sum of rows (D) and the sum columns (R)

Create a causal-effect diagram by mapping the dataset of (D+R) and (D-R), and developing managerial implications

4. CALCULATIONS AND RESULTS

The application of the above research method is shown in this section; other points of interest are given further.

Step 1: A panel of experts consisting of 20 experts was performed to define the purpose of this study, to analyze the sustainable circular supplier selection criteria. The selection of the experts was chosen based on their experience (a minimum eight years' experience) and their expertise in their area (individual profile). The experts were highly skilled and were capable in decision-making regarding selecting and evaluating suppliers.

Twenty-two criteria as shown in Fig. (1). were proposed according to extensive literature review and were validated by the experts' opinions.

Step 2: Experts made a pair-wise comparisons between the criteria of sustainable circular supplier selection using the scale provided in Table (2), to figure out the interdependencies between the criteria. **APPENDIX I** indicates the direct relation matrix.

Step 3: The normalized fuzzy direct-relation matrix was attained using the formulas explained in the methodology section. **APPENDIX II** indicates the normalized fuzzy direct-relation matrix.

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

Step 5: APPENDIX IV shows the crisp total-relation matrix.

Step 6: The summation of rows (D) and the summation of columns (R) of the sustainable circular supplier selection criteria were calculated by using the formulas determined in **step 5** the methodology part.

Step 7: The dataset (D+R) and (D-R) of the sustainable circular supplier selection criteria were calculated and shown in **Table 3**.

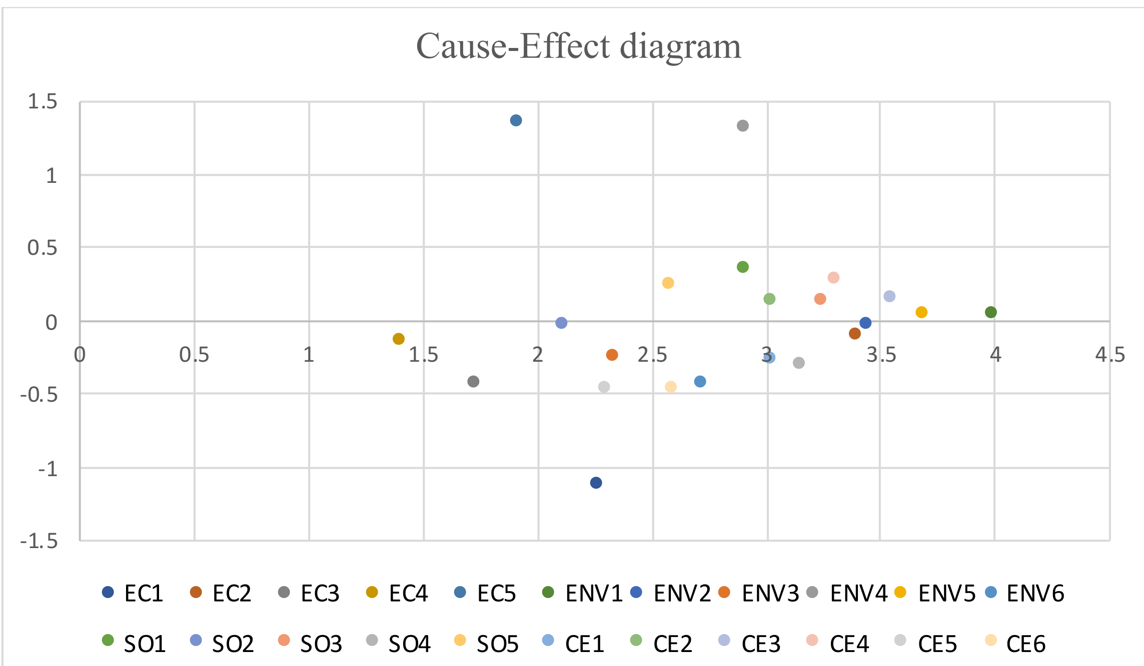
Additionally, ranking the criteria of sustainable circular supplier selection were made based on (D+R) dataset, and were categorized into cause-and-effect groups based on (D-R) dataset (for more details, please see Table 3). In the last step, (D+R) and (D-R) datasets were developed to conclude a causal diagram as shown in **Fig. 3**.

Table 3. Calculations (D+R) and (D-R) datasets of the sustainable circular supplier selection criteria.

Criteria	R	D	D+R	Rank	D-R	Cause/Effect
EC1	1.692	0.57	2.262	18th	-1.121	Effect
EC2	1.749	1.647	3.396	5th	-0.103	Effect
EC3	1.085	0.65	1.734	21st	-0.435	Effect
EC4	0.766	0.634	1.4	22nd	-0.132	Effect
EC5	0.279	1.632	1.911	20th	1.352	Cause
ENV1	1.974	2.013	3.986	1st	0.039	Cause
ENV2	1.738	1.705	3.443	4th	-0.032	Effect
ENV3	1.296	1.045	2.34	16th	-0.251	Effect
ENV4	0.792	2.112	2.905	12th	1.32	Cause
ENV5	1.821	1.87	3.691	2nd	0.049	Cause
ENV6	1.572	1.15	2.721	13th	-0.422	Effect
SO1	1.278	1.632	2.911	11th	0.354	Cause
SO2	1.072	1.045	2.117	19th	-0.028	Effect

SO3	1.56	1.686	3.246	7th	0.126	Cause
SO4	1.73	1.423	3.153	8th	-0.308	Effect
SO5	1.17	1.406	2.576	15th	0.236	Cause
CE1	1.643	1.377	3.02	10th	-0.266	Effect
CE2	1.447	1.576	3.023	9th	0.13	Cause
CE3	1.701	1.848	3.55	3rd	0.147	Cause
CE4	1.511	1.795	3.307	6th	0.284	Cause
CE5	1.387	0.915	2.302	17th	-0.471	Effect
CE6	1.531	1.065	2.596	14th	-0.466	Effect

Fig. 3. The cause-and-effect diagram of the sustainable circular sustainable selection criteria.



Prominence (D+R) represents the importance of the criteria. Likewise, relation (D-R) represents the categorization of the cause-and-effect group. The causal effect diagram delivers useful insight to analyze the evaluated criteria. With respect to different criteria, their position and the relative importance, experts distinguish the criteria which affects the decisions selecting the suitable supplier regarding sustainable circular, and thus, improvements are made appropriately.

5. DISCUSSIONS

According to the values of (D+R) given in **Table 3**, which represents the degree of importance, the importance order of the twenty-two criteria for selecting sustainable circular supplier is given as ENV1- ENV5- CE3- ENV2- EC2- CE4- SO3- SO4- CE2- CE1- SO1- ENV4- ENV6- CE6- SO5- ENV3- CE5- EC1- SO2- EC5- EC3- EC4. The results showed that Environmental Mgt. Systems (ENV1), GHG emissions (ENV5), and Air pollution resulting from recycling process (CE3) retain the highest significance in comparison to the other criteria with values 3.9, 3.6, and 3.5 respectively. These findings contradicts previous literature such as (Kar and Pani, 2014) that found in their results that "Cost" is the most important criteria of supplier. What this mean is that, nowadays, environmentally competitive conditions have led buying firms to prioritize their suppliers' selection criteria towards more sustainable and circular ones rather than thinking only economically. Therefore, supplier companies must put in more attempts and resources to improve these top ranked criteria to expand their opportunity for engaging with buying firms. Moreover, Financial Stability (EC5), Delivery & Services (EC3), and Flexibility (EC4) and have the values 1.9, 1.7, and 1.4.

Regarding the value of (D-R) given in **Table 3,** which represents the degree of influence of each criteria on the sustainable circular supplier process, the criteria are divided into two groups; causal group and effect group. The positive value of (D-R) signifies that the criteria is in the causal group, and the negative value of (D-R) represents that the criteria is in the effect group. As shown in **Figure 3**, the causal group includes the criteria EC5, ENV1, ENV4, ENV5, SO1, SO3, SO5, CE2, CE3, and CE4. Although experts did not consider the criteria EC5 (Financial Stability) and ENV4 (Green Technology) as very important evaluation criteria of significance, these criteria are the most causal criteria with (D-R) scores 1.352 and 1.32, respectively. This tells that EC5 and ENV4 have the more impact on the whole process of sustainable circular supplier selection. Therefore, suppliers must improve their financial resources in a feasible way to guarantee that they are trusted by the buying firms. Moreover, suppliers must use innovative green technology in their operations.

On the other hand, the effect criteria, as it is known, they can effectively be influenced by other criteria. According to the cause-and-effect diagram in **Figure 3**, EC1 (Cost) has the highest negative D-R value, with score (-1.121). Hence, it is the criteria that all other sustainable circular criteria affect it. Mavi and Shahabi (2015) confirmed this, and they stated that cost is one of the major outcomes in supplier selection process and if the companies evaluate and select the best suppliers, they can save enormous money in their operations. The other effect criteria are EC2, EC3, EC4, ENV2, ENV3, ENV6, SO2, SO4, CE1, CE5, and CE6.

6. PRACRTICAL IMPLICATION

Since that this study presents an applicable supplier selection model for assisting decision makers in selecting suppliers towards sustainability and circular economy, based on MCDM method called FDEMATEL, it has some significant implications for manufacturing companies especially for decision makers while selecting and evaluating their suppliers. These implications come from two perspectives: (1) the perspective of the proposed model, and (2) the perspective of the integrated Fuzzy-DEMATEL method. This study provides a supplier selection model for decision makers in MENA region to help them identify the suitable criteria for sustainable circular supplier selection. The model can be applied across different industries in MENA region. By evaluating and ranking the proposed criteria, this study principally helps decision makers to identify which criteria are important over the others for supporting sustainable supply chain management towards circular economy.

Methodologically, the integration of Fuzzy and DEMATEL into a unified method, though not novel, its application to the sustainable circular supplier selection in the MENA region is a novel. The FDEMATEL provides the structure of interdependencies between criteria. Thus, by identifying the structure and interdependencies, the crucial criteria influencing sustainable circular supplier selection have been recognized, which can be beneficial for decision makers to rank and prioritize their suppliers regarding sustainability and circular economy issues, to improve their companies' sustainable circular supply chain performance.

7. CONCLUSION

The integration of sustainability within the circular economy is a developing worldview that can offer a long-term vision to realize environmental and social targets. However, there have been limited studies concerning the supplier selection process towards sustainability within the circular economy context. To remedy the gap, this study proposed a supplier selection model towards sustainability and circular economy based on a combined method of fuzzy sets and DEMATEL. The method is used in order to evaluate the interdependencies of sustainable circular criteria for supplier selection. The method is useful in finding out the relationships among the criteria and ranking them according to the type of relationships and seriousness of their effects on each other. As the DEMATEL delivers a smart decision-making approach to sustainable circular supplier selection criteria by dividing them into cause-effect groups, the fuzzy sets empower to manage with uncertain and unclear judgments in group decision making. Thus, the sustainable circular supplier selection criteria are identified and assessed associated with causal-effect relation diagram. The main findings of this study show that Environmental Mgt. Systems (ENV1), GHG emissions (ENV5), and Air pollution resulting from recycling process (CE3) retain the highest significance, which means that they are the most important criteria over the other criteria. Furthermore, EC5 (Financial Stability) and ENV4 (Green Technology) are the most causal criteria with the highest values of (D-R). On the other hand, EC1 (Cost) is mostly influenced by other factors.

This study results are not feasible without some limitations. These limitations provide some areas for improvement and offer useful basis for future research in sustainable circular supplier selection in particular and sustainable circular supply chain in general. For example, the results of the study based in a single MCDM method (FDEMATEL). More MCDM methods can be applied for the proposed criteria and compare the results.

Further study may involve the extension of the proposed model and combine it with another MCDM method such as TOPSIS to select and rank the suppliers in order to improve the buying companies' sustainable circular supply chain performance.

APPENDIX I

Direct Relation Matrix

CE7	(0.0	(0.0	(0.0 50)	(0.0	(0.0	(0.5	(0.0	(0.0	(0.0
CE6	(0.1	(0.3 00)	(0.7	(0.6	(0.7	(0.6	(0.5	(0.6	(0.6
CE5	(0.0 38)	(0.0	(0.0	(0.0	(0.6	(0.1	(0.4	(0.0	(0.7
CE4 88)	(0.0	(0.2	(0.0	(0.0	(0.7	(0.6	(0.7	(0.1	(0.7
CE3	(0.0	(0.3	(0.0	(0.0	(0.3	(0.6	(0.6	(0.0	(0.6
CE2	(0.0	(0.1	(0.0	(0.0	(0.5	(0.6	(0.7	(0.0	(0.7
CE1	(0.0	(0.6	(0.0	(0.0	(0.1	(0.1	(0.7	(0.0	(0.6
SO	(0.0	(0.3	(0.0	(0.0	(0.2	(0.6	(0.0	(0.0	(0.7
SO	(0.1	(0.4	(0.0	(0.0	(0.0	(0.5	(0.5	(0.5	(0.5
SO	(0.0	(0.1	(0.0	(0.0	(0.4	(0.1	(0.6	(0.2	(0.7
SO	(0.0	(0.0	(0.0	(0.0	(0.0	(0.2	(0.0	(0.0	(0.2
SO	(0.0	(0.0	(0.0	(0.0	(0.0	(0.6	(0.4	(0.0	(0.5
EN	(0.0	(0.4	(0.0	(0.0	(0.3	(0.6	(0.4	(0.3	(0.6
EN	(0.0	(0.5	(0.0	(0.0	(0.5	(0.1	(0.7	(0.7	(0.6
EN	(0.0	(0.0	(0.0	(0.0	(0.7	(0.1	(0.0	(0.0	(0.0
EN	(0.1	(0.0	(0.3	(0.0	(0.7	(0.1	(0.1	(0.0	(0.7
EN	(0.0	(0.4	(0.1	(0.0	(0.7	(0.1	(0.0	(0.0	(0.6
EN	(0.0	(0.6	(0.0	(0.0	(0.7	(0.0	(0.6	(0.6	(0.7
EC5	(0.1	(0.0	(0.0	(0.0	(0.0	(0.0	(0.0	(0.0	(0.2
EC4	(0.3	(0.2	(0.6	(0.0	(0.6	(0.0	(0.0	(0.0	(0.3
EC3	(0.2	(0.3	(0.0	(0.6	(0.7	(0.0	(0.0	(0.3	(0.3
EC2	(0.1	(0.0	(0.4	(0.4	(0.7	(0.6	(0.7	(0.0	(0.7
EC1	(0.0	(0.7	(0.5	(0.5	(0.5	(0.5	(0.6	(0.6	(0.6
	EC1	EC2	EC3	EC4	EC5	EN	EN	EN	EN

EN	(0.5	(0.6	(0.0	(0.0	(0.0	(0.7	(0.7	(0.5	(0.0	(0.0	(0.7	(0.6	(0.6	(0.6	(0.5	(0.7	(0.7	(0.6	(0.7	(0.7	(0.4	(0.0	(0.0
EN	(0.0	(0.1	(0.0	(0.0	(0.0	(0.6	(0.1	(0.0	(0.0	(0.0	(0.0	(0.4	(0.0	(0.4	(0.4	(0.3	(0.3	(0.2	(0.3	(0.2	(0.1	(0.0	(0.0
SO	(0.1	(0.3	(0.0	(0.0	(0.0	(0.7	(0.6	(0.6	(0.0	(0.7	(0.6	(0.0	(0.4	(0.6	(0.6	(0.1	(0.7	(0.4	(0.4	(0.4	(0.1	(0.0	(0.0
SO	(0.0	(0.5	(0.2	(0.1	(0.0	(0.1	(0.0	(0.0	(0.0	(0.1	(0.0	(0.6	(0.0	(0.5	(0.0	(0.0	(0.2	(0.0	(0.1	(0.5	(0.0	(0.0	(0.0
SO	(0.3	(0.4	(0.0	(0.0	(0.0	(0.7	(0.6	(0.4	(0.1	(0.6	(0.7	(0.5	(0.7	(0.0	(0.4	(0.0	(0.6	(0.6	(0.6	(0.5	(0.1	(0.0	(0.0
SO	(0.0	(0.0	(0.0	(0.0	(0.0	(0.2	(0.4	(0.4	(0.0	(0.6	(0.5	(0.7	(0.2	(0.2	(0.0	(0.4	(0.2	(0.3	(0.4	(0.3	(0.4	(0.1	(0.3
SO	(0.0	(0.3	(0.0	(0.0	(0.0	(0.4	(0.4	(0.4	(0.0	(0.5	(0.3	(0.5	(0.0	(0.2	(0.6	(0.0	(0.4	(0.2	(0.3	(0.2	(0.2	(0.0	(0.0
CE	(0.4	(0.1	(0.3	(0.0	(0.0	(0.1	(0.4	(0.0	(0.0	(0.6	(0.4	(0.0	(0.6	(0.6	(0.6	(0.2	(0.0	(0.0	(0.4	(0.0	(0.0	(0.3	(0.0
CE	(0.5	(0.1	(0.2	(0.0	(0.0	(0.6	(0.1	(0.0	(0.0	(0.6	(0.3	(0.0	(0.3	(0.4	(0.1	(0.0	(0.1	(0.0	(0.6	(0.4	(0.1	(0.6	(0.0
CE	(0.5	(0.6	(0.1	(0.0	(0.0	(0.7	(0.6	(0.6	(0.5	(0.6	(0.4	(0.3	(0.0	(0.2	(0.6	(0.3	(0.6	(0.6	(0.0	(0.6	(0.6	(0.5	(0.5
CE	(0.5	(0.7	(0.0	(0.3	(0.3	(0.7	(0.7	(0.0	(0.3	(0.7	(0.5	(0.0	(0.3	(0.6	(0.4	(0.3	(0.5	(0.6	(0.6	(0.0	(0.7	(0.3	(0.0

CE5	(0.6	(0.0	(0.0	(0.0	(0.0	(0.7	(0.0	(0.0	(0.0	(0.1	(0.0	(0.0	(0.0	(0.0	(0.3	(0.2	(0.0	(0.2	(0.3	(0.0	(0.0	(0.4	(0.0
CE6	(0.4	(0.2	(0.4	(0.5	(0.0	(0.7	(0.4	(0.2	(0.0	(0.2	(0.0	(0.0	(0.0	(0.0	(0.0	(0.0	(0.0	(0.0	(0.5	(0.1	(0.3	(0.0	(0.0
CE7	(0.[illegible]	(0.3	(0.0	(0.0	(0.4	(0.3	(0.6	(0.0	(0.6	(0.5	(0.0	(0.3	(0.0	(0.[illegible]	(0.3	(0.2	(0.[illegible]	(0.[illegible]	(0.[illegible]	(0.[illegible]	(0.[illegible]	(0.[illegible]	(0.0

APPENDIX II

The normalized fuzzy direct-relation matrix

	EC	EC	EC	EC	EC	EN	EN	EN	EN	EN	EN	SO	SO	SO	SO	SO 1	CE	CE	CE	CE	CE	CE	CE
EC	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 4	(0.	(0.	(0.	(0.	(0.	(0. 6)
EC	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 2	(0.	(0.	(0.	(0.	(0. 3)
EC	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 2	(0.	(0.	(0.	(0. 3)
EC	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 5	(0.	(0.	(0. 3)
EC	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 5	(0.	(0. 3)
EN	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 5)

																						4	
EN	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 3) 1
EN	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 3)
EN	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 3)
EN	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 4)
EN	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 8)
SO	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 8)
SO	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 5)
SO	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 4)
SO	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 1)
SO	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 8)
CE	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 4)

CE	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 4)
CE	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 9)
CE	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 3)
CE	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 5)
CE	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 4)
CE	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 0)

APPENDIX III

The fuzzy total relation matrix

	EC	EC	EC	EC	EC	EN	EN	EN	EN	EN	EN	SO	SO	SO	SO	SO	CE 8	CE	CE	CE	CE	CE	CE
EC	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 2	(0.	(0.	(0.	(0.	(0. 1)
EC	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 8	(0.	(0.	(0.	(0. 1)
EC	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0. 9)

	(0. 8)	(0. 5)	(0. 2) 8	(0. 1)	(0. 1)	(0. 3)	(0. 7)	(0. 3)	(0. 6)	(0. 4)	(0. 2)
	(0.	(0. 9	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.
	(0. 6	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.
7	(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.	(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.	(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.	(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.	(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.	(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.	(0.	(0.	(0.	(0.	(0.
	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.
	EC	EC	EN	EN	EN	EN	EN	EN	SO	SO	SO

SO	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.
SO	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.
CE	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.
CE	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.
CE	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.
CE	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.
CE	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.
CE	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.
CE	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.	(0.

APPENDIX IV

The crisp total-relation matrix

EC	EC	EC	EC	EC	EN	EN	EN	EN	EN	EN	SO	SO	SO	SO	SO	CE	CE	CE	CE	CE	CE	CE

0	0	0	0	0	0	0	0	0	0	0
0	0.07	0.068	0.064	0.102	0.102	0.086	0.074	0.103	0.072	0
0	0	0	0	0.091	0.1	0.079	0	0.101	0.084	0
0	0	0	0	0.098	0.102	0.095	0	0.104	0.101	0.064
0	0.071	0	0	0.09	0.112	0.099	0	0.111	0.107	0.073
0	0	0	0	0.088	0.103	0.092	0	0.104	0.094	0
0	0.084	0	0	0.079	0.114	0.102	0	0.11	0.107	0.073
0	0	0	0	0.068	0.091	0	0	0.092	0.088	0
0	0.077	0	0	0.071	0.109	0.095	0.073	0.109	0.103	0.079
0	0	0	0	0.088	0.109	0.094	0	0.108	0.101	0.074
0	0	0	0	0	0.067	0	0	0.068	0.079	0
0	0	0	0	0	0.094	0.074	0	0.089	0.089	0.064
0	0.076	0	0	0.085	0.106	0.086	0.062	0.108	0.104	0
0	0.084	0	0	0.105	0.121	0.107	0.084	0.118	0.071	0
0	0	0	0	0.075	0.077	0	0	0	0	0
0	0	0	0	0.092	0.097	0	0	0.098	0.084	0
0	0.079	0	0	0.107	0.117	0	0	0.114	0.109	0
0	0.091	0	0	0.116	0.085	0.107	0.083	0.126	0.116	0.089
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0.073	0	0	0	0	0	0
0	0	0	0	0.086	0	0	0	0.07	0	0
0	0	0	0	0.109	0.11	0.102	0	0.115	0.104	0
0	0.091	0.065	0	0.104	0.105	0.097	0.078	0.109	0.097	0
E(	E(	E(	E(	E(	EN	EN	EN	EN	EN	EN

0	0	0	0	0	0	0	0.063	0	0	0
0	0	0.064	0	0	0.065	0.089	0.097	0.084	0.063	0
0.064	0	0.064	0.076	0.064	0	0	0.093	0.096	0	0
0.083	0.07	0.088	0.076	0.068	0	0.075	0.097	0	0	0
0.089	0	0.097	0.084	0.079	0.074	0.095	0.068	0.103	0	0.075
0.082	0	0.089	0.075	0.068	0	0	0.097	0.093	0	0
0.1	0.064	0.098	0.078	0.085	0	0.097	0.105	0.1	0	0
0	0	0	0.071	0	0	0	0.074	0.072	0	0
0.1	0	0.092	0	0.093	0.088	0.097	0.108	0.097	0.063	0
0.095	0.073	0	0.072	0.071	0.083	0.08	0.085	0.098	0	0
0.068	0	0.08	0	0	0.072	0	0	0.068	0	0
0	0.067	0.081	0.083	0.075	0	0	0.076	0	0	0
0.094	0	0.098	0.086	0.075	0.077	0.078	0.092	0.094	0	0
0.106	0	0.105	0.098	0.09	0.092	0.098	0.111	0.111	0	0.064
0	0	0	0	0	0	0	0.066	0	0	0
0.082	0	0.077	0.07	0.071	0	0	0.088	0	0	0
0.098	0	0.099	0.087	0.086	0.081	0.099	0.109	0.107	0	0.071
0.108	0	0.11	0.084	0.092	0.097	0.103	0.119	0.116	0.082	0.084
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
0.087	0.074	0.092	0.063	0.08	0.091	0.098	0.107	0.108	0	0
0.075	0	0.084	0	0	0.077	0.09	0.102	0.1	0.074	0.074
SC	SC	SC	SC	SC	CI	CI	CI	CI	CI	CI

CI	0.079	0.089	0	0	0	0.093	0.102	0	0.069	0.101	0.069	0.069	0	0.067	0.09	0.068	0.103	0.097	0.105	0.098	0.095	0.098	0

REFERENCES

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.

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.

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.

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.

Awan, U. (2022) 'applied sciences Sustainability in the Circular Economy : Insights and Dynamics of Designing Circular Business Models', *Applied science*, 12(1521).

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.

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.

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.

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.

Chain, K. and Zanin, A. (2019) 'ScienceDirect ScienceDirect ScienceDirect An Analysis on Sustainable Supply Chain for Circular Economy b Circular Economy An Analysis on Sustainable for Costing models for capacity optimization in Industry 4 . 0 : Trade-off between used capacity and opera', *Procedia Manufacturing*, 33, pp. 477–484. doi: 10.1016/j.promfg.2019.04.059.

Chan, F. T. S. *et al.* (2008) 'Global supplier selection: A fuzzy-AHP approach', *International Journal of Production Research*, 46(14), pp. 3825–3857. doi: 10.1080/00207540600787200.

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.

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.

Dantas, T. E. T. *et al.* (2021) 'How the combination of Circular Economy and Industry 4.0 can contribute towards achieving the Sustainable Development Goals', *Sustainable Production and Consumption*, 26, pp. 213–227. doi: 10.1016/j.spc.2020.10.005.

Fallahpour, A. (2016) 'Development of Multi Criteria Decision Making Model for Supplier Selection Using Gene Expression Programming Alireza Fallahpour Faculty of Engineering', pp. 1–146.

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.

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.

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. *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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

Kar, A. K. and Pani, A. K. (2014) 'Exploring the importance of different supplier selection criteria', *Management Research Review*, 37(1), pp. 89–105. doi: 10.1108/MRR-10-2012-0230.

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.* (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.

Kusi-Sarpong, S.; Gupta, H., Khan, S.A.; Chiappetta Jabbour; C.J., Rehman; S.T. and Kusi-Sarpong, H. (2019) 'Sustainable supplier selection based on industry 4.0 initiatives within the context of circular economy implementation in supply chain operations', *Production Planning & Control*.

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.

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.

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.

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.

Mani, V., Gunasekaran, A. and Delgado, C. (2018) 'Enhancing supply chain performance through supplier social sustainability: An emerging economy perspective', *International Journal of Production Economics*, 195(October 2017), pp. 259–272. doi: 10.1016/j.ijpe.2017.10.025.

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.

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.

Mirosław-Świątek, D. *et al.* (2021) 'Analysis of factors influencing levee safety using the DEMATEL method', *PLoS ONE*, 16(9 September), pp. 1–18. doi: 10.1371/journal.pone.0255755.

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.

Nikolaou, I. E. and Tsagarakis, K. P. (2021) 'An introduction to circular economy and sustainability: Some existing lessons and future directions', *Sustainable Production and Consumption*, 28, pp. 600–609. doi: 10.1016/j.spc.2021.06.017.

Nosratabadi, S. *et al.* (2019) 'Sustainable business models: A review', *Sustainability (Switzerland)*, 11(6), pp. 1–30. doi: 10.3390/su11061663.

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.

Ottomano Palmisano, G. *et al.* (2016) 'Greenways for rural sustainable development: An integration between geographic information systems and group analytic hierarchy process', *Land Use Policy*, 50, pp. 429–440. doi: 10.1016/j.landusepol.2015.10.016.

Pieroni, M. P. P., Mcaloone, T. C. and Pigosso, D. C. A. (2019) 'Business model innovation for circular economy and sustainability : A review of approaches', *Journal of Cleaner Production*, 215, pp. 198–216. doi: 10.1016/j.jclepro.2019.01.036.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

Tseng, M. L. *et al.* (2022) ‘Assessing data-driven sustainable supply chain management indicators for the textile industry under industrial disruption and ambidexterity’, *International Journal of Production Economics*, 245(December 2021), p. 108401. doi: 10.1016/j.ijpe.2021.108401.

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.

Wu, H. and Tsai, Y. (2012) ‘An integrated approach of AHP and DEMATEL methods in evaluating the criteria of auto spare parts industry’, 7721. doi: 10.1080/00207721.2011.564674.

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.

Zadeh, L. A. (1965) ‘Fuzzy sets’, *Information and Control*, 8(3), pp. 338–353. doi: 10.1016/S0019-9958(65)90241-X.