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Analyzing the causal dynamics of circular-economy drivers in SMES using interpretive structural modeling

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A B S T R A C T

The circular economy has emerged as a crucial way for companies to achieve their sustainability goals. Numerous businesses, especially small and medium-sized enterprises (SMEs), are integrating circular-economy projects into their operations. However, this undertaking presents multiple challenges as many managers must grapple with constraints in resources and expertise. This study's primary objective is to develop a process-oriented decision-making system designed to deal with complex circular-economy scenarios. The proposed analysis system can help SMEs identify the driving forces behind circular-economy principles and evaluate the intricate connections between these determinants, using a unique combination of multiple criteria decision analysis methods (*i.e.*, cognitive mapping, and interpretive structural modeling). Collaborative sessions involving circular-economy experts were instrumental in refining the analysis system, and in-depth discussions with other specialists from the International Labor Organization further enriched this decision-support system. The findings include that circular-economy drivers can be grouped into five clusters: *products*, *processes*, *policies/regulations*, *attitudes/behaviors*, and *communication/awareness*. This structured breakdown provides SMEs with the tools to comprehend and address the pivotal factors that shape circular-economy initiatives. This pioneering study thus produced a comprehensive decision-making model attuned to the intricacies of the circular economy while highlighting the benefits of collaborative endeavors involving industry experts and global decision makers.

1. Introduction

Sustainability is currently a growing concern at all levels of society (Chatzidakis and Shaw, 2018; Dey et al., 2018; Malik et al., 2022; Estupendo et al., 2023). As a result, companies are increasingly looking for ways to achieve greater sustainability. The circular economy is one of these means that has recently become especially prominent in the literature as an exponential number of scholarly studies have lately focused on the circular economy (Lamba et al., 2023).

A few years ago, this topic was rarely explored or expanded upon by the academic community, but companies' sustainability strategies have increasingly required greater know-how about the circular economy, so more authors have concentrated on this subject (Agrawal et al., 2021; Panwar, 2023). Various researchers have sought to define and conceptualize this type of economy, including its advantages and disadvantages, as well as barriers to its implementation (Esposito et al., 2018; Malik et al., 2022). A rising number of case studies are also being conducted to examine the application of circular-economy strategies in

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specific companies, sectors, industries, and localities (Fernandes et al., 2018; Mendes et al., 2022).

Despite the rapidly expanding literature on the circular economy, two major recurring limitations have restricted previous research: (1) the unclear way in which circular-economy drivers are organized (*cf.* Arranz et al., 2022); and (2) the scarcity of analyses of the causal relationships between these determinants (*cf.* Estupendo et al., 2023). The present study, therefore, sought to develop an analysis system that addresses these two limitations. The resulting analysis system applies two methods that improve decision-making processes involving multiple complex problems and/or contexts: (1) cognitive mapping; and (2) interpretive structural modeling (ISM). This analysis system can be an important decision-support tool for those implementing circular-economy projects and/or solving problems in circular-economy contexts.

The proposed analysis system was developed based on specific methodologies that can achieve these objectives using the multiple criteria decision analysis (MCDA) approach (Belton and Stewart, 2002), and can thus integrate objective and subjective aspects. The two methods applied were cognitive mapping and ISM, which both concentrate on solving complex decision problems and fall within the MCDA category. Notably, drawing on these methodologies, the study provides a process-oriented analysis system designed to navigate the complexities of circular-economy scenarios. In doing so, it contributes a novel approach to understanding and managing circular-economy drivers in SMEs, filling another gap in the literature highlighted by Chatzidakis and Shaw (2018), Goworek et al. (2018) and Arranz et al. (2022). A literature review found no prior research that has applied this dual methodology specifically to small and medium-sized enterprise (SME) contexts, so the insights gained through this study's results add to the extant literature on the circular economy, operational research, and management science.

Cognitive mapping was used in the initial problem-structuring phase. This method provided a clearer and more holistic vision of the entire decision problem under study and facilitated the identification of circular-economy drivers by arranging them in a well-organized, easy-to-understand way. Cognitive mapping also highlighted whether the effect of these drivers on circular-economy projects is positive or negative. ISM was applied in the subsequent problem-assessment phase of the MCDA to identify and examine the causal relationships between the circular-economy drivers identified in the first phase. ISM was also used to prioritize circular-economy drivers based on their relative importance. The results show that SMEs can use the proposed analysis system to ascertain which drivers are more important—and how they influence each other—in specific business contexts.

The process-oriented nature of this research (see Bell and Morse, 2013; Vaz-Patto et al., 2024) ensured that the panel of decision makers recruited played a central role in the system's development as their shared expertise and interactions were needed to apply the proposed methods. The knowledge shared by these participants was thus integrated into the final proposed analysis system. The expert panel specifically identified multiple circular-economy drivers, verifying not only how they influence this type of economy but also how they influence each other. The panel further defined a hierarchy—by order of importance—of the previously identified determinants. The analysis system developed can serve as a decision-making tool for SMEs and larger companies facing complex problems in circular-economy contexts. In addition, its emphasis on collaboration with both circular-economy experts and specialists from the United Nations' International Labor Organization adds practical relevance to the debates, potentially influencing future discussions on scaling sustainability and managerial responses within the broader context of the circular economy.

The present paper has a five-section structure. Section one contains the introduction, while section two presents the results of the literature review. Section three covers the methodological background, and section four provides details on the methods' application and analyses of the results. The last section offers the conclusions and lines for future research.

2. Related literature and research gaps

The circular economy is, at a linguistic level, the antonym of a linear economy based on a one-way system that, at its core, transforms natural resources into waste through production processes (Murray et al., 2017; Malik et al., 2022; Lamba et al., 2023). The circular economy is, in contrast, a closed loop formed by the extraction and transformation of resources and the distribution, use, and recovery of goods and materials (Park et al., 2010; Stahel, 2016; Agrawal et al., 2021). Companies first extract resources from the natural environment to transform them into products and services. Then, these goods and amenities are distributed and consumed by people and other businesses. Finally, the cycle is closed by the collection and recovery of these products and services. At this stage, innovation plays a major role in giving new value to previously consumed goods (Stahel, 2016; de Arroyabe et al., 2021; Panwar, 2023).

The first explicit definitions of the circular economy emerged in China, where the term was first conceptualized as a closed, cyclical flow of materials encompassing the entire economic system (Geng and Doberstein, 2008; Lamba et al., 2023). According to Peters et al. (2007) and Agrawal et al. (2021), the basic processes of the circular economy are to close material flows, reduce resources, and recycle and reuse products to improve people's quality of life by increasing resource efficiency. Gregson et al. (2015) and Malik et al. (2022) add that this type of economy seeks to maximize the life of products and materials by recovering them after they have been consumed. The circular-economy logic thus translates into reusing what is possible, recycling what cannot be reused, repairing what is damaged, and rebuilding what cannot be repaired (Stahel, 2016; Esposito et al., 2018; Panwar, 2023).

