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Exploring barriers to smart and sustainable circular economy: The case of an automotive eco-cluster

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ABSTRACT

The transition process from linear economy to circular economy (CE) has brought many challenges and barriers. The three core concepts, which are smartness, sustainability, and circularity, need to be intertwined and adapted by companies to overcome these barriers. Based on this intertwined structure, this paper presents the concept of Smart and Sustainable Circular Economy (SSCE) at the macro-level and addresses the barriers of SSCE under four main aspects: technology, producers, consumers, and policy. Moreover, these four aspects are investigated for small and medium-sized enterprises of an Eco-Cluster in the automotive industry. The fuzzy DEMATEL method is used to uncover, analyse, and discuss the influencing and affected SSCE barriers critically. Finding these SSCE barriers gives an insight into the underlying problems of CE practices, as the only way to ensure an opportunity to achieve SSCE goals is to overcome them. The principal results show that problems of ownership issues in an Eco-Cluster, lack of governmental support and administrative burden, and lack of effective execution of environmental regulations are found as causal barriers that are difficult to change. Furthermore, lack of integration and collaboration among supply chain partners, ineffective CE framework adoption, and product complexity for CE principles are classified as effect barriers that are easily affected by the other factors and the implications can be shown in the short-term. Besides, the cooperation between supply chain partners can be encouraged to provide a solution to the lack of integration and collaboration between supply chain partners and the adoption of an ineffective CE framework.

1. Introduction

Circular economy (CE) has gained increasing interest as a promising concept worldwide for improving sustainability and economic potential (Ranta et al., 2018) by alleviating the growing amount of waste (Kerdlap et al., 2019) as an alternative approach to the linear economy. The CE concept is defined as an economic system that aims to change the relationship between nature and society in order to restrain resource depletion, closed-loop energy, and materials, and facilitate sustainable development (Ormazabal et al., 2018). Efficient resource and utility management is a key requirement against a circular economy in terms of eliminating wastes/losses, pollution, and extraction of natural resources (Van Fan et al., 2019). Moreover, CE provides sustainable production and consumption by using discarded products in a design that these products can be remanufactured and reused again (Cesur et al., 2020; Ozkan-Ozen et al., 2020). However, sustainable development goals (SDGs) are required to ensure the broad expansion of CE principles across the region and, economy (Balanay and Halog, 2016). SDGs can be defined at a macro-level that includes a wide range of economic, ecological, and social sustainability (Sauvé et al., 2016).

The integration of CE and sustainability, called the Sustainable Circular Economy (SCE) (Nelles et al., 2016), can achieve many beneficial impacts such as energy recovery, resource efficiency, continued economic growth, sustained consumption, circularity at the macro-level. Digitalisation can promote the transition to a more SCE via closing the loop, reducing and decelerating the loop of material, and limiting the loop by increasing resource efficiency (Antikainen et al., 2018). Therefore, smart enabling technologies and digitalisation are seen as one of the pathways towards sustainability (Zhang et al., 2019). Thus, the integration of smart enabling technologies into the SCE, which can be named as Smart and Sustainable Circular Economy (SSCE), can help businesses perform more effective, efficient, smart, inclusive, and sustainable operations.

Eco-Clusters are important mediators among environmental

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technologies and sustainable development to achieve smartness, sustainability, and circularity perspectives of CE at the macro-level. Eco-Clusters are also seen as a way to generate the CE model for the assessment of industrial systems (Gómez et al., 2018; Ghisellini et al., 2016). The transition of these green-oriented business models, Eco-Clusters, into SSCE includes some challenges that remain a research gap in the current literature. The main motivation of this paper concerns the current challenges and barriers facing Eco-Clusters, a novel approach in developing countries, that needs to be explored in detail to provide a guideline to the Eco-Clusters in terms of the role of environmental management partnership. Therefore, the existence of the relevant barriers and their relationships with each other should be analysed from the perspective of Eco-Cluster. In this context, the following research questions (RQs) are presented to reveal the SSCE barriers that Eco-Clusters may encounter in their transition process.

RQ1: What are the main barriers in terms of technology, producers, consumers, and policy aspects that inhibit the SSCE practices in Eco-Clusters?
RQ2: What are the interrelationships between these barriers to the transition of Eco-Cluster into the SSCE concept?

In order to answer the aforementioned RQs, this paper aims to address and discuss the barriers of SSCE under the interrelationship between technology, producers, consumers, and policy aspects. These four aspects are necessary for the implementation of the CE principles efficiently in small and medium-sized enterprises (SMEs) of Eco-Cluster because in emerging economies across the world, SMEs are classified as the main contributor to industrial growth (Kumar et al., 2020; Rauch et al., 2019). The automotive industry is selected as an Eco-Cluster in the case study. Another purpose of this paper is to highlight and examine the SSCE concept at the macro-level. The related literature on SSCE has been examined and synthesized to identify the existing SSCE barriers under three substantial perspectives and the Eco-Cluster as seen in Fig. 1. In this research, the Fuzzy Decision-Making Trial and Evaluation Laboratory (Fuzzy DEMATEL) method is used to analyse barriers.

The remainder of this paper is organized as follows: the theoretical background, related literature, and the SSCE concept in the Eco-Cluster perspective are explained in section 2. Then, barriers to SSCE barriers are presented in-depth in section 3. The Fuzzy DEMATEL method is defined in section 4. Details of the case study and results are given in section 5. Section 6 discusses the managerial and theoretical implications of this research. Finally, the paper ends with conclusions, limitations of the research, and future research directions in section 7.

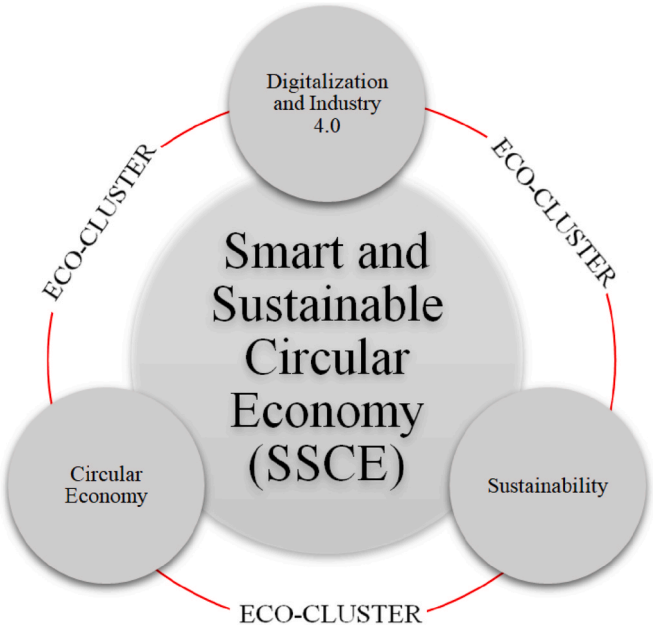

Fig. 1. The three substantial perspectives of the SSCE within eco-cluster.

2. Theoretical background

This section of the study involves two sub-sections as follows: the existing barriers to the CE and SSCE concept in the Eco-Cluster perspective. Firstly, the literature review of existing CE barriers is addressed. Then, the SSCE concept is examined from the perspective of the Eco-Cluster.

2.1. Existing barriers to CE

Many studies in the literature focus on the barriers to CE. For instance, Geng and Doberstein (2008) presented a series of barriers of the CE for long-term promotion and implementation of the concept in China to lead decision-makers more sustainably. Prendeville et al. (2014) studied key challenges for the implementation of the CE principles in eco-design and possible alternatives to CE. Baldassarre et al. (2019) studied industrial symbiosis and conducted a comparative analysis to design processes for the eco-industrial cluster by adapting CE and industrial ecology aspects. Huang et al. (2018) examined the interaction among eco-efficiency and urban clusters in order to understand the intrinsic mechanism by conducting employing data envelopment analysis and comparative study in China. Rizos et al. (2015, 2016) conducted a literature review for examining the key barriers and enablers for the adaptation of CE business practices for SMEs. Galvão et al. (2018) investigated and analysed the main barriers of CE into the following aspects: technological, policy and regulatory, financial and economic, performance indicators, customer, and social. De Jesus and Mendonça (2018), discussed "how transformative innovation" can boost this transition process and overcome the barriers of CE in terms of sustainability perspective. Koszewska (2018) aimed to determine and assess the challenges that the CE model faced in the clothing and textile industry. Neczaj and Grosser (2018) proposed related challenges and barriers which present for the development of wastewater treatment plans in the sense of CE and Smart Cities concept. Ormazabal et al. (2018) explored the barriers and opportunities for the application of CE an SME's perspective. Agyemang et al. (2019) studied to determine the drivers and barriers for CE implementation in Pakistan's automotive manufacturing industry. Bressanelli et al. (2019) also pointed out the challenges, that the companies faced redesigning their supply chain for CE. Zhang et al. (2019) focused on achieving smart waste management barriers for CE with the help of smart enabling technologies. Govindan and Hasanagic (2018) examined the drivers, barriers, and practices of CE from the various stakeholders for CE in the context of the supply chain in a multi-perspective framework. Yadav et al. (2020b) explored to identify the indicators that facilitate the CE transition process in an emerging economy context in order to examine the cause-effect interaction and intensity of influence. Mura et al. (2020) aimed to provide an understanding of the actions to take that SMEs to confront as challenges and opportunities for the CE. Werning and Spinler (2020) presented 29 barriers for the transition to a CE business model (CEBM). Yadav et al. (2020) concerned with providing a framework that identified sustainable supply chain challenges towards offering solutions to Industry 4.0 (I4.0) and CE. Rajput and Singh (2019) studied the hidden relationship and connection among CE and I4.0 within the context of supply chain and represent 26 substantial enablers and 15 challenges related to the topic in the study. Bag et al. (2020) aimed to present an understanding of procurement 4.0 (procurement strategy, planning, and review) effect on the optimization process in CE performance. Jakhar et al. (2019) presented a conceptual/theoretical framework that focuses on the effects of stakeholder pressure and innovative capabilities for the development of CE initiatives of firms. Van Fan et al. (2019) draw upon sustainable

strategies for efficient resource management by looking from the environmental perspectives by proposing a cross-disciplinary study for accomplishing smart, resilient, and sustainable CE. Kumar et al. (2020) have observed that the adoption of I4.0 technologies and CE, can be offered many beneficial effects towards making sustainable operations more ethical and sustainable for SMEs. In this context, fifteen challenges have been prepared in order to reveal the role of smart technologies in ethical issues, and CE and then DEMATEL method has applied to emphasize the cause-effect relationship among these challenges.

2.2. SSCE concept in Eco-Cluster perspective

Sustainability is another substantial perspective and necessity for the smooth functioning of the CE. However, the environmental sustainability framework limits manufacturing processes in terms of ecological constraints (Bonilla et al., 2018) and high cost required features, accessibility to resources, and so on. For that purpose, the adoption of smart enabling technologies can facilitate the transition into a more SCE. It can enable more efficient usage of natural resources with less waste by eliminating the costs. The major environmental barriers of the latest I4.0 technologies are often related to increased energy demand and the urgent need to implement low carbon energy systems (Wang et al., 2016). In order to overcome these barriers and achieve CE, Eco-Clusters need to be smart, sustainable, and circular. Hence, the SSCE concept may assist the transition process of the Eco-Clusters into more smart, sustainable and circular, because of the effective implementation of CE principles within Eco-Clusters which is a research gap.

The cluster may be defined as an "Eco-Cluster" when collaboration between public and private organizations is focused not just on the economic development of the cluster, but also on the creation of an environmental development for the cluster. Thus, Eco-Clusters are important mediators among environmental technologies and sustainable development to achieve smartness, sustainability, and circularity perspectives of CE at the macro-level. Eco-Clusters are so important for sustainable development, because the stakeholders of the whole supply chain (e.g., manufacturers, suppliers, companies, service providers, government agencies) provide service, knowledge, research, and technical support to the regional economy to achieve green growth. However, each and every party of these Eco-Clusters must have the same technical and technological infrastructure to provide the required collaboration. That is why smartness and sustainability are becoming substantial for these Eco-Clusters to adapt the implementations of CE principles.

3. Barriers to SSCE

In this section of the paper, a search string related to the SSCE concept was created and the potential barriers found throughout the literature review were selected according to this search string as seen in Table 1 to answer RQ1. Note that, since there are few publications on Eco-Cluster, the barriers that were found are adapted to the Eco-Cluster, although they include general barriers. The publications found throughout the study were searched from databases: Web of Science, Scopus, Science Direct, Emerald Insight, and Taylor & Francis. As a result of that, 303 publications have been found and the most appropriate 226 publications out of them used in our study. After reviewing all selected literature, 67 barriers were found in total. However, the number of barriers was too high for further analysis of the interrelations between them. For this purpose, the relevant barriers were reduced to 34 with the consensus of the academic group, which consists of six international academics with average of 10 years of experiences in the circular economy field. All founded barriers were critically examined and rated on a scale from 1 to 5 by academics group to reach the consensus for each barrier, where 1 indicates "low consensus" and 5 indicates "high consensus". Then, the agreed 34 barriers were listed according to the consensus status and classified under four main aspects depending on

Table 1
Search strings.

Sustainability	("sustainability" OR "sustainable development" OR "eco-friendly" OR "social sustainability" OR "environmental sustainability" OR "economic sustainability" OR "corporate sustainability")
AND	
Digitalisation and Industry 4.0 (I4.0)	("industry 4.0" OR "I4.0" OR "manufacturing 4.0" OR "digit*" (i. e. digital, digitalisation etc.) OR "internet" OR "big data" OR "Blockchain" OR "sensors" OR "actuators" OR "internet of things" OR "IoT" OR "sensors" OR "machine learning" OR "cyber-physical systems" OR "artificial intelligence" OR "AI" OR "cognitive computing" OR "virtual reality" OR "augmented reality" OR "VR/AR" OR "3D Printing" OR "4D printing" OR "additive manufacturing" OR "cloud" OR "Cloud Computing" OR "edge computing" OR "mobile" OR "mobile devices" OR "5G" OR "social media" OR "Robotics" OR "Omnichannel" OR "unmanned aerial vehicle" OR "UAV" OR "Nanotechnology" OR "self-driving vehicles" OR "Automated Guided Vehicles" OR "AGV" OR "radio frequency identification" OR "RFID" OR "near field communication" OR "NFC" OR "M2M" OR "Bluetooth" OR "ZigBee" OR "WiFi" OR "wireless technology" OR "drone")
AND	
Circular Economy (CE)	("circular economy" OR "green economy" OR "closed-loop economy" OR "Circularity" OR "Sustainable Development Goals")
AND	
Smartness	("cooperation" OR "integration" OR "connectivity" OR "autonomous control" OR "adaptiveness" OR "cognition" OR "transparency" OR "traceability")
AND	
Circularity	("circularity" OR "closing the loop" OR "resource productivity" OR "product end of life cycle" OR "lifecycle management" OR "rethink" OR "reuse" OR "recycle" OR "remanufacture" OR "repair" OR "recover" OR "reduce" OR "refurbish" OR "repurpose")
AND	
Barriers	("barriers")

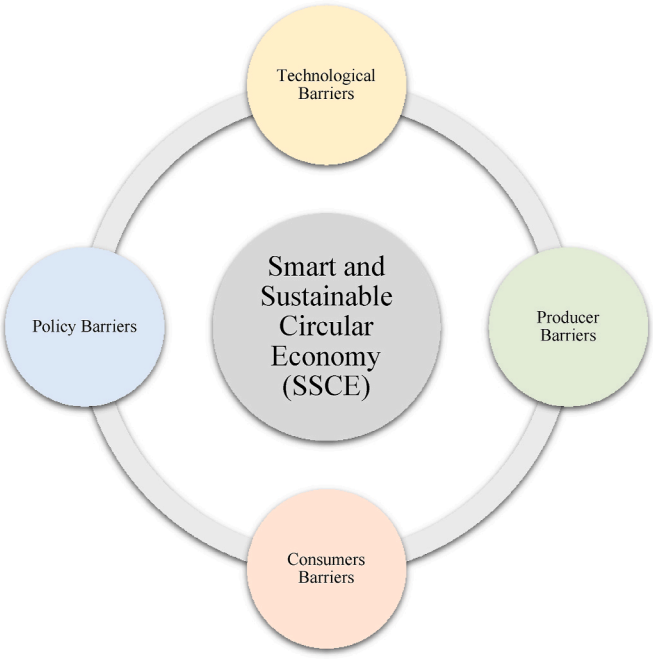

Fig. 2. Four aspects of SSCE in eco-cluster.

their relevance respectively: technology, producers, consumers, and policy as seen in Fig. 2. Barriers within the four aspects are shown in Table 2.

3.1. Technological aspect

Technology is a necessity for CE implementation because CE is a technology-oriented concept (Agyemang et al., 2019). For that reason, the investments and the policies cannot be implemented in practice successfully when there are technical and technological limitations in capacity and resource B1: Technical and technological limitations in capacity and resource. Apart from that, B2: Lack of data integration stands for lack of data integration due to a vast amount of various data from different sources data, scale, volume, and variety, lack of data integration causes limited storage of the data, scalability, and unproductive utilization of the data. Also, eco-innovation and eco-efficient technological developments B3: Eco-innovation and eco-efficient technological developments are a demand for environmentally superior technologies for environmental, financial, and technical reasons to many recycling activities and leads to losses, disruption, and contamination of natural resources, pollution, energy consumption, and jeopardizing the eco-system. Lack of data privacy and security problems B4: Lack of data privacy and security problems are a growing concern because the accessibility, transparency, and traceability functions of IoT systems make it difficult to protect and secure the data. Lastly, smart device development B5: Lack of smart device development and, limited or underdeveloped availability of information B6: Limited or underdeveloped availability of information is required towards the improvement of the CE and implementation of its principles.

3.2. Producer aspect

The producer aspect contains the barriers for the entire process of the production phase that the producer faced with such as operational, managerial, financial, and personal skill. Firstly, lack or absence of business processes B7: Lack of availability of business process indicators, which include standardized workflows, lower cost, simplified operations, process optimization, and modelling, reduced risks, enhanced productivity, etc., affect companies' productivity, efficiency, the profitability. Congruently, ineffective framework adoption B8: Ineffective CE framework adoption is critical for the implementation of the business processes. The next barrier, overcoming the lack of integration and collaboration among supply chain partners B9: Lack of integration and collaboration among supply chain partners is a must for the companies in order to support each other for the accomplishment of a common goal. Accordingly, better, effective performance and less complexity in supply chain operations can be achieved via resource sharing, data integration, etc. Moreover, product complexity for CE principles B10: Product complexity for CE principles is one of the fundamental barriers since the product's multi-functionality causes an increase in product complexity that affects circular operations adversely (De Schoenmakere and Gillabel, 2017). Also, the possible combination of complex processes of CE principles with product complexity is an important problem to overcome. Operational risks B11: Operational risk that companies faced consists of outsourcing, product damage costs, maintenance of the product, regulations, human factors, etc. Lack of resources B12: Lack of resources, which is caused by the difficulties in collecting used products for circular activities, prevents companies' CE principles. Moreover, effective implementation of CE initiatives can be obtained by overcoming high initial investment cost B13: High initial investment cost. Also, the high cost of CE principles and transaction search activities B14: High cost of CE processes and transaction search activities is a hurdle for the companies which decreases the attention and investments into CE because it requires various costs such as transaction cost, search cost for resources, etc. In addition, the mismatch between cost and profit B15: Mismatch between cost and profit is a barrier to the effective implementation of CE initiatives. Lack of financial resources and support B16: Lack of financial resources and support is another barrier that requires consideration for the investments in the transition from the linear economy model to CE that contains many activities such as planning of distribution requirements, inventory management, production planning, and reverse logistics network management (Rizos et al., 2016; Kok et al., 2013). Uncertain market demand level B17: Uncertain market demand is a fundamental obstacle for companies for shifting into CE because the demand for the circular product is not on the desired level to balance the cost and revenue level. Therefore, it detracts the attention and awareness of CE implementations because the demand rise can show if more consumers pay attention and trust in circular products (Agyemang et al., 2019). Moreover, poor leadership & management B18: Poor leadership & management causes great damage in the enterprise in terms of resource mismanagement, falling sale performance, high turnover rate, loss of motivation, morale, and lack of engagement, etc. In addition, lack of expert labour B19: Lack of expert labour is another barrier to the effective implementation of CE initiatives. Lack of detailed knowledge and relevant expertise B20: Lack of knowledge and expertise about CE principles or the transition into CE is the main bottleneck for CE (Agyemang et al., 2019; Shahbazi et al., 2016). Lack of producers' awareness and perception B21: Lack of producers' awareness and perception affects the adoption of CE. Also, assigning low priority to CE principles can be considered under these barriers because of the lack of information and difficulty for defining CE principles B22: Difficulty in defining CE principles leads to ineffective management of the CE. Lastly, capacity building is highly required for addressing the needs of CE implementations at various levels. For that reason, capacity building needs to be designed as a long-term process by articulating the periods as short-, medium-, and long-term goals (Geng and Doberstein, 2008). Difficulty in defining CE principles is another common barrier for CE implementations because there is a lack of eco-literacy amongst the supply chain partners B23: Lack of eco-literacy amongst supply chain partners and a lack of information and experience about CE practices.

3.3. Consumers aspect

Consumers' unawareness of some circular products B24: Consumers' unawareness for some circular products is the first barrier which is generally considered as poor quality by the consumers because of using used/discarded materials through CE implementations. This perception of the consumers leads to poor demand and accordingly inhibits the dissemination of CE. Another consumers' barrier is a misperception of high prices for circular products B25: Misperception of high prices for circular products. This misperception often could dissuade consumers from buying CE products, even if the consumers are aware of the environmental issues and interested in circular products. Also, lack of incentive campaigns for circular products B26: Lack of incentive campaigns for circular products is another important barrier. Therefore, the governments should assist companies to conduct incentive advertisement campaigns to create an understanding of this issue. For instance, the electrical and electronic industry is one of the sectors which have the highest production and waste, and the governments have been limiting the consumption of white goods via some regulations that make companies collect waste electrical and electronic equipment from consumers. For this purpose, white goods companies are conducting some recall campaigns where consumers can bring old, eligible, or inoperable devices, and receive promotions in part exchange for a new product. Therefore, renewable, non-renewable, and valuable materials in white goods are no longer waste by collecting and using them as raw materials for remanufacturing. Finally, the lack of environmental culture perception in society B27: Lack of environmental culture perception in society is the last barrier of consumers' barriers. Along with the diversity between companies against different sectors, their perception, responses, and capabilities across the "green solution" are generally depending on the organization and management (Rizos et al., 2015).

Table 2
Barriers to SSCE in eco-cluster.

Aspects		Barriers	References
Technology Barriers	**B1**	Technical and technological limitations in capacity and resource	Agyemang et al. (2019); Bressalini et al. (2019); De Jesus & Mendonça (2018); Galvão et al. (2018); Govindan & Hasanagic (2018); Ormazabal et al. (2018); Ormazabal et al. (2016); Rizos et al. (2016); Preston (2012); Geng & Doberstein (2008); Shi et al. (2008)
	B2	Lack of data integration	Rajput and Singh (2019); Bressalini et al. (2019); Antikainen et al. (2018); Galvão et al. (2018); Mangla et al. (2018); Ormazabal et al. (2018); Ritzén & Sandström (2017); Ormazabal et al. (2016); Rizos et al. (2016); Rizos et al. (2015); Geng & Doberstein (2008)
	B3	Eco-innovation and eco-efficient technological developments	Dev et al. (2020); Mura et al. (2020); Santander et al. (2020); Werning and Spinler (2020); Bressalini et al. (2019); Rajput and Singh (2019); Sandvik and Stubbs (2019); de Sousa Jabbour et al. (2018); De Jesus & Mendonça (2018); Koszewska et al. (2018); Mangla et al. (2018); Ormazabal et al. (2018); Butzer et al. (2017); Ritzén & Sandström (2017); Ormazabal et al. (2016); Rizos et al. (2016); Li et al. (2015); Preston (2012); Geng & Doberstein (2008); Shi et al. (2008);
	B4	Lack of data privacy and security problems	Bressalini et al. (2019); de Sousa Jabbour et al. (2018); Leitão et al. (2016); Wells et al. (2014)
	B5	Lack of smart device development	Santander et al. (2020); Werning and Spinler (2020); Rajput and Singh (2019); Zhang et al. (2019); Butzer et al. (2017)
	B6	Limited or underdeveloped availability of information	Dev et al. (2020); Wan et al. (2020); Yadav et al. (2020); Bressalini et al. (2019); Antikainen et al. (2018); Bianchini et al. (2018); de Sousa Jabbour et al. (2018); Elmualim et al. (2018); Govindan & Hasanagic (2018); Masi et al. (2017); Van Buren et al. (2016)
Producer Barriers	**B7**	Lack of availability of business process	Rocca et al. (2020);; Bianchini et al. (2018); De Angelis et al. (2018)
	B8	Ineffective CE framework adoption	Garrido-Hidalgo et al. (2020); Yadav et al. (2020); Alcayaga et al. (2019); Bressalini et al. (2019);; Antikainen et al. (2018); Bianchini et al. (2018); De Angelis et al. (2018); Govindan and Hasanagic (2018);
	B9	Lack of integration and collaboration among SC partners	Tseng et al. (2020); Werning and Spinler (2020); Agyemang et al. (2019); Zhang et al. (2019); Mangla et al. (2018);
	B10	Product complexity for CE principles	Werning and Spinler (2020); Agyemang et al. (2019); Bressalini et al. (2019)
	B11	Operational risk	Bressanelli et al. (2019); Saidani et al. (2018); Linder and Williander (2017); Tukker (2015); Baines and Lightfoot (2014); Barquet et al. (2013); Krikke (2011); Mont (2008)
	B12	Lack of resources	Agyemang et al. (2019); Koszewska et al. (2018)
	B13	High initial investment cost	Mura et al. (2020); Yadav et al. (2020); Agyemang et al. (2019); Alcayaga et al. (2019); Rajput and Singh (2019); Zhang et al. (2019); Govindan and Hasanagic (2018); De Jesus and Mendonça (2018); Quieroz & Telles (2018); Geng et al. (2017); Wang et al. (2015)
	B14	High cost of CE processes and transaction search activities	Santander et al. (2020); Antikainen et al. (2018); Bianchini et al. (2018); Govindan and Hasanagic (2018); Koszewska et al. (2018); Pang et al. (2015)
	B15	Mismatch between cost and profit	Yadav et al. (2020); Agyemang et al. (2019); Bressalini et al. (2019); Zhang et al. (2019); Antikainen et al. (2018); Bianchini et al. (2018); Mangla et al. (2018); Saidani et al. (2018); Linder and Williander (2017); Rizos et al. (2016); Shahbazi et al. (2016); Tukker (2015); Baines and Lightfoot (2014); Barquet et al. (2013); Metta and Badurdeen (2012); Krikke (2011); Mont (2008)
	B16	Lack of financial resources and support	Bressanelli et al. (2019); Sandvik and Stubbs (2019); Zhang et al. (2019); Bianchini et al. (2018); De Jesus and Mendonça (2018); Galvão et al. (2018); Govindan and Hasanagic (2018); Mangla et al. (2018); Ormazabal et al. (2018); Butzer et al. (2017); Linder and Williander (2017); Ormazabal et al. (2016); Rizos et al. (2016); Li et al. (2015); Rizos et al. (2015); Tukker (2015); Baines & Lightfoot (2014); Krikke (2011); Geng & Doberstein (2008); Shi et al. (2008)
	B17	Uncertain market demand	Agyemang et al. (2019); De Jesus and Mendonça (2018); Koszewska et al. (2018)
	B18	Poor leadership & management	Rossi et al. (2020); Yadav et al. (2020); Agyemang et al. (2019); Bressalini et al. (2019); Antikainen et al. (2018); Galvão et al. (2018); Govindan and Hasanagic (2018); Mangla et al. (2018); Ormazabal et al. (2018); Ünal et al. (2018); Butzer et al. (2017); Ormazabal et al. (2016); Su et al. (2013); Negny et al. (2012); Biondi et al. (2002); Geng & Doberstein (2008); Shi et al. (2008)
	B19	Lack of expert labor	Rossi et al. (2020); Yadav et al. (2020); Bianchini et al. (2018); de Sousa Jabbour et al. (2018); Queiroz and Telles (2018)
	B20	Lack of knowledge and expertise	Yadav et al. (2020); Rossi et al. (2020); Agyemang et al. (2019); Bressalini et al. (2019); Zhang et al. (2019); Antikainen et al. (2018); De Jesus and Mendonça (2018); Govindan and Hasanagic (2018); Mangla et al. (2018); Ormazabal et al. (2018); Butzer et al. (2017); Masi et al. (2017); Ormazabal et al. (2016); Rizos et al. (2016); Van Buren et al. (2016); Rizos et al. (2015); Preston (2012); Geng & Doberstein (2008); Shi et al. (2008)
	B21	Lack of producers awareness and perception	Garrido-Hidalgo et al. (2020); Santander et al. (2020); Werning and Spinler (2020); Bressalini et al. (2019);; Govindan and Hasanagic (2018); Mangla et al. (2018); Butzer et al. (2017)
	B22	Difficulty in defining CE principles	Garrido-Hidalgo et al. (2020); Werning and Spinler (2020);; Govindan and Hasanagic (2018); Van Buren et al. (2016); Park et al. (2010)
	B23	Lack of eco-literacy amongst SC partners	Agyemang et al. (2019); Bressalini et al. (2019); De Angelis et al. (2018); Geng et al. (2017);
Consumers Barriers	**B24**	Consumers' unawareness for some circular products	De Jesus and Mendonça (2018); Ormazabal et al. (2018); Nußholz (2017); Ormazabal et al. (2016); Preston (2012); Geng & Doberstein (2008)
	B25	Misperception of high prices for circular products	Koszewska et al. (2018); Geng and Doberstein (2008)
	B26	Lack of incentive campaigns for circular products	Ormazabal et al. (2018); Ormazabal et al. (2016); Rizos et al. (2016); Preston (2012); Geng and Doberstein (2008)
	B27	Lack of environmental culture perception in society	Galvão et al. (2018); Rizos et al. (2016); Rizos et al. (2015); Geng and Doberstein (2008)
Policy Barriers	**B28**	Lack of conductive legal system	Mura et al. (2020); Bianchini et al. (2018); De Jesus and Mendonça (2018); Govindan and Hasanagic (2018); Butzer et al. (2017); Rizos et al. (2016); Rizos et al. (2015); Geng and Doberstein (2008)
	B29	Policy challenges	Yadav et al. (2020); Sandvik and Stubbs (2019); Govindan and Hasanagic (2018); Park et al. (2010); Agyemang et al. (2019); Rizos et al. (2015) & Rizos et al. (2016); Geng and Doberstein (2008)
	B30	Lack of effective execution of environmental regulations	Werning and Spinler (2020); Mangla et al. (2018); Geng et al. (2017); Rizos et al. (2016); Li et al. (2015); Rizos et al. (2015); Geng and Doberstein (2008)
	B31	Misaligned vision and conflict between central and local governments	Yadav et al. (2020); Mura et al. (2020); Li et al. (2015)

(*continued on next page*)

Table 2 (*continued*)

Aspects		Barriers	References
	B32	Lack of standards for CE performance assessment	Werning and Spinler (2020); Yadav et al. (2020); Bressalini et al. (2019); Zhang et al. (2019); Antikainen et al. (2018); Govindan and Hasanagic (2018); Van Buren et al. (2016)
	B33	Problems of ownership issues in an Eco-Cluster	Werning and Spinler (2020); Bressalini et al. (2019); Govindan and Hasanagic (2018)
	B34	Lack of governmental support and administrative burden	Mura et al. (2020); Werning and Spinler (2020); Agyemang et al. (2019); Galvão et al. (2018); Rizos et al. (2016); Li et al. (2015); Rizos et al. (2015); Su et al. (2013)

3.4. Policy aspect

Policy barriers are one of the main and substantial barriers that affect CE implementations. Thus, for the implementation of CE principles, the lack of a conductive legal system B28: Lack of conductive legal system is a barrier for fragmented, non-specific legal systems that create a gap for the understanding of the CE principles. Also, policy challenges B29: Policy challenges such as lack of effective taxation policy, consumption taxes, industrial pollution emissions policy, etc. Can be considered as substantial barriers against the CE that discourage CE implementations and long-term green investments. Therefore, these taxation-related policies and unstable and ever-changing political conditions lead to short-term government policies for CE principles (Agyemang et al., 2019). Because of the lack of effective execution of environmental regulations B30: Lack of effective execution of environmental regulations, the understanding of the initiatives for CE principles and implementations is not a priority of many Eco-Clusters. Misaligned vision and conflict between central and local governments B31: Misaligned vision and conflict between central and local governments can cause uncertainty and hesitations of CE implementations. Moreover, lack of standards for CE performance assessment B32: Lack of standards for CE performance assessment reveals the need for more appropriate policies for CE by identifying the key barriers to the industrial symbiosis of Eco-Clusters by considering local realities (Galvão et al., 2018). In addition to that, problems of ownership issues in an Eco-Cluster B33: Problems of ownership issues in an Eco-Cluster such as the ownership of waste in an Eco-Cluster among producers, suppliers, consumers, etc. Is a questionable issue that prevents CE implementation. Lack of industrial, governmental support, and administrative burden (Legislation's role typically involves assessing the risk of waste and proposing (or motivating) initiatives that owners can take if they intend to relinquish ownership (Pongrácz & Pohjola, 1999). B34: Lack of governmental support and administrative burden e.g., available and shared technical support from professionals and other stakeholders (Agyemang et al., 2019) affects the CE adoption, so these barriers should be overcome to support, regulate, and monitor their CE principles (Galvão et al., 2018; Su et al., 2013).

4. Proposed methodology

Decision-making problems and implementations need to be conducted under uncertainty due to goals; limitations and potential actions are unclear in the real world (Seker and Zavadskas, 2017). Also, subjective judgments, the vagueness of human thoughts are affecting the results of the decision-making in many aspects. For that reason, the Fuzzy Decision-Making Trial and Evaluation Laboratory method, in short Fuzzy DEMATEL, has been decided to deal with the indecisive and vague human thoughts that can be caused by the complexity of the factors, equivocal linguistic terms, and so on. Fuzzy DEMATEL starts after obtaining the survey documents from the experts as seen in Fig. 3.

4.1. Fuzzy logic

The fuzzy set theory assists researchers in order to deal with the vagueness of human thoughts and language in decision-making (Lin and Wu, 2008) because the outcome of the decision-making process is substantially affected by subjective judgment which is vague and indecisive (Wu and Lee, 2007). Therefore, these linguistic variables need to be converted into fuzzy numbers and, triangular fuzzy numbers Ã are used for this purpose. The membership function is defined as:

$$\mu_{\tilde{x}}(y) = \begin{cases} 0, & x < l, \\ (y-a)/(b-a), & l \le x \le m, \\ (c-y)/(c-b), & m \le x \le r, \\ 0 & x > r, \end{cases}$$

A triangular fuzzy numberÃ, as seen in Fig. 4, is presented as a triplet (l, m, r) and a membership.

4.2. Fuzzy DEMATEL method

Fuzzy DEMATEL allows decision-makers to rely deeper on important measures and execute effective mission-oriented approaches by analysing cause and effect interactions. Therefore, the Fuzzy DEMATEL method has been decided to use in this study to segment these complicated factors. The evaluations obtained from the expert committee are firstly converted into crisp scores for the application of Fuzzy DEMATEL. Then, the classical DEMATEL method steps have been applied. There are various forms of defuzzification method in the literature such as centroid method, mean of maximum (MOM); centre of average methods. However, converting fuzzy data into crisp scores (CFCS) method is preferred for this study because of the benefits it provides.

Let$A_{ij} = (l_{ij}^n, m_{ij}^n, r_{ij}^n)$; mean the degree of criterion i that affects criterion j and fuzzy questionnaires n ($n = 1, 2, 3...p$). The CFCS method involves a five-step algorithm as follows:

(1) Normalization:

$$xl_{ij}^k = \left(l_{ij}^k - \min l_{ij}^k\right) \Big/ \Delta_{\min}^{\max},$$

$$xm_{ij}^k = \left(m_{ij}^k - \min l_{ij}^k\right) \Big/ \Delta_{\min}^{\max},$$

$$xr_{ij}^k = \left(r_{ij}^k - \min l_{ij}^k\right) \Big/ \Delta_{\min}^{\max},$$

Where$\Delta_{\min}^{\max} = \max r_{ij}^k - \min l_{ij}^k$.

(2) Compute left (l_s) and right (r_s) normalized value:

$$xls_{ij}^k = xm_{ij}^k \Big/ \left(1 + xm_{ij}^k - xl_{ij}^k\right),$$

$$xrs_{ij}^k = xr_{ij}^k \Big/ \left(1 + xr_{ij}^k - xm_{ij}^k\right).$$

(3) Compute total normalized crisp value:

$$x_{ij}^k = \left[xls_{ij}^k\left(1 - xls_{ij}^k\right) + xrs_{ij}^k xrs_{ij}^k\right] \Big/ \left[1 - xls_{ij}^k + xrs_{ij}^k\right].$$

(4) Compute crisp values:

$$z_{ij}^{k} = \min l_{ij}^{k} + x_{ij}^{k}\Delta_{\min}^{\max}.$$

(5) Integrate crisp values:

$$z_{ij}^{k} = \frac{1}{p}\left(z_{ij}^{1} + z_{ij}^{2} + \cdots + z_{ij}^{p}\right).$$

A revised version of the DEMATEL definitions and steps which are obtained from Fontela and Gabus (1976) and Wu and Lee (2007) are seen as below.

Step 1: Generating the initial direct relation matrix *Z*. For computing the initial direct relation matrix, a pair-wise comparison scale is needed. For this purpose, the interaction among any two factors needs to be assessed by asking respondents to indicate the direct relation by using an integer scale which is classified as four as follows: "No influence (0); " "Low influence (1); " "Medium influence (2); " "High influence (3); " and "Very high influence (4)" and the comparison scale of the DEMATEL method are shown in Table 3.

Step 2: The initial direct relation matrix *Z* is a$[n \times n]$ matrix that is provided by pair-wise comparisons. Respondents have ranked the criteria in terms of influences and directions thatz_i, j is represents the decision maker's judgments and denoted as the degree to which the criterion *Di* affects criterion*Dj*. The obtained data have been placed to the matrix where all principal diagonal elements are equal to zero.

$$z_{ij} = \frac{1}{l}\sum_{k=1}^{l} z_{ij}^{k},\ i,j = 1,2,\ldots,n.$$

$$D_1 D_2 \quad \ldots D_n$$

$$Z = \begin{matrix} D_1 \\ D_2 \\ \vdots \\ D_n \end{matrix} \begin{bmatrix} 0 & z_{12} & \cdots & z_{1n} \\ z_{21} & 0 & \cdots & z_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ z_{n1} & z_{n2} & \cdots & 0 \end{bmatrix}$$

Fig. 4. A triangular fuzzy number A~

Step 3: Calculation and establishment of the normalized direct-relation matrix *X* can be obtained through the formula:

$$X = \frac{Z}{s},$$

$$s = \left(\max_{1\le i\le n}\sum_{j=1}^{n} z_{ij},\ \max_{1\le i\le n}\sum_{i=1}^{n} z_{ij}\right)$$

All elements in the matrix *X* are complying with,

$$0 \le x_{ij} < 1$$

$$0 \le a$$

$$\Sigma n_j = 1$$

$$x_{ij} \le 1,$$

and at least one *i*such that. $\Sigma n_j = 1z_{ij} \le s$.

Step 4: Calculation of the total relation matrix T which can be defined as follows:

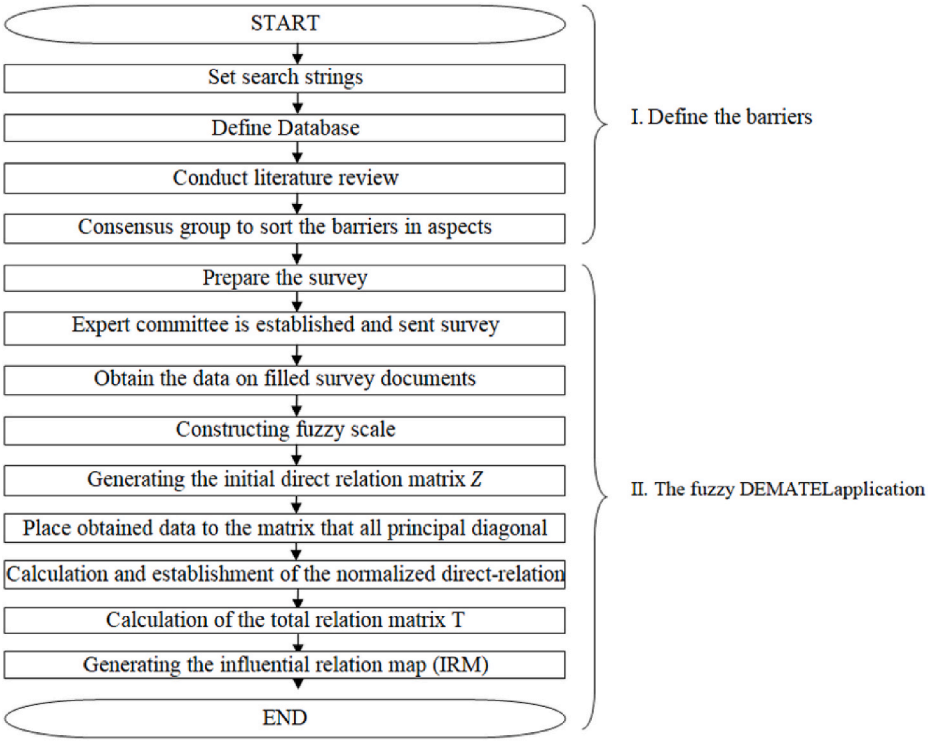

Fig. 3. Flowchart of Selecting the Barriers and fuzzy DEMATEL.

$$T = X + X^2 + X^3 + \ldots + X^h = X(1 - X)^{-1},$$

when. $h \to \infty$,

In which I is denoted as an identity matrix.

Step 5: Generating the influential relation map (IRM). In this step, the sum of the rows and the sum of the columns are calculated separately and denoted as $R$and C within the total relation matrix by the following formulas:

$$R = [r_i]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1}; \; C = [c_j]_{1\times n} = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n}^{T},$$

where R and C denote the sum of rows and the sum of columns, respectively.

Step 6: Establishment of the causal diagram. A causal diagram can be obtained by mapping the datasets and adding or subtracting the C from R. The formula $(R + C)$represents the horizontal axis and named "Cause". $(R+C)$ indicates the degree of importance of the criteria plays in the entire system. On the contrary, the formula $(R - C)$ represents the vertical axis and named "Effect". If $(R - C) > 0$, a net cause is resulted while criteria is a net receiver or result if$(R - C) < 0$.

5. Case study: SSCE barriers in Eco-Cluster

In our study, the analysis of barriers was carried out for SMEs of an Eco-Cluster in the automotive industry in Turkey. There is an initiative for "Turkey Connected and Autonomous Vehicles Cluster" created to increase cooperation and communication with the automobile, software, and similar sectors (TOSB, 2019), but the missing part of this initiative is the environmental concerns to define Eco-Cluster in the automobile industry. The reasons for preferring this initiative in this study are that this cluster is extremely close to the automobile Eco-Cluster community in Turkey and this initiative is suitable for the definition of Eco-Cluster.

In this part of the study, it is aimed to reveal the interrelationship between these barriers by analysing the DEMATEL results to answer to RQ2. To analyse the barriers, a survey is prepared based on the 34 barriers. An expert committee is defined by consisting of five experts on their proven knowledge and level of expertise in the circular economy field, who are working in Tuzla Industrial Zone in Istanbul. They are highly experienced plant manager, project manager, company owner, production manager, and procurement manager with average of 19 years of work experience in the automotive industry. All of them obtained bachelor's degree in mechanical or industrial engineering. The Fuzzy DEMATEL method has been chosen in order to deal with the vagueness and indecisive thoughts of human thoughts of the respondents' thoughts. It is also good at resolving human-related problems. It is also good at resolving human-related problems.

After obtaining survey results from selected experts, the fuzzy linguistic scale has been used to convert the collected fuzzy data into linguistic values, as seen in Table 4. Firstly, the arithmetic means of the judgments of the experts and the points they deemed appropriate were obtained while creating the initial relationship matrix as seen in Table 5. Later, the total relation matrix was generated by calculating the degree of C and R values as seen in Table 6. Table 7 displays the influence matrix or cause group $(R - C)$ that points out the influencing factors. The next table, when examining the B9: lack of integration and collaboration among supply chain partners criterion that is the most influential factor among the criteria examined as demonstrated in Table 7, the greatest degree of $(R + C)$ among all criteria is observed which is 9.0. Besides, the degree of C is 4.5 which are the highest score amidst all criteria and the degree of R with the score of 4.6 ranked as first. However, $(R - C)$ corresponds to 0.1 which is one of the least scores in all criteria. After all of the steps of Fuzzy DEMATEL, the causal diagram is obtained as seen in Fig. 5. Following on from this, the causal diagram. It can be deducted from Fig. 5 that the cause criteria can be determined as B8, B9, B10, B16, B17, B18, B19, B20, B21, B22, B23, B25, B26, B27, B28, B29, B30, B31, B32, B33 and B34 and effect criteria as B1, B2, B3, B4, B5, B6, B7, B11, B12, B13, B14, B15, and B24.

Obtained results show that the barriers in producers, consumers, and policy aspects can affect the other barriers in technological aspect and some other barriers in producer's aspect such as operational risk, lack of resources and various financial barriers and so on. Therefore, these 19 cause criteria provide important information on how to overcome the barriers in Eco-Clusters. Besides, the effect criteria show the weak spot of the barriers that require attention. For that reason, focusing on effect criteria and trying to improve the standards also crucial to overcome the barriers.

For $(R - C)$, B33: Problems of ownership issues in an Eco-Cluster and B34: Lack of governmental support and administrative burden have the highest-level effect (1.1) on other criteria among the cause group. The highest score on the influence matrix means that related criterion/criteria have the greatest degree of effect on the entire system. The second-highest level effect is belonging to B30: Lack of effective execution of environmental regulations with a score of 0.9. Accordingly, the third greatest impact degree is B29: Policy challenges. Moreover, B22: Difficulty in defining CE principles and B32: Lack of standards for CE performance assessment is ranked as the fifth place among all the causal criteria examined. On the other hand, negative values which are below zero mean that this criterion is slightly affected by other criteria in examined factors.

For$(R + C)$, the greatest degree of importance is B9: Lack of integration and collaboration among supply chain partners with 9.0 meaning. Then, B8: Ineffective CE framework adoption, B10: Product complexity for CE principles, and B11: Operational risk ranked as second influential impact criteria with the same score of 8.6. Furthermore, the third greatest influential impact belongs to B13: High initial investment cost with 8.2. The fourth and fifth ones are B12: Lack of resources (8.0), and B16: Lack of financial resources and support (7.7).

In degree of influenced impact$R$, B9: Lack of integration and collaboration among supply chain partners is ranked as in the top place with 4.6 score which means that B9: Lack of integration and collaboration among supply chain partners is the most influenced criterion among others. Then, B8: Ineffective CE framework adoption and B10: Product complexity for CE principles come as second place right after B9: Lack of integration and collaboration among supply chain partners with 4.3. On the contrary, B31: Misaligned vision and conflict between central and local governments is the criterion that has the smallest effect from other criteria. Also, the degree of influential impact C displays the

Table 3
A comparison scale of the DEMATEL method.

Normal Values	Linguistic terms
4	Very high influence (VH)
3	High influence (H)
2	Low influence (L)
1	Very low influence (VL)
0	No influence (No)

Table 4
The correspondence of linguistic terms and linguistic values.

Normal Values	Linguistic terms	Linguistic values
4	Very high influence (VH)	(0.75, 1.0, 1.0)
3	High influence (H)	(0.5, 0.75, 1.0)
2	Low influence (L)	(0.25, 0.5, 0.75)
1	Very low influence (VL)	(0, 0.25, 0.5)
0	No influence (No)	(0, 0, 0.25)

Table 5
Initial direct relation matrix.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26	B27	B28	B29	B30	B31	B32	B33	B34	SUM
B1	0.00	0.78	0.97	0.87	0.78	0.83	0.73	0.78	0.83	0.64	0.64	0.59	0.45	0.50	0.27	0.27	0.08	0.22	0.36	0.13	0.27	0.27	0.13	0.31	0.50	0.27	0.17	0.08	0.22	0.22	0.08	0.22	0.08	0.22	13.75
B2	0.83	0.00	0.69	0.87	0.87	0.83	0.83	0.64	0.64	0.59	0.50	0.50	0.45	0.55	0.27	0.36	0.27	0.22	0.31	0.41	0.36	0.41	0.45	0.22	0.22	0.36	0.27	0.13	0.27	0.22	0.17	0.27	0.08	0.22	14.26
B3	0.73	0.73	0.00	0.78	0.50	0.69	0.50	0.41	0.64	0.41	0.59	0.45	0.27	0.50	0.22	0.08	0.08	0.03	0.17	0.17	0.27	0.27	0.31	0.27	0.17	0.08	0.35	0.03	0.08	0.08	0.08	0.13	0.03	0.03	10.14
B4	0.83	0.78	0.45	0.00	0.83	0.87	0.41	0.45	0.73	0.50	0.55	0.41	0.31	0.31	0.27	0.36	0.27	0.13	0.31	0.41	0.27	0.27	0.45	0.22	0.13	0.27	0.35	0.08	0.31	0.17	0.03	0.22	0.08	0.08	12.10
B5	0.92	0.92	0.69	0.83	0.00	0.64	0.59	0.55	0.55	0.45	0.36	0.31	0.22	0.36	0.22	0.08	0.13	0.03	0.17	0.31	0.13	0.27	0.27	0.55	0.17	0.22	0.31	0.08	0.17	0.08	0.08	0.27	0.03	0.03	10.99
B6	0.83	0.87	0.64	0.92	0.69	0.00	0.78	0.69	0.87	0.69	0.55	0.55	0.41	0.59	0.45	0.41	0.41	0.36	0.41	0.50	0.36	0.55	0.36	0.45	0.03	0.50	0.36	0.17	0.22	0.22	0.13	0.36	0.03	0.22	15.57
B7	0.57	0.56	0.43	0.53	0.62	0.65	0.00	0.79	0.61	0.58	0.60	0.44	0.50	0.60	0.39	0.40	0.28	0.33	0.49	0.54	0.23	0.44	0.43	0.43	0.44	0.44	0.35	0.24	0.29	0.50	0.18	0.50	0.17	0.19	14.73
B8	0.73	0.78	0.73	0.64	0.41	0.78	0.92	0.00	0.73	0.87	0.69	0.69	0.64	0.83	0.64	0.73	0.69	0.64	0.73	0.55	0.45	0.64	0.59	0.78	0.64	0.69	0.69	0.50	0.59	0.73	0.36	0.45	0.64	0.55	21.73
B9	0.64	0.64	0.50	0.78	0.41	0.83	0.83	0.78	0.00	0.69	0.69	0.78	0.73	0.78	0.50	0.87	0.78	0.59	0.69	0.69	0.64	0.69	0.83	0.69	0.73	0.73	0.78	0.64	0.64	0.69	0.73	0.50	0.73	0.64	22.85
B10	0.64	0.64	0.55	0.50	0.45	0.59	0.69	0.69	0.50	0.00	0.73	0.73	0.87	0.83	0.64	0.73	0.55	0.55	0.69	0.59	0.45	0.83	0.78	0.64	0.78	0.87	0.64	0.64	0.73	0.64	0.50	0.59	0.78	0.64	21.68
B11	0.45	0.69	0.55	0.73	0.50	0.87	0.78	0.78	0.83	0.73	0.00	0.69	0.83	0.73	0.59	0.73	0.69	0.59	0.55	0.55	0.41	0.55	0.55	0.55	0.78	0.55	0.50	0.59	0.83	0.59	0.55	0.59	0.78	0.59	21.26
B12	0.69	0.55	0.50	0.64	0.41	0.64	0.73	0.69	0.78	0.69	0.73	0.00	0.73	0.59	0.50	0.73	0.59	0.45	0.50	0.36	0.50	0.55	0.50	0.55	0.69	0.69	0.50	0.64	0.73	0.50	0.31	0.59	0.64	0.55	19.44
B13	0.73	0.59	0.78	0.69	0.69	0.87	0.59	0.73	0.59	0.78	0.78	0.78	0.00	0.69	0.69	0.83	0.73	0.55	0.55	0.45	0.27	0.45	0.31	0.50	0.69	0.55	0.36	0.59	0.83	0.31	0.45	0.41	0.78	0.55	20.14
B14	0.78	0.69	0.78	0.45	0.73	0.36	0.64	0.69	0.64	0.69	0.59	0.59	0.78	0.00	0.69	0.69	0.55	0.50	0.50	0.41	0.31	0.41	0.41	0.50	0.45	0.41	0.17	0.27	0.64	0.36	0.50	0.64	0.50	0.55	17.85
B15	0.41	0.69	0.50	0.64	0.31	0.64	0.36	0.36	0.55	0.64	0.87	0.78	0.78	0.69	0.00	0.45	0.50	0.36	0.36	0.45	0.22	0.45	0.45	0.31	0.41	0.31	0.13	0.17	0.50	0.22	0.17	0.36	0.27	0.36	14.68
B16	0.64	0.59	0.78	0.55	0.69	0.50	0.41	0.59	0.78	0.31	0.55	0.59	0.87	0.87	0.69	0.00	0.83	0.59	0.45	0.64	0.55	0.59	0.55	0.59	0.64	0.64	0.50	0.69	0.78	0.41	0.59	0.50	0.59	0.59	20.14
B17	0.50	0.13	0.55	0.13	0.45	0.31	0.27	0.59	0.55	0.59	0.87	0.87	0.87	0.83	0.69	0.64	0.00	0.55	0.50	0.45	0.45	0.69	0.41	0.36	0.55	0.73	0.55	0.64	0.59	0.36	0.45	0.41	0.41	0.55	17.48
B18	0.17	0.22	0.31	0.27	0.36	0.59	0.83	0.78	0.73	0.69	0.69	0.55	0.64	0.59	0.59	0.69	0.59	0.00	0.45	0.55	0.41	0.59	0.27	0.41	0.31	0.45	0.50	0.55	0.41	0.36	0.22	0.36	0.45	0.41	15.99
B19	0.27	0.17	0.41	0.36	0.31	0.55	0.50	0.69	0.64	0.78	0.87	0.59	0.69	0.55	0.59	0.45	0.45	0.59	0.00	0.87	0.55	0.69	0.78	0.41	0.59	0.55	0.64	0.50	0.41	0.41	0.50	0.41	0.31	0.41	17.48
B20	0.69	0.69	0.55	0.64	0.41	0.83	0.78	0.83	0.69	0.69	0.64	0.50	0.50	0.50	0.64	0.36	0.59	0.64	0.69	0.00	0.69	0.83	0.73	0.78	0.69	0.59	0.73	0.59	0.45	0.50	0.69	0.50	0.41	0.55	20.56
B21	0.73	0.50	0.78	0.59	0.59	0.55	0.59	0.55	0.73	0.55	0.59	0.73	0.59	0.78	0.45	0.69	0.50	0.59	0.78	0.83	0.00	0.64	0.78	0.55	0.64	0.64	0.73	0.55	0.45	0.69	0.64	0.45	0.36	0.45	20.28
B22	0.55	0.55	0.50	0.45	0.31	0.36	0.73	0.73	0.59	0.64	0.69	0.59	0.59	0.55	0.55	0.78	0.78	0.64	0.92	0.97	0.78	0.00	0.73	0.50	0.55	0.55	0.69	0.73	0.36	0.64	0.31	0.41	0.50	0.50	19.72
B23	0.55	0.41	0.64	0.41	0.36	0.45	0.55	0.78	0.83	0.97	0.87	0.55	0.59	0.59	0.45	0.59	0.69	0.73	0.59	0.73	0.78	0.83	0.00	0.31	0.41	0.41	0.64	0.36	0.31	0.31	0.27	0.41	0.31	0.17	17.85
B24	0.31	0.17	0.50	0.17	0.50	0.73	0.36	0.55	0.31	0.69	0.73	0.27	0.78	0.08	0.27	0.69	0.55	0.22	0.45	0.59	0.55	0.45	0.41	0.00	0.59	0.64	0.69	0.45	0.41	0.36	0.36	0.45	0.41	0.41	15.10
B25	0.45	0.08	0.36	0.17	0.45	0.45	0.55	0.36	0.59	0.87	0.87	0.83	0.73	0.69	0.69	0.69	0.36	0.45	0.41	0.45	0.69	0.55	0.50	0.92	0.00	0.69	0.92	0.50	0.55	0.31	0.50	0.45	0.31	0.45	17.85
B26	0.36	0.41	0.59	0.36	0.59	0.64	0.41	0.36	0.45	0.41	0.22	0.45	0.59	0.64	0.59	0.64	0.45	0.59	0.50	0.69	0.78	0.64	0.87	0.92	0.83	0.00	0.65	0.78	0.64	0.55	0.69	0.50	0.41	0.83	19.03
B27	0.27	0.27	0.08	0.13	0.41	0.36	0.27	0.59	0.73	0.41	0.41	0.41	0.41	0.41	0.59	0.41	0.83	0.55	0.50	0.50	0.92	0.69	0.97	0.78	0.73	0.92	0.00	0.69	0.64	0.69	0.59	0.59	0.41	0.73	17.85
B28	0.31	0.13	0.27	0.41	0.31	0.59	0.78	0.83	0.78	0.87	0.78	0.69	0.87	0.31	0.50	0.31	0.41	0.59	0.36	0.41	0.55	0.17	0.22	0.31	0.64	0.69	0.60	0.00	0.64	0.55	0.55	0.59	0.50	0.50	17.02
B29	0.36	0.22	0.36	0.22	0.22	0.36	0.45	0.73	0.69	0.73	0.83	0.73	0.87	0.83	0.92	0.83	0.69	0.59	0.69	0.78	0.59	0.64	0.64	0.45	0.55	0.64	0.14	0.83	0.00	0.64	0.83	0.78	0.78	0.87	20.48
B30	0.45	0.31	0.41	0.22	0.36	0.55	0.55	0.59	0.78	0.59	0.64	0.87	0.78	0.50	0.64	0.50	0.64	0.41	0.45	0.59	0.73	0.55	0.73	0.83	0.78	0.69	0.15	0.64	0.73	0.00	0.83	0.73	0.50	0.83	19.56
B31	0.08	0.17	0.27	0.41	0.22	0.41	0.41	0.64	0.83	0.69	0.59	0.87	0.59	0.55	0.41	0.55	0.45	0.27	0.36	0.73	0.59	0.31	0.78	0.59	0.55	0.83	0.13	0.55	0.73	0.78	0.00	0.50	0.27	0.64	16.74
B32	0.55	0.59	0.69	0.55	0.31	0.73	0.83	0.92	0.69	0.73	0.73	0.73	0.78	0.50	0.50	0.50	0.78	0.13	0.27	0.45	0.78	0.08	0.17	0.55	0.69	0.55	0.43	0.45	0.50	0.69	0.59	0.00	0.50	0.64	18.57
B33	0.13	0.45	0.27	0.41	0.17	0.69	0.64	0.69	0.83	0.78	0.69	0.73	0.73	0.69	0.64	0.69	0.78	0.69	0.64	0.64	0.69	0.45	0.50	0.27	0.64	0.55	0.45	0.59	0.59	0.83	0.87	0.50	0.00	0.45	19.34
B34	0.27	0.22	0.55	0.41	0.41	0.64	0.78	0.78	0.87	0.73	0.64	0.73	0.83	0.83	0.50	0.83	0.73	0.59	0.45	0.31	0.59	0.45	0.41	0.69	0.64	0.69	0.66	0.55	0.69	0.78	0.69	0.64	0.87	0.00	20.44
																																		MAX	22.85

Table 6
Total relation matrix.

T	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26	B27	B28	B29	B30	B31	B32	B33	B34
B1	0.06	0.09	0.10	0.10	0.09	0.11	0.10	0.11	0.11	0.10	0.10	0.09	0.09	0.09	0.07	0.08	0.06	0.06	0.07	0.07	0.07	0.07	0.06	0.07	0.08	0.07	0.06	0.05	0.07	0.06	0.05	0.06	0.05	0.06
B2	0.10	0.06	0.09	0.10	0.10	0.11	0.11	0.10	0.11	0.10	0.10	0.09	0.09	0.09	0.07	0.08	0.07	0.06	0.07	0.08	0.07	0.08	0.08	0.07	0.07	0.08	0.07	0.06	0.07	0.06	0.06	0.07	0.05	0.06
B3	0.08	0.08	0.05	0.08	0.06	0.08	0.07	0.07	0.08	0.07	0.08	0.07	0.06	0.07	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.04	0.04	0.04	0.04
B4	0.09	0.09	0.08	0.05	0.09	0.10	0.08	0.09	0.10	0.09	0.09	0.08	0.08	0.07	0.06	0.07	0.06	0.05	0.06	0.07	0.06	0.06	0.07	0.06	0.06	0.07	0.06	0.05	0.06	0.05	0.04	0.06	0.05	0.05
B5	0.09	0.09	0.08	0.08	0.05	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.05	0.05	0.05	0.04	0.05	0.06	0.05	0.06	0.06	0.07	0.05	0.06	0.06	0.04	0.05	0.04	0.04	0.05	0.04	0.04
B6	0.11	0.10	0.10	0.11	0.09	0.08	0.11	0.11	0.12	0.11	0.11	0.10	0.10	0.10	0.09	0.09	0.09	0.07	0.08	0.09	0.08	0.09	0.08	0.09	0.07	0.09	0.08	0.07	0.08	0.07	0.06	0.07	0.06	0.07
B7	0.09	0.09	0.09	0.09	0.09	0.11	0.08	0.12	0.11	0.11	0.11	0.10	0.10	0.10	0.08	0.09	0.08	0.07	0.08	0.09	0.07	0.08	0.08	0.08	0.09	0.09	0.08	0.07	0.08	0.08	0.06	0.08	0.06	0.07
B8	0.13	0.13	0.13	0.12	0.11	0.15	0.15	0.12	0.16	0.16	0.15	0.14	0.15	0.15	0.12	0.14	0.13	0.11	0.12	0.12	0.11	0.12	0.12	0.13	0.13	0.13	0.12	0.11	0.12	0.12	0.10	0.11	0.11	0.11
B9	0.13	0.12	0.13	0.13	0.11	0.16	0.15	0.16	0.13	0.16	0.16	0.15	0.16	0.15	0.12	0.15	0.14	0.12	0.13	0.13	0.13	0.13	0.14	0.13	0.14	0.14	0.13	0.12	0.13	0.12	0.12	0.11	0.12	0.12
B10	0.13	0.12	0.12	0.12	0.11	0.14	0.14	0.15	0.15	0.12	0.15	0.15	0.16	0.15	0.13	0.14	0.12	0.11	0.12	0.12	0.11	0.13	0.13	0.12	0.13	0.14	0.12	0.12	0.13	0.11	0.10	0.11	0.11	0.11
B11	0.12	0.12	0.12	0.13	0.11	0.15	0.14	0.15	0.16	0.15	0.12	0.14	0.15	0.14	0.12	0.13	0.13	0.11	0.11	0.12	0.11	0.12	0.12	0.12	0.13	0.12	0.11	0.11	0.13	0.11	0.10	0.11	0.11	0.11
B12	0.12	0.11	0.11	0.11	0.10	0.13	0.13	0.14	0.15	0.14	0.14	0.10	0.14	0.13	0.11	0.13	0.12	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.12	0.10	0.11	0.12	0.10	0.09	0.10	0.10	0.10
B13	0.12	0.11	0.13	0.12	0.11	0.14	0.13	0.14	0.14	0.14	0.14	0.14	0.11	0.13	0.12	0.13	0.12	0.10	0.11	0.11	0.10	0.11	0.10	0.11	0.12	0.12	0.10	0.11	0.12	0.09	0.09	0.10	0.11	0.10
B14	0.12	0.11	0.12	0.10	0.10	0.11	0.12	0.13	0.13	0.13	0.12	0.12	0.13	0.09	0.11	0.11	0.10	0.09	0.10	0.10	0.09	0.10	0.10	0.10	0.10	0.10	0.08	0.08	0.11	0.09	0.09	0.10	0.09	0.09
B15	0.09	0.09	0.09	0.09	0.08	0.11	0.09	0.10	0.11	0.11	0.12	0.11	0.11	0.11	0.07	0.09	0.09	0.07	0.08	0.09	0.07	0.08	0.09	0.08	0.09	0.08	0.07	0.07	0.09	0.07	0.06	0.07	0.07	0.07
B16	0.12	0.11	0.13	0.11	0.11	0.13	0.12	0.14	0.15	0.13	0.14	0.13	0.15	0.14	0.12	0.10	0.13	0.10	0.10	0.12	0.11	0.11	0.11	0.11	0.12	0.12	0.10	0.11	0.12	0.10	0.10	0.10	0.10	0.11
B17	0.10	0.08	0.11	0.08	0.09	0.11	0.10	0.12	0.13	0.13	0.14	0.13	0.14	0.13	0.11	0.11	0.08	0.09	0.10	0.10	0.10	0.11	0.10	0.10	0.11	0.12	0.10	0.10	0.11	0.09	0.09	0.09	0.08	0.10
B18	0.08	0.08	0.09	0.08	0.08	0.11	0.12	0.12	0.13	0.12	0.12	0.11	0.12	0.11	0.10	0.11	0.10	0.07	0.09	0.10	0.09	0.10	0.09	0.09	0.09	0.10	0.09	0.09	0.09	0.08	0.07	0.08	0.08	0.08
B19	0.09	0.08	0.10	0.09	0.09	0.12	0.11	0.13	0.13	0.13	0.14	0.12	0.13	0.12	0.11	0.11	0.10	0.10	0.08	0.12	0.10	0.11	0.11	0.10	0.11	0.11	0.10	0.09	0.10	0.09	0.09	0.09	0.08	0.09
B20	0.12	0.12	0.12	0.12	0.10	0.14	0.14	0.15	0.15	0.14	0.14	0.13	0.13	0.13	0.12	0.11	0.12	0.11	0.12	0.09	0.12	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.10	0.11	0.10	0.09	0.10
B21	0.12	0.11	0.13	0.11	0.11	0.13	0.13	0.14	0.15	0.14	0.14	0.14	0.14	0.14	0.11	0.13	0.11	0.10	0.12	0.13	0.09	0.12	0.12	0.11	0.12	0.12	0.11	0.10	0.11	0.11	0.10	0.10	0.09	0.10
B22	0.11	0.11	0.11	0.11	0.10	0.12	0.13	0.14	0.14	0.14	0.14	0.13	0.14	0.13	0.11	0.13	0.12	0.11	0.12	0.13	0.12	0.09	0.12	0.11	0.12	0.12	0.11	0.11	0.10	0.11	0.09	0.10	0.10	0.10
B23	0.11	0.10	0.11	0.10	0.09	0.12	0.12	0.13	0.14	0.14	0.14	0.12	0.12	0.12	0.10	0.11	0.11	0.10	0.10	0.11	0.11	0.12	0.08	0.09	0.10	0.10	0.10	0.09	0.09	0.09	0.08	0.09	0.08	0.08
B24	0.08	0.07	0.09	0.08	0.08	0.11	0.10	0.11	0.10	0.11	0.12	0.09	0.12	0.08	0.08	0.10	0.09	0.07	0.09	0.10	0.09	0.09	0.09	0.07	0.10	0.10	0.09	0.08	0.09	0.08	0.07	0.08	0.07	0.08
B25	0.10	0.08	0.10	0.09	0.09	0.12	0. 12	0.12	0.13	0.14	0.14	0.13	0.13	0.12	0.11	0.12	0.10	0.09	0.10	0.10	0.11	0.10	0.10	0.12	0.09	0.12	0.11	0.10	0.10	0.09	0.09	0.09	0.08	0.09
B26	0.10	0.10	0.11	0.10	0.10	0.13	0.12	0.12	0.13	0.12	0.12	0.12	0.13	0.12	0.11	0.12	0.11	0.10	0.10	0.12	0.12	0.11	0.12	0.12	0.12	0.09	0.11	0.11	0.11	0.10	0.10	0.10	0.09	0.11
B27	0.09	0.09	0.09	0.08	0.09	0.11	0.11	0.13	0.14	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.12	0.10	0.10	0.11	0.12	0.11	0.12	0.12	0.12	0.13	0.08	0.10	0.11	0.10	0.10	0.10	0.09	0.11
B28	0.09	0.08	0.09	0.09	0.09	0.12	0.12	0.13	0.13	0.14	0.13	0.12	0.13	0.10	0.10	0.10	0.10	0.09	0.09	0.10	0.10	0.09	0.09	0.09	0.11	0.11	0.10	0.07	0.11	0.09	0.09	0.10	0.09	0.09
B29	0.11	0.10	0.11	0.10	0.10	0.13	0.13	0.15	0.15	0.15	0.15	0.14	0.15	0.14	0.13	0.14	0.13	0.11	0.12	0.13	0.12	0.12	0.12	0.11	0.12	0.13	0.09	0.12	0.09	0.11	0.12	0.12	0.11	0.12
B30	0.11	0.10	0.11	0.10	0.10	0.13	0.13	0.14	0.15	0.14	0.14	0.14	0.14	0.12	0.12	0.12	0.12	0.10	0.10	0.12	0.12	0.11	0.12	0.12	0.13	0.12	0.09	0.11	0.12	0.08	0.11	0.11	0.10	0.12
B31	0.08	0.08	0.09	0.09	0.08	0.11	0.11	0.12	0.14	0.13	0.12	0.13	0.12	0.11	0.10	0.11	0.10	0.08	0.09	0.11	0.10	0.09	0.11	0.10	0.11	0.12	0.08	0.09	0.11	0.10	0.07	0.09	0.08	0.10
B32	0.11	0.11	0.12	0.11	0.09	0.13	0.13	0.14	0.14	0.14	0.14	0.13	0.14	0.12	0.11	0.11	0.12	0.08	0.09	0.10	0.11	0.09	0.09	0.11	0.12	0.11	0.10	0.09	0.10	0.10	0.10	0.07	0.09	0.10
B33	0.10	0.10	0.10	0.10	0.09	0.13	0.13	0.14	0.15	0.14	0.14	0.14	0.14	0.13	0.12	0.13	0.13	0.11	0.11	0.12	0.11	0.11	0.11	0.10	0.12	0.12	0.10	0.11	0.11	0.11	0.11	0.10	0.07	0.10
B34	0.11	0.10	0.12	0.11	0.10	0.14	0.14	0.15	0.16	0.15	0.14	0.14	0.15	0.14	0.12	0.14	0.13	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.13	0.11	0.11	0.12	0.12	0.11	0.11	0.11	0.08

Table 7
Prominence and relation axis for the causal diagram.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26	B27	B28	B29	B30	B31	B32	B33	B34
C's	3.5	3.3	3.6	3.4	3.2	4.1	4.0	4.3	4.5	4.3	4.3	4.1	4.2	4.0	3.5	3.7	3.5	3.0	3.3	3.5	3.3	3.4	3.5	3.4	3.6	3.7	3.2	3.1	3.4	3.1	2.9	3.1	2.8	3.1
R's	2.7	2.8	2.0	2.4	2.1	3.0	2.9	4.3	4.6	4.3	4.2	3.9	4.0	3.5	2.9	4.0	3.6	3.3	3.6	4.1	4.0	4.0	3.6	3.1	3.6	3.8	3.7	3.5	4.2	4.0	3.5	3.7	4.0	4.1
R + C	6.2	6.1	5.5	5.8	5.3	7.1	6.9	8.6	9.0	8.6	8.6	8.0	8.2	7.5	6.4	7.7	7.1	6.3	6.8	7.6	7.3	7.4	7.1	6.5	7.2	7.5	6.8	6.6	7.6	7.0	6.3	6.8	6.8	7.2
R–C	−0.9	−0.5	−1.6	−1.0	−1.1	−1.0	−1.1	0.0	0.1	0.0	−0.1	−0.2	−0.3	−0.5	−0.5	0.3	0.0	0.2	0.3	0.6	0.7	0.6	0.2	−0.4	0.1	0.1	0.5	0.4	0.8	0.9	0.6	0.7	1.1	1.1
	E	E	E	E	E	E	E	C	C	C	E	E	E	E	E	C	C	C	C	C	C	C	C	E	C	C	C	C	C	C	C	C	C	C

criterion that has an effect on other causal factors. B9: Lack of integration and collaboration among supply chain partners is ranked as first with 4.5 score from all amidst the causal criteria.

6. Implications

6.1. Managerial implications

The main causal barriers that have the greatest impact on the entire system of Eco-Cluster in the automobile industry over the long-term are B33: Problems of ownership issues in an Eco-Cluster, B34: Lack of governmental support and administrative burden, and B30: Lack of effective execution of environmental regulations which are under policy barriers and difficult to change. This result shows that the government needs to take a more active role to make more serious regulations and rewrite applicable laws favour circularity to develop a government program that facilitates and promotes circular initiatives (Bet et al., 2018). For example, ownership issues are generally controversial subjects among the research communities. Ownership of waste is an undesirable condition for many businesses because of the responsibility of collecting waste. In this context, legislation has a key role that consists of assessing the risk of waste and proposing (or motivating) initiatives that owners can take if they intend to relinquish ownership (Pongrácz & Pohjola, 1999). Therefore, the ownership of waste material and responsibility of the waste, which requires government support, legal legislations, and act upon instructions, needs specific consideration to eliminate confusion and manipulations.

The three fundamental effect barriers that need attention to influence the entire system of an Eco-Cluster in the automobile industry over the short-term are B9: Lack of integration and collaboration among supply chain partners, B8: Ineffective CE framework adoption, and B10: Product complexity for CE principles. Furthermore, these barriers can be easily affected by other factors and they are easier to overcome, as they will have more obvious results in the short term in comparison with causal barriers. The complexities, uncertainties, and risks involved with CE practices and business models are linked to the CE by nature (Bianchini et al., 2019). For this purpose, the connection, communication, coordination, and collaboration among the supply chain with the full support of all partners are substantial in order to overcome these barriers because the lack of finding an effective CE framework is not a concern of a single company. However, the integration and collaboration among the supply chain partners are overly complex and for that reason, this is considered as an absence in the sector. Successful experiences of the organizations can be shared with the supply chain partners and can be used as a base to encourage governments about practical regulations, executions, and governmental support (Bet et al., 2018). On the other side, product complexity for CE principles can be overcome by dividing the automobile parts into a set of decomposable groups that can be organized as hierarchical structures -from subsystems to components, to parts, to materials/attributes/features/parameters, and standards (Prasad, 1998). This hierarchical system can be adapted to every sector to cope with the product complexity for CE principles.

6.2. Theoretical implications

The theoretical contribution of this study to the literature is that it focuses on Eco-Clusters, which is a subject that has not been studied much, and its application on SMEs in the automotive industry by adapting the general SSCE barriers to Eco-Clusters. In this study, theoretically Fuzzy DEMATEL method was used while analysing the SSCE barriers, but it should not be overlooked that different analysis methods and decision-making mechanisms can be used to obtain different results. For example, hybrid models can be used such as the Analytic Hierarchy Process (AHP) method and the DEMATEL method. In addition to that Technique for Order Preference by Similarity to Ideal Solution, Analytical Network Process, and Data Envelopment Analysis can be used for analysing the barriers.

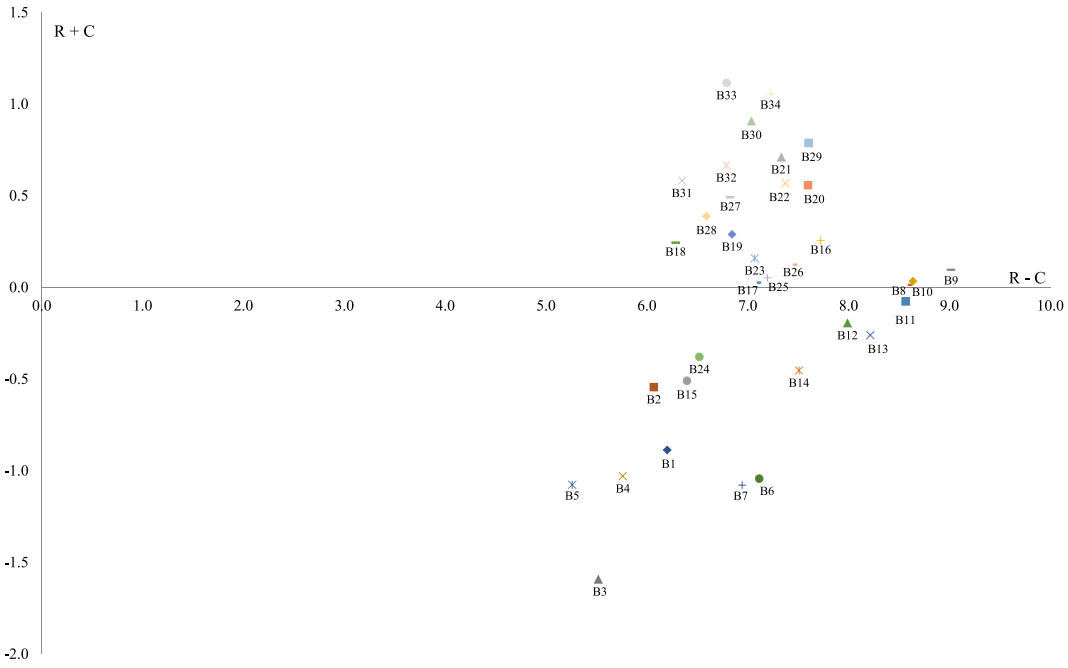

Fig. 5. The causal diagram.

7. Conclusion and future directions

This paper discusses the SSCE barriers under technology, producers, consumers, and policy aspects for SMEs of Eco-Cluster in the automotive industry. Previously mentioned intertwined terms, which are smartness, sustainability, and circularity, presented as a must for companies to overcome SSCE barriers. In addition, barriers discovered throughout the study have been adapted to the Eco-Clusters due to insufficient implementation and publication. Thereby, this study can facilitate the process of those who want to set up an Eco-Cluster in the automotive industry area in the future in terms of which kind of barriers to encountering and how to overcome. In this study, the accredited automotive industrial zone, namely Turkey Connected and Autonomous Vehicles Cluster due to its connection to the automotive Eco-Cluster community in Turkey is taken as an example of Eco-Cluster. In order to propose a solution, SSCE barriers are searched and prioritized by using Fuzzy DEMATEL to provide a guide map that encourages companies to become smarter, more sustainable, and more circular by overcoming these barriers. Based on the results, some managerial implications were recommended to overcome barriers.

Results of the study revealed the that three main causal barriers (B33: Problems of ownership issues in an Eco-Cluster, B34: Lack of governmental support and administrative burden, and B30: Lack of effective execution of environmental regulations) appeared under the same barrier group which is policy barriers. Policy requirements and a need for good execution of current legislation about waste material ownership is an action that requires immediate action. In this context, these three barriers are also connected and propose a solution to overcome the barrier. In addition to that, B9: Lack of integration and collaboration among supply chain partners, B8: Ineffective CE framework adoption, and B10: Product complexity for CE principles is stated as the most influential barriers to the entire Eco-Cluster.

The limitations of this study are the sample size of the analysis conducted throughout the study. Therefore, it would be appropriate to expand the number of respondents to be a more comprehensive and valid analysis. Another limitation of this study is that there is not a real Eco-Cluster example in Turkey. For that reason, the closest structure and network to the Eco-Clusters have been taken as an example for this study to examine interrelationships between the barriers. For further research directions, these barriers can be applied to other types of Eco-Clusters such as the textile and clothing, electronic, consumer goods, construction, chemical industry, and the food sector. Also, the absence of a well-designed and effective framework and strategies for Eco-Cluster for the transition into smart and sustainable CE can be a guideline for multi-tiers of Eco-Clusters.

CRediT authorship contribution statement

Yaşanur Kayikci: Conceptualization, Data curation, Formal analysis, Methodology, Supervision, Writing – review & editing. **Yigit Kazancoglu:** Formal analysis, Validation, Writing – review & editing. **Cisem Lafci:** Methodology, Investigation, Visualization, Writing – original draft. **Nazlican Gozacan:** Methodology, Investigation, Visualization, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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