Scholars have developed multiple definitions of the circular economy. Prieto-Sandoval et al. (2018), for example, integrated the findings of different researchers to arrive at a cohesive, coherent conceptualization of this economy. The authors assert that four components should be included in the circular-economy concept, of which the first is the circulation of resources and energy to ensure a decreasing demand for resources and the addition of value to used goods. The second feature is strategies at the micro, meso, and macro level, while the third is the function of the circular economy as a pathway to environmental sustainability (Huang et al., 2023). The last component is a close relationship with the level of innovation in each society.

The most cohesive, explicit definition given by Prieto-Sandoval et al. (2018, p. 610) is as follows: *"The circular economy is an economic system that represents a change of paradigm in the way that human society is interrelated with nature and aims to prevent the depletion of resources, close energy and materials loops, and facilitate sustainable development through its implementation at the micro (enterprises and consumers), meso (economic agents integrated in symbiosis) and macro (city, regions, and governments) levels. Attaining this circular model requires cyclical and regenerative environmental innovations in the way society legislates, produces, and consumes"*.

Prieto-Sandoval et al.'s (2018) second circular-economy component provides the most comprehensive understanding. Three distinct levels are involved in implementations of this type of economy: micro, meso, and macro (Yuan et al., 2006; Malik et al., 2022). The micro level includes businesses and consumers, so the focus is on improving internal processes and developing eco-innovations. Firms' willingness to implement circular-economy strategies depends on the environmental management maturity of each company, which is affected by the positive impact that the implementation of the circular economy has on consumers, as well as the associated cost reduction (Ormazabal et al., 2016; Goworek et al., 2018; Lamba et al., 2023). At the meso level, companies are part of industrial symbioses, and these organizations benefit from the surrounding regional economy because they can collect recycled waste from the entire region (Geng et al., 2012; Panwar, 2023). The macro level comprises the development of eco-cities through new environmental policies (Yuan et al., 2006). The circular economy, therefore, encompasses varied areas that ultimately form its basic components. For instance, related initiatives focus on increasing product life and material efficiency and on ensuring sustainable production and consumption. This economy also emphasizes waste management and asset recovery networks. In addition, supply chains are closed loops based on a cradle-to-cradle approach, which suggests that products, once used, can become resources to make new products (De Pauw et al., 2014; Esposito et al., 2018).

Innovation is widely acknowledged to be a key pillar of the circular economy, especially innovation in production, legislation, and the way consumers use products (Prieto-Sandoval et al., 2018; Lamba et al., 2023). Thus, environmental innovation—or eco-innovation—has evolved over time in parallel with the circular economy. This process has been described by Hofstra and Huisingh (2014) and Arranz et al. (2022) as a major shift in viewing nature from an anthropocentric perspective to an ecosphere-centered one, which increasingly influences the behavior of societies and the development of environmental innovations. According to Hofstra and Huisingh (2014) and Garcés-Ayerbe et al. (2019), four distinct types of eco-innovation exist: two shaped by the anthropocentric view and two by the ecosphere-centered approach. The latter includes the circular economy, so these two forms of eco-innovation are cyclical and regenerative. Cyclical creativity connects humans and nature with ecosystems and improves systems' ability to close cycles. Regenerative eco-innovation relates to the capability of these ecosystems for creating additional value for humans and nature.

SMEs represent 90% of the world's businesses and employ between 50% and 60% of the world's population (*cf.* Dey et al., 2018; Garcés-Ayerbe et al., 2019), so understanding the circular-economy concept is important in SME contexts. These companies are at different levels of environmental maturity, and some have never heard of this type of economy (Ormazabal et al., 2016; Garcés-Ayerbe et al., 2019). Ormazabal et al. (2015) identify six stages of maturity in firms' environmental management.

In Stage 1: Legal Requirements, each company identifies which environmental requirements it must fulfil by law. In Stage 2: Assignment of Environmental Responsibility, the firms assign the task of managing the company's environmental commitments to fulfil the necessary legal requirements. In Stage 3: Systematization, each firm formalizes its environmental management practices and becomes a certified environmental management system. In Stage 4: ECO2, companies proactively reduce their environmental impacts and encourage employees to produce ideas for how to improve efficiency to obtain financial benefits. In Stage 5: Eco-innovative Products and Services, firms develop new products or services with environmental impacts in mind. In Stage 6: Leading Green Company, companies becomes a reference point in environmental management through marketing and communication. Firms with more flexible business models tend to be at later stages of maturity and provide information to their customers on how to consume their products correctly to increase these items' life cycle (Ormazabal et al., 2016; Esposito et al., 2018).

The implementation of the circular economy is a gradual process, starting with the introduction of measures for recycling and reusing materials. These strategies are followed by procedures that minimize energy consumption and new products that consider environmental effects. Finally, firms become more proactive in implementing the circular economy in terms of reducing their water consumption and switching to renewable energy sources. These measures are applied gradually, starting with control measures (*e.g.*, reduction of pollution levels) and ending with proactive and preventive measures (Garcés-Ayerbe et al., 2019).

SMEs find that implementing the circular economy is a challenging process as these companies encounter major barriers during the transition period. Ormazabal et al. (2016) and Malik et al. (2022) report that the main obstacles to SME circular-economy projects are: (1) a lack of financial incentives from the government; (2) the absence of internal technical and economic resources; and (3) consumers' disinterest in protecting the environment. Chatzidakis and Shaw (2018) also emphasize the lack of support from both the supply side (*i.e.*, suppliers) and the demand side (*i.e.*, consumers). Few suppliers offer the input needed by SMEs to produce their products sustainably and in line with the circular economy. In terms of consumer demand, the main problem is that clients receive little information about the circular economy, so they stop short of consuming these types of environmentally friendly products because consumers are ignorant of the benefits of the circular economy.

When implemented properly, this kind of economy offers multiple benefits to SMEs. Ormazabal et al. (2016) and Malik et al. (2022) assert that SMEs with an advanced level of environmental management maturity receive three benefits from the circular economy: (1) increased corporate prestige among consumers; (2) cost reduction; and (3) guaranteed sustainability for the future. Chatzidakis and Shaw (2018), in turn, identify the main benefits of the circular economy as reduced material costs, fresh competitive advantages, and new markets to explore. Ormazabal et al. (2016), however, found that most industrial-sector companies obtain no advantages from implementing circular-economy strategies. The literature review highlights the importance of the circular economy to SMEs. Table 1 provides an additional summary of the contributions of previous studies to this field of research, as well as their limitations.

Table 1 presents a sample of related studies conducted over the years. Their main limitations can be divided into two broad categories. The first is the scarcity of studies that have identified circular-economy determinants in SMEs and the unclear methods used to do this. The present research used cognitive mapping to address this limitation, thereby providing a more lucid, informed visualization of the complex decision problem in question and isolated the most important determinants (*i.e.*, determining factors and/or drivers) of circular economy.

The second limitation is inadequate analysis of the causal relationships between circular-economy determinants. The ISM method was applied in this study to define the causal relationships between each pair of determinants and a hierarchy of the significance of these same drivers within the decision-support system.

While several authors contend that no single method or technique stands out as universally superior (*cf.* Belton and Stewart, 2002; Santos et al., 2024), the method selection in the present study was guided by four key factors. First, cognitive mapping and ISM are well-established socio-technical methods praised for their ease of application and effectiveness in facilitating decision-making across various organizational settings. Second, following Belton and Stewart's (2002) recommendations, the chosen methods were tailored to the specific decision context and the characteristics of the expert panel. Third, ISM excels in integrating qualitative and quantitative criteria and managing their interdependencies when examining cause-and-effect relationships (Çipi et al., 2023). Lastly, although cognitive mapping and ISM are relatively popular individually, their combined application is rare, highlighting the originality of this framework within the field of the circular economy.

3. Methodological background

This investigation is based on the MCDA approach, which includes cognitive mapping and ISM. MCDA focuses on supporting decision making involving quantitative and qualitative objectives, so it supports complex problem solving by creating a platform in which stakeholders share information with each other to reach consensual decisions (Dehe and Bamford, 2015). According to Jalali et al. (2016), Oliveira et al. (2017), and Fernandes et al. (2018), the decision-support process comprises three phases for each MCDA application: (1) structuring; (2) evaluation; and (3) recommendations. The current decision problem was thus first structured using cognitive mapping in order to identify the

Table 1
Contributions to circular-economy research.

AUTHORS	OBJECTIVES	CONTRIBUTIONS	LIMITATIONS
Geng and Doberstein (2008)	Define the circular economy and its development in China, as well as the challenges and barriers to its implementation	▪ Formulation of objectives, legislation, policies, and measures implemented in China to promote firms' transition to the circular economy in order to reduce this country's environmental impacts.	▪ Scarce data available for this study. ▪ Research based on the authors' professional experience.
Ormazabal et al. (2016)	Analyze the relationship between the levels of environmental management maturity and of circular-economy implementation in SMEs in Spain's Basque Country	▪ Confirmation of a positive relationship between companies' level of environmental management maturity and their need to implement circular-economy strategies.	▪ Extremely small sample of only 17 SMEs.
Prieto-Sandoval et al. (2018)	Propose a cohesive, consensual definition of the circular economy and clarify its relationship with eco-innovation	▪ Knowledge map of the circular economy, including its main definitions, principles, and determinants. ▪ Examples of eco-innovation developed in circular-economy implementations.	▪ Study mostly based on academic articles. ▪ Search for articles using only one database.
Garcés-Ayerbe et al. (2019)	Examine circular-economy practices and their implementation by European SMEs	▪ Circular-economy implementation is a gradual process, starting with control measures and ending with prevention measures.	▪ Lack of data for analysis, so only preliminary results.
Malik et al. (2022)	Develop a comprehensive multilevel conceptual framework for understanding the adoption of circular economy practices specifically by SMEs in emerging markets	▪ Practical insights beneficial for SMEs and policymakers in fostering sustainable business practices.	▪ The applicability to diverse emerging markets and variations in industry contexts may be constrained, potentially leading to validation challenges in real-world settings.

most crucial circular-economy drivers.

3.1. Cognitive mapping and causal dynamics

The term "cognitive map" is used to describe a visual depiction of a person or group's ideas about a challenge they need to overcome. Eden (2004, p. 673) specifies that *"a cognitive map is the representation of thinking about a problem that follows from the process of mapping"*. This type of map structures decision problems by presenting them in a simple, visually informative format and facilitating communication among decision makers based on their mental associations (Ferreira et al., 2022). Ferreira et al. (2014, p. 5) further observe that: "[Because cognitive maps are] *simple, interactive and extremely versatile, they promote discussion among the agents involved in a decision-making process. This allows increased transparency and a reduction in omitted criteria. Thus, simplicity and transparency lead to a better understanding of the problem under consideration*".

Cognitive mapping is widely recognized as an important way to structure complex decision problems because this method is one of the most versatile decision-support tools available (Oliveira et al., 2017). Cognitive maps are usually based on interviews, so these representations tend to represent the subjective components of interviewees' ideas (Eden, 2004), and describe how people think about a decision problem, including their values, beliefs, and attitudes (Ferreira et al., 2022). The maps are made up of nodes that represent concepts, which are interconnected by arrows pointing in specific directions that represent the nodes' implications and consequences for each other (Eden and Ackermann, 2004) and constitute the cause-and-effect relationships between concepts. The implications are based on individuals' opinions (*i.e.*, answers given in interviews), so their thinking is represented by the resulting cognitive map. When the causal relationship is positive (*i.e.*, one factor with a constructive influence on another variable), the arrow includes a plus sign (+). A negative cause-and-effect relationship is represented by an arrow with a minus sign (−) (Klein and Cooper, 1992; Abramova, 2016; Ferreira et al., 2022).

Village et al. (2013) divide the cognitive mapping process into various steps. The first is choosing the information collection method, namely either open-ended questions or pre-selected closed-ended ones. The second step is clarifying the facilitator's role as s/he will influence and expedite the participation of those involved in constructing the cognitive map. The next step is selecting the mapping method, which can be done in a traditional manual way (*i.e.*, pen and paper) or with software developed to draw maps and analyze decision makers' input (*e.g.*, *bioCOmplexes Contact Map*, *Decision Explorer*, *VisionQuest*, and *COPE software*). The fourth step is choosing the best method for creating the group map, which can be composed exclusively by the facilitator, jointly by the facilitator and participants, or only by the participants with minor input from the facilitator. The last step is deciding how to analyze and interpret the cognitive map (*i.e.*, by the number of concepts and links, by form and structure, and/or by content). The advantages of these maps are the interactive procedures required to formulate the visualizations and their flexibility and ease of use (Ferreira et al., 2022). The next subsection describes how ISM is used in the evaluation phase of the decision-support process.

3.2. Interpretive structural modeling

The ISM method was created by Warfield (1974) to identify relationships between multiple influential factors in complex socioeconomic systems (*cf.* Sohani and Sohani, 2012; Yu et al., 2018; Xu and Zou, 2020; Mathivathanan et al., 2021). The ISM technique allows individuals or groups to develop graphs that represent the complex links between the components of a decision problem. This method combines three distinct linguistic levels—(1) words; (2) diagrams; and (3) mathematics—used to organize complex problems (Ansari et al., 2013) and provide a fuller understanding of them *via* ISM diagrams (Khan and Rahman, 2017; Kumar et al., 2017). This format facilitates complex decisions by analyzing causal relationships, for instance, between circular-economy drivers in SMEs.

The ISM is interpretive in the sense that entire groups of individuals can decide which—and how—variables are related. This method is also structural since it develops a framework based on the network of variables and relationships between the relevant factors (Sohani and Sohani, 2012). In the present study, ISM was chosen because it assumes that the circular-economy determinants identified are interrelated (*i.e.*, that dependency links exist between the variables and/or drivers). In contrast, other decision-support methodologies (*e.g.*, analytic hierarchy process) focus more on specific behaviors in singular circumstances as opposed to concentrating on the dynamic complexities of the relationships between variables (Shahabadkar, 2012).

The ISM method was selected for the current research in order to utilize experts' knowledge and skills to identify and analyze measures that help solve the complex decision problem selected and then build a multi-level structural analysis system. According to Eswarlal et al. (2011) and Jayant and Azhar (2014), ISM applications should follow nine steps:

1. Identify the variables of the problem or issue with experts' help.
2. Establish contextual relationships between the variables defined in step one, again with the experts' assistance.
3. Develop a structural self-interaction matrix (SSIM) to define the links between pairs of variables, thereby revealing their binary correlations.
4. Construct an accessibility or reachability matrix (RM) based on the SSIM by assigning a 1 or 0 according to the paired variables' relationships.
5. Check this matrix for transitivity.
6. Divide the RM into different levels.
7. Draw a diagram based on the links between the variables previously defined in the RM.
8. Translate the diagram into the final ISM graph by converting the nodes of variables into coordinates.
9. Review the ISM to ascertain if no non-conformities exist and make changes if necessary.

The first ISM step must include a comprehensive literature review in order to identify possible determinants of importance to the decision problem. Step two analyzes the variables from step one by discussing them in a meeting with a panel of relevant experts to determine which factors should be examined. The third step produces an SSIM that includes the variables' contextual relationships as determined by the specialists. These links can be of four distinct types: (1) one variable that affects another variable (*V*); (2) one variable that is affected by another (*A*); (3) both variables affecting each other (*X*); and (4) unrelated variables (*O*). In the fourth step, the RM (*i.e.*, the accessibility matrix) is developed based on the SSIM by replacing the symbols *A*, *X*, *V*, and *O* with "0" and "1" depending on the experts' assessment of the variables' contextual relationships. The fifth step is to check the transitivity of these connections, which is one of ISM's main theoretical assumptions. The transitivity rule states that, if variable *A* is related to variable *B* and *B* is related to variable *C*, then variable *A* is related to *C*. Step six involves organizing the variables into a hierarchy. To do this, the antecedent and accessibility sets of each factor are identified based on the previous matrix. The antecedent set consists of each variable and the factors that affect it. The accessibility set comprises each variable and the factors affected by that variable. The hierarchical level for each factor is determined by the intersection of its accessibility and antecedent sets. If the intersection set of a variable is equal to its accessibility set, that factor's level is "1", which is the highest in the ISM hierarchy. For variables that are at another level, the previous procedure is repeated but with Level 1 variables no longer appearing in the identified sets. This process is repeated for each factor until the intersection set is equal to the accessibility set. In the seventh and eighth steps, a diagram is drawn that presents the variables by their hierarchical levels. A complementary *matrice d'impacts croisés multiplication appliqués à un classement* (MICMAC) analysis is also conducted. Finally, the entire ISM model is reviewed, and changes are made as needed.

The methodologies applied were considered of particular value because of their potential contribution to the subsequent analysis of the causal dynamics between circular-economy drivers. Both methods (*i.e.*, cognitive mapping and ISM) were expected to facilitate the creation of an innovative analysis system for assessing these dynamics. No previous studies with the same objectives or similar methodologies were found in the literature even though cognitive mapping is an important tool for decision making, especially in complex contexts and with scarce information—as was the case of the present research topic.

This MCDA method thus had the potential to provide a more structured visualization of the intricate decision problem in question that incorporated the causal relationships and interactions between the varied variables under study. Cognitive mapping was selected for this research because the resulting map could present multiple circular-economy drivers in a well-organized, informed way, including the causal links found between them. The resulting tool was developed to help not only companies that want to implement circular-economy strategies in their business and/or in their daily operations but also firms that already engage in circular-economy activities but want to increase their positive effect on the company's output.

In addition, ISM offered two major potential contributions to this research. First, this method identifies established relationships between the multiple variables (*i.e.*, measures, factors, and/or drivers) affecting the complex decision problem at hand. A panel of experts were asked to identify the connections between each pair of variables. Second, ISM can create a hierarchy showing the relative importance of the variables that can resolve the problem. This prioritization of circular-economy measures and/or factors (*i.e.*, drivers) is fundamental for companies that want to implement circular-economy tactics, providing them with a clearer understanding of which drivers should ensure more positive outcomes. The results of this study can both complement previous studies and drive future research.

4. Application and results

The first phase of the study (*i.e.*, problem structuring) began with a procedure using the "post-its technique" (Eden and Ackermann, 2004), which resulted in an elaborate cognitive map. The map presents the circular-economy drivers in a clear, informed way because it structures the decision problem. ISM was applied next in the evaluation phase to facilitate the panel's identification of the causal relationships between the drivers and to create a hierarchy according to the importance of these factors. The combination of these techniques, therefore, organized and clarified the decision problem under study.

4.1. Cognitive structure

Two working sessions were held with a panel of experts. Each meeting lasted three hours and included seven specialists. This number of participants followed Eden and Ackermann's (2004) guidelines, namely between 5 and 12 panel members. Three criteria were considered while recruiting the experts: (1) know-how about the circular economy; (2) decision-making positions in SMEs; and (3) heterogeneity in terms of gender, professional experience, and business area. Although the experts were based in Portugal, they all had previously worked on projects throughout Europe. They were chosen from diverse backgrounds, each bringing over ten years of professional experience in relevant fields and extensive knowledge of circular-economy projects, thus enriching the discussions. Participation was voluntary, despite their selection based on professional expertise.

Notably, the process-oriented nature of the current research meant that representativeness was not—and did not need to be—a concern as the primary goal was for the experts to discuss the decision problem and learn from each other's knowledge and prior experience. As explained by Bell and Morse (2013), in a process-oriented study, the primary objective is to delve into and comprehend the dynamics and steps of a specific process. This implies that the focus is on the exchange of insights and expertise rather than obtaining a representative sample of individuals. Because the research is process-oriented, collaborative learning among the panel members is prioritized over detailed individual characterizations. The goal is to gain a holistic understanding of the decision-making process by facilitating meaningful discussions among experts. Therefore, the need for a deep characterization of each panel member is diminished as the emphasis is on the overall process and collective expertise rather than individual attributes or representativeness (*cf.* Bell and Morse, 2013).

The working sessions were coordinated by two facilitators who guided the entire process and who were responsible for recording the results. Both meetings took place remotely (*i.e.*, online) even though the two methods are usually applied in face-to-face sessions. Technological advances allowed these meetings to be conducted in the Zoom platform, so all the experts could be present and the necessary interactions were generated as if the panel members were there in person.

The first meeting started with a brief presentation of each expert's professional experience, current company, and business areas in which they were active. The facilitators then explained the techniques that would be applied and the *Miro* platform features used to facilitate the cognitive mapping procedures based on the "post-its technique" developed by Eden and Ackermann (2004). The rest of the session was divided into three parts.

First, the facilitators asked the following trigger question: *"Based on your professional experience and values, what are the drivers and/or catalysts of circular-economy projects in SME contexts?"*. The decision makers wrote down the determinants they considered important on post-it notes, each of which could contain only one factor. The panel members had to add a "+" or "–" to each post-it note depending on the influence of that driver on the circular economy. The *Miro* platform ensured that all the decision makers could participate and interact in real time. Throughout this procedure, the experts discussed their ideas continuously, which resulted in a list of more than 100 drivers.

In the second part, all the drivers identified were grouped into clusters. Once again, the decision makers debated and interacted in order to generate a list of clusters and allocate each factor to the best cluster. Five clusters were identified and labeled as follows: *Products* (C1); *Processes* (C2); *Policies/Regulations* (C3); *Communication/ Awareness* (C4); and *Attitudes/Behaviors* (C5).

In the last part of the first meeting, the panel created a three-level hierarchy according to the degree of importance of the circular-economy drivers within each cluster. The decision makers placed the most significant factors at the top, those of intermediate importance in the middle, and, at the bottom of the cluster, the least significant drivers. After the first working session with the panel, the results were translated into a group cognitive map, using the *Decision Explorer* software. The map presented in Fig. 1 was validated by the decision makers in the second meeting (size restrictions prevent a detailed visualization, but an editable version of the complete group cognitive map can be obtained by contacting the corresponding author).

As shown in Fig. 1, the cognitive map developed provides clarity in decision-making, guiding the panel to focus on the most impactful circular-economy drivers. The use of a systematic approach additionally adds objectivity to the representation, and the validation of the map in a subsequent meeting underscores its credibility. This iterative decision-making process demonstrates a commitment to refining and improving the visual representation of circular-economy factors based on collective insights, ultimately enhancing the effectiveness of the decision-making process. The next step was the evaluation phase.

4.2. *Application of ISM method*

The second session with the experts started with a presentation and discussion of the group cognitive map based on the results of the first meeting. The facilitators then briefly explained the ISM method, procedures, and main objectives, that is: (1) to analyze how circular-economy drivers are related (*i.e.*, each factor's influence on the others and the influence of other drivers on that variable); and (2) to rank the drivers by overall importance. The ISM application began with a multi-voting process, in which the panel chose the circular-economy drivers they considered to be the most influential within each cluster. Table 2 presents the results of this selection process.

In the last part of the second session, the panel members defined the causal relationships between circular-economy drivers. Multiple matrices were developed and filled in by the experts, namely an inter-cluster matrix for the links between clusters and additional matrices for the connections within each cluster. To fill in the matrices, the decision makers determined which kind of causal relationship exists between each pair of clusters and of drivers within the same cluster in order to understand the connections between the clusters and each cluster's factors. The links can be: direct (V); inverse (A); unrelated (O); or bidirectional (X). The expert panel discussed the possible connection for each pair of clusters or drivers. Only after the panel had reached a consensus was the type of relationship placed in the corresponding matrix.

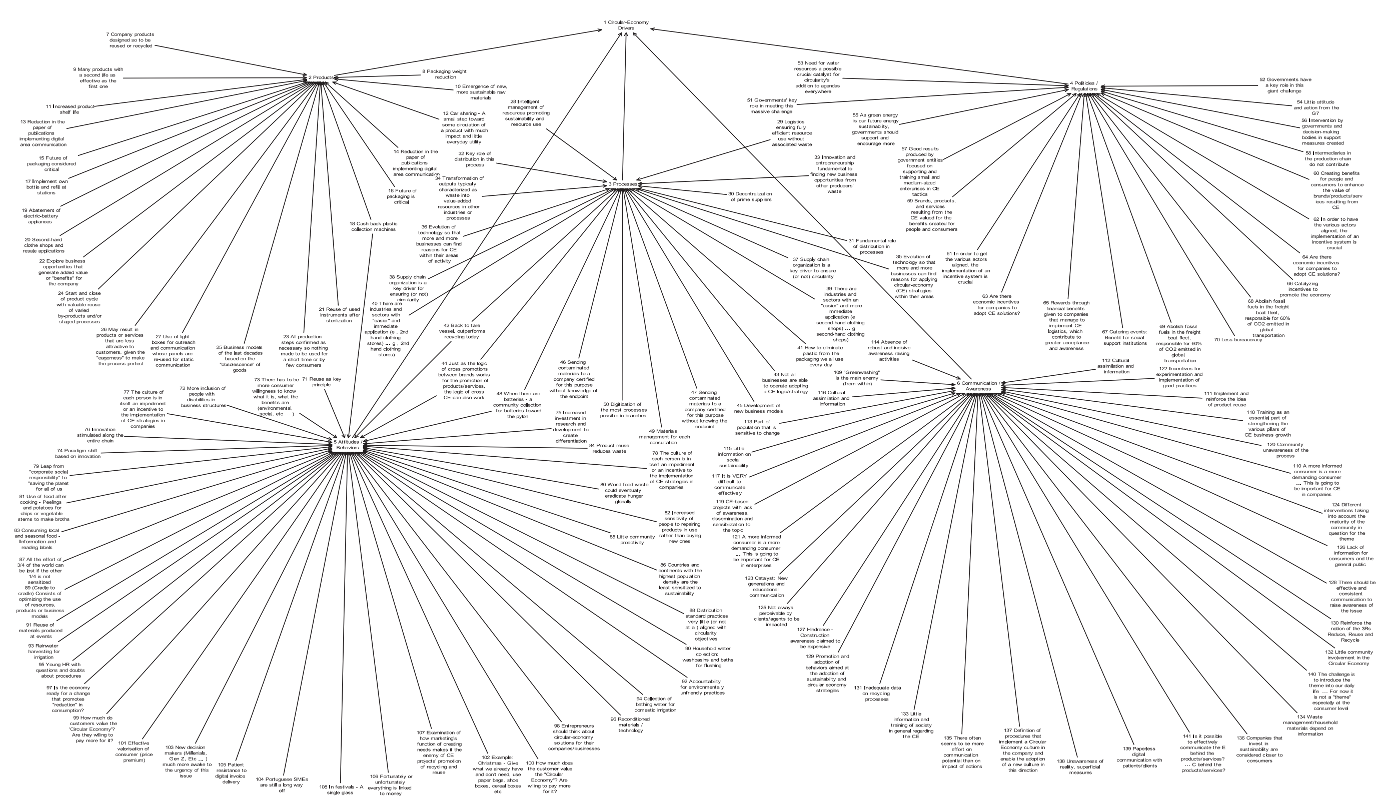

Fig. 1. Group cognitive map.

Table 2
Selected criteria (SC) in each cluster (C).

PRODUCTS (C1)	PROCESSES (C2)	POLICIES/REGULATIONS (C3)	ATTITUDES/BEHAVIORS (C4)	COMMUNICATION/ AWARENESS (C5)
Company products designed so to be reused or recycled (SC7)	Intelligent management of resources promoting sustainability and resource use (SC28)	Governments' key role in meeting this massive challenge (SC51)	Innovation stimulated along the entire chain (SC76)	Training as an essential part of strengthening the various pillars of CE business growth (SC118)
Many products with a second life as effective as the first one (SC9)	Logistics ensuring fully efficient resource use without associated waste (SC29)	Intervention by governments and decision-making bodies in support measures created (SC56)	Reuse as key principle (SC71)	Absence of robust and incisive awareness-raising activities (SC114) (−)
Emergence of new, more sustainable raw materials (SC10)	Transformation of outputs typically characterized as waste into value-added resources in other industries or processes (SC34)	Brands, products, and services resulting from the CE valued for the benefits created for people and consumers (SC59)	Increased investment in research and development to create differentiation (SC75)	Part of population that is sensitive to change (SC113)
Increased product shelf life (SC11)	Fundamental role of distribution in processes (SC31)	Need for water resources a possible crucial catalyst for circularity's addition to agendas everywhere (SC53)	Examination of how marketing's function of creating needs makes it the enemy of CE projects' promotion of recycling and reuse (SC107)	Incentives for experimentation and implementation of good practices (SC122)
Start and close of product cycle with valuable reuse of varied by-products and/or staged processes (SC24)	Digitization of the most processes possible in branches (SC50)	Good results produced by government entities focused on supporting and training small and medium-sized enterprises in CE tactics (SC57)	More inclusion of people with disabilities in business structures (SC72)	Cultural assimilation and information (SC116)
All production steps confirmed as necessary so nothing made to be used for a short time or by few consumers (SC23)	Innovation and entrepreneurship fundamental to finding new business opportunities from other producers' waste (SC33)	Rewards through financial benefits given to companies that manage to implement CE logistics, which contribute to greater acceptance and awareness (SC65)	Paradigm shift based on innovation (SC74)	Inadequate data on recycling processes (SC131) (−)
Future of packaging considered critical (SC15)	Evolution of technology so that more and more businesses can find reasons for applying circular-economy (CE) strategies within their areas (SC35)	Less bureaucracy (SC70)	Accountability for environmentally unfriendly practices (SC92)	Little information and training of society in general regarding the CE (SC133) (−)

All the matrices were filled in and the causal links between drivers were identified so that the ISM method could be used to create an analysis system that would support the implementation of circular-economy strategies in companies and/or solve problems associated with the circular economy. This analysis system was designed to help companies understand which drivers are the most important, how they influence each other, and which of these same determinants should be prioritized. SMEs, in particular, can use the analysis system as a basic decision-support system to solve complex challenges in circular-economy implementations.

As discussed previously in section three, decision makers need to follow multiple steps to apply the ISM method and generate the final diagram summarizing the entire analysis system. The first step was to develop the SSIMs (see Table 3), which present the causal relationships identified by the expert panel.

After completing an SSIM for all the clusters and for each cluster's most important criteria, the next step was to develop the RM for each cluster in order to reveal any binary links. Using the SSIMs created, a "1" was assigned to all *V* or *X* relationships and a "0" to all other connections. Table 4 exemplifies the RM for C2.

The final RMs (FRMs) were then created by using Warshall's (1962) algorithm to do the auxiliary calculations. This algorithm was applied to all the clusters at once and as many times as needed to cover all the selected criteria (*i.e.*, drivers) in each cluster. Table 5 presents the FRM obtained for C2. The totals of this matrix's rows and columns subsequently constituted the coordinates for each selected criterion in the MICMAC analysis, as explained in greater detail below.

Once the FRMs had been constructed, the panel could focus on meeting the second objective of our ISM application (*i.e.*, the hierarchization of drivers). The selected criteria of each cluster were organized into a hierarchy by order of importance within that cluster. For example, Table 5 was used to carry out the calculations to produce C2's hierarchy. Table 6 in turn used that FRM as a starting point, analyzing that matrix row by row and column by column, with each row of the FRM corresponding to a specific criterion.

The left column of Table 6 shows the reachability sets, which consist of the drivers that have a "1" in the relevant row. The middle column shows the antecedent sets, which consist of the criteria that have a "1" in the pertinent column. The right column contains the intersection sets formed by the overlap between the accessibility and antecedent sets in the two previous columns. The accessibility and intersection sets determined the hierarchical level assigned to each criterion as the drivers for which these two sets were equal were assigned to Level 1.

The last step in the ISM application is MICMAC analysis, which categorizes all the criteria in terms of driving and dependency power. The FRMs provided the totals of the rows and columns needed to define each driver's coordinates and thus its quadrant. Fig. 2 shows the MICMAC results for C2 as an example. The first quadrant (*i.e.*, I: Autonomous) of this graph contains the criteria with reduced driving and dependency power. The second quadrant (*i.e.*, II: Dependent) comprises the factors with low driving power but high dependency power. The third quadrant (*i.e.*, III: Linkage) encloses the drivers with strong driving and dependency power. Finally, the fourth quadrant (*i.e.*, IV: Independent) has the criteria with high driving power but low dependency power.

After completing all the calculations of the ISM application for the five clusters and their selected criteria, the ISM diagram was created to summarize the final analysis system. Fig. 3 presents the diagram, which aggregates the results of the five clusters, including the hierarchies of the drivers of each cluster.

According to Fig. 3, the determinants within C1 share a common ground in elevating the principles of circular economy within product-centric approaches. This seems to align with the conclusions of Mendes et al. (2022) and Estupendo et al. (2023). Positioned at the same

Table 3
Structural self-interaction matrices for inter-cluster and intra-cluster analyses.

CLUSTERS

	C1	C2	C3	C4	C5
C1		X	A	X	X
C2			A	X	X
C3				V	V
C4					X
C5					

STRUCTURAL SELF-INTERACTION MATRIX (SSIM)-CLUSTER (C)1

	SC7	SC9	SC10	SC11	SC24	SC23	SC15
SC7		X	X	X	O	X	X
SC9			X	X	O	X	X
SC10				X	X	X	X
SC11					X	X	X
SC24						X	X
SC23							X
SC15							

SSIM-C2

	SC28	SC29	SC34	SC31	SC50	SC33	SC35
SC28		X	X	X	O	X	X
SC29			X	X	X	X	X
SC34				X	O	X	X
SC31					O	X	X
SC50						O	X
SC33							X
SC35							

SSIM-C3

	SC51	SC56	SC59	SC53	SC57	SC65	SC70
SC51		X	V	X	V	V	V
SC56			V	X	V	V	V
SC59				O	O	X	A
SC53					O	O	O
SC57						V	V
SC65							O
SC70							

SSIM-C4

	SC76	SC71	SC75	SC107	SC72	SC74	SC92
SC76		X	X	X	O	X	O
SC71			O	X	O	X	O
SC75				O	O	X	O
SC107					O	X	O
SC72						O	O
SC74							X
SC92							

SSIM-C5

	SC118	SC114	SC113	SC122	SC116	SC131	SC133
SC118		X	V	X	X	X	X
SC114			V	A	X	X	X
SC113				A	V	V	V
SC122					X	V	V
SC116						A	A
SC131							X
SC133							

Note. C = cluster; *X* = bidirectional; *A* = inverse; *V* = direct.
Note. C = cluster; SC = selected criterion; *X* = both variables affect each other; *O* = the variables are unrelated; *V* = first variable affects another driver; *A* = first variable is affected by another driver.

Table 4
Reachability matrix for C2.

	SC28	SC29	SC34	SC31	SC50	SC33	SC35
SC28	1	1	1	1	0	1	1
SC29	1	1	1	1	1	1	1
SC34	1	1	1	1	0	1	1
SC31	1	1	1	1	0	1	1
SC50	0	1	0	0	1	0	1
SC33	1	1	1	1	0	1	1
SC35	1	1	1	1	1	1	1

Note. SC = selected criterion.

Table 5
Final reachability matrix for C2.

	SC28	SC29	SC34	SC31	SC50	SC33	SC35	Dr Pw
SC28	1	1	1	1	1*	1	1	7
SC29	1	1	1	1	1	1	1	7
SC34	1	1	1	1	1*	1	1	7
SC31	1	1	1	1	1*	1	1	7
SC50	1*	1	1*	1*	1	1*	1	7
SC33	1	1	1	1	1*	1	1	7
SC35	1	1	1	1	1	1	1	7
Dp Pw	7	7	7	7	7	7	7	

Note. SC = selected criterion; Dr Pw = driving power; 1* = transitivity; Dp Pw = dependency power.

Table 6
Partition matrix of C2.

	REACHABILITY SET	ANTECEDENT SET	INTERSECTION SET	LEVEL
SC28	SC28-SC29-SC34-SC31-SC50-SC33-SC35	SC28-SC29-SC34-SC31-SC50-SC33-SC35	SC28-SC29-SC34-SC31-SC50-SC33-SC35	1
SC29	SC28-SC29-SC34-SC31-SC50-SC33-SC35	SC28-SC29-SC34-SC31-SC50-SC33-SC35	SC28-SC29-SC34-SC31-SC50-SC33-SC35	1
SC34	SC28-SC29-SC34-SC31-SC50-SC33-SC35	SC28-SC29-SC34-SC31-SC50-SC33-SC35	SC28-SC29-SC34-SC31-SC50-SC33-SC35	1
SC31	SC28-SC29-SC34-SC31-SC50-SC33-SC35	SC28-SC29-SC34-SC31-SC50-SC33-SC35	SC28-SC29-SC34-SC31-SC50-SC33-SC35	1
SC50	SC28-SC29-SC34-SC31-SC50-SC33-SC35	SC28-SC29-SC34-SC31-SC50-SC33-SC35	SC28-SC29-SC34-SC31-SC50-SC33-SC35	1
SC33	SC28-SC29-SC34-SC31-SC50-SC33-SC35	SC28-SC29-SC34-SC31-SC50-SC33-SC35	SC28-SC29-SC34-SC31-SC50-SC33-SC35	1
SC35	SC28-SC29-SC34-SC31-SC50-SC33-SC35	SC28-SC29-SC34-SC31-SC50-SC33-SC35	SC28-SC29-SC34-SC31-SC50-SC33-SC35	1

Note. SC = selected criterion.

level, these determinants form a robust foundation for advancing CE principles within product design and lifecycle management. They encompass crucial aspects such as designing for reuse/recycling, ensuring long-term product effectiveness, integrating sustainable materials, extending product lifespan, emphasizing by-product reuse, aligning all production steps with long-term use, and acknowledging the significance of sustainable packaging.

The factors within C2 share equal significance and are crucial for advancing CE principles by optimizing resource use, minimizing waste generation, repurposing materials, streamlining distribution, embracing technology, fostering innovation, and facilitating the adoption of sustainable practices across operational frameworks.

The *Policies/Regulations* (C3) cluster presents four distinct levels. Specifically, governments' role in setting policies, the interventions through supportive measures, and water resource needs that drive

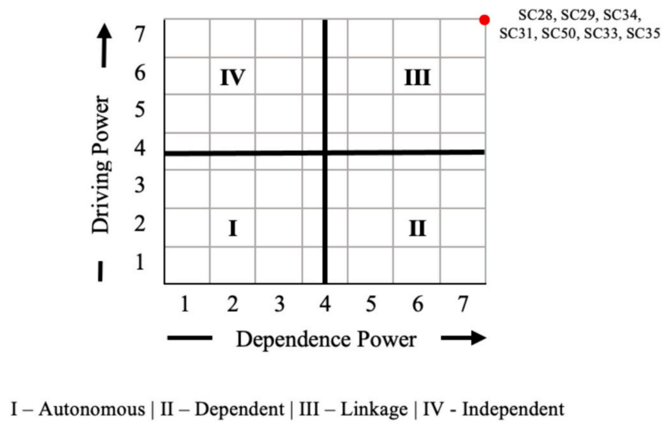

Fig. 2. MIMAC results for C2.

global agendas toward circularity are the primary drivers, as they are positioned at the bottom level. Supporting SMEs and reducing bureaucracy streamline CE implementation, thus, emphasizing the significance of government participation in promoting a sustainable CE. These results also appear to align with the conclusions reached by Garcés-Ayerbe et al. (2019).

C4 comprises a set of attitudes and/or behaviors aimed at fostering a mindset more open to change and the pursuit of innovative solutions, along with raising awareness about the importance of reusing materials, impacting consumption and disposal behaviors. As pointed out by Prieto-Sandoval et al. (2018), it is crucial to foster an understanding of the positive role of research and development in creating unique and sustainable solutions while recognizing the negative impact of marketing practices that encourage excessive consumption. All these factors influence more conscientious and sustainable behaviors.

The last cluster (C5) is the only one presenting negative criteria. As all drivers within this cluster hold the same level of importance, special attention should be given to those negatively impacting the CE. The absence of awareness campaigns related to CE principles hampers the dissemination of crucial information, hindering widespread understanding and adoption of sustainable practices. Additionally, as argued by Estupendo et al. (2023), the inadequate data on recycling processes hinders decision-making and effective planning, adversely affecting initiatives and progress in recycling. Similarly, the lack of information and general societal training on CE diminishes the engagement and participation in sustainable practices, impacting progress toward a CE.

Notably, our framework goes beyond existing literature by offering a structured breakdown of circular-economy drivers into five clusters. This categorization equips users with a nuanced understanding of the diverse factors influencing circular-economy initiatives and delves into the causal relationships between these drivers, prioritizing them based on relative importance. The results also provide SME managers with a specialized and actionable knowledge base for navigating the complexities of circular-economy projects, which are induced by novel insights into the intricacies of circular-economy implementation within SMEs.

4.3. Discussion, consolidation, and recommendations

After the analysis system was developed, its practical applicability needed to be verified. To this end, a consolidation session was held with two experts in the circular economy who were considered external to this research and impartial judges because they did not participate in the two working sessions during the application of the methodologies. The two invited specialists were employees of the United Nations' International Labor Organization. At different points in their professional careers, both experts had been part of various circular-economy projects, so these individuals were extremely well informed about this topic.

The final meeting was also held online but this time in the *Teams* platform. The meeting was divided into four parts. The first two were a presentation of the methodologies applied and discussion of the results. The third part was an analysis of the practical applicability of the proposed analysis system, while the last comprised the two interviewees' recommendations.

After the methods and their contributions to the study were explained to them, the experts noted that they were unfamiliar with these techniques. Next, the application of the techniques was described step by step so that the specialists could fully understand the methodology. At this point, the interviewees asserted that the present study's coverage of many circular-economy drivers was quite positive, especially given that a restricted number of determining factors has been a limitation of previous research. The main results were then described, and the clusters' diagrams and the final analysis system were presented.

The two experts carefully analyzed the different outcomes and praised the methods applied. The most positive point was that, until then, the specialists had never come across a study similar to the one described. They asserted that the methods were extremely interesting and that their application to the question of how to implement the circular economy was new to them, thereby underlining the potential to expand SME participation in this economy and to support companies in related projects.

However, the experts detected two major limitations in the research. The first was that the results were entirely dependent on the input of a small group of professionals whose experience with the circular economy was possibly inadequate. To address this issue, the interviewees suggested that the same study should be conducted with a panel of specialists with expertise in the circular economy developed while working exclusively with related projects in multiple fields over a long period. In response to this recommendation, the interviewees were informed that this research is process-orientated by nature. The findings were thus not expected to be representative or generalizable to other contexts. Instead, the same methodologies can be applied by other decision makers, with the results being contextualized, that is, shaped by the situation in which the decision-making process occurs (*cf.* Bell and Morse, 2013; Mendes et al., 2022; Estupendo et al., 2023).

The interviewees also mentioned a second limitation—the absence of drivers in the area of competencies (*i.e.*, skills)—which the experts considered to be a key area of the circular economy. If companies lack the necessary skills to implement circular-economy practices, the outcomes will never be those expected. The specialists suggested that the competencies cluster could include skills needed to participate in the circular economy or even the negative effects of missing competencies or key drivers listed in this new cluster. The interviewer pointed out that the proposed analysis system was designed to be flexible and to accommodate fresh input whenever this is justified. The methodologies, therefore, allow decision makers to adjust and update the assessment system as needed due to the recursive and constructivist nature of the methods used.

Because the analysis system is process-oriented, it should be seen as a learning mechanism rather than an end in itself or a way to find optimal solutions. The experts' closing remarks emphasized that, despite the limitations mentioned, the analysis system has enormous potential as a tool for supporting SME circular-economy projects.

Overall, our results hold significant importance because they not only address the identified limitations in existing research regarding the organization of circular-economy drivers and causal relationships but also offer practical solutions for decision-makers in SMEs. By providing a structured breakdown of circular-economy drivers and their interconnections, this study empowers SMEs to comprehend and prioritize the factors influencing sustainable initiatives. In addition, by using expert opinions, the methodology proposed in our study assumes a different stance, and we were able to bring added realism into our map, as the use of cognitive mapping brought new insights to the analysis processes based on the experts' know-how, which would not have been

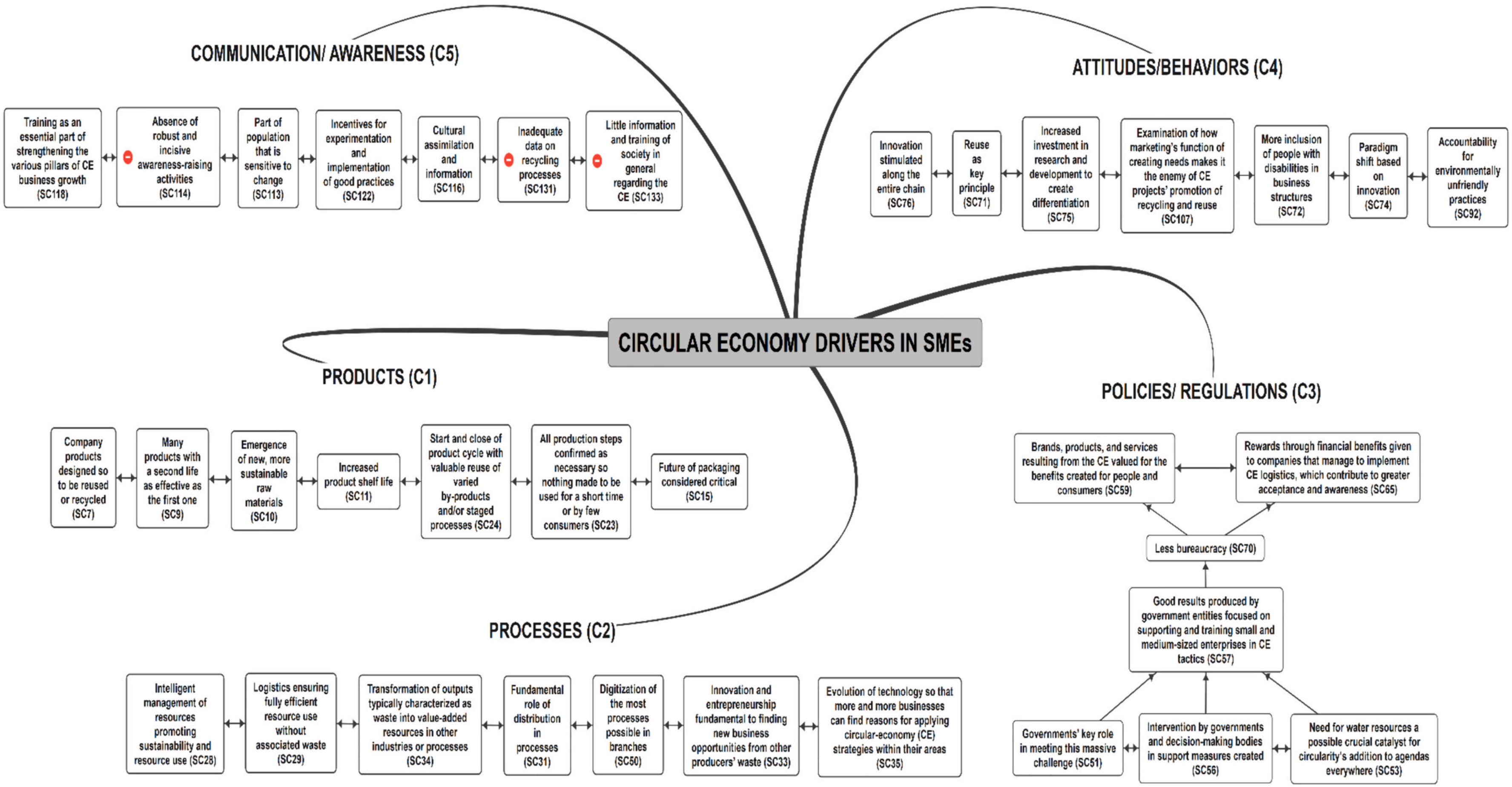

Fig. 3. Final interpretive structural modeling diagram.
Note. SC = selected criterion; C = cluster; CE = circular economy.

detected through the use of statistical methods alone. Issues such as *less bureaucracy* (SC70) and *part of population that is sensitive to change* (SC113), for instance, can be easily overlooked, but are not without consequence. This is crucial for SMEs grappling with resource constraints and the need for expertise in navigating the complexities of circular-economy scenarios. Ultimately, the knowledge imparted by this research facilitates informed decision-making, contributing to the broader goal of fostering sustainability within the SME sector and, by extension, influencing positive environmental and social impacts.

5. Conclusion

The circular economy has grown exponentially in recent years in different dimensions. More and more companies have adopted business models that include circular-economy strategies, and the literature on this area of knowledge has consequently expanded greatly. A few years ago, the circular economy was not widely discussed in the academic world, but numerous recent investigations have focused on this topic.

Firms are increasingly concerned about sustainability, so circular-economy strategies have become a way for companies to achieve the desired level of sustainability while still being able to reduce costs. This type of economy can be a means to an end to be used by a growing number of firms, but many companies, especially SMEs, lack the know-how to implement successful circular-economy tactics in their business. In addition, many firms focus only on achieving the level of sustainability they want and lowering costs while ignoring everything else. Thus, companies often end up failing to implement the circular-economy approach effectively because they have insufficient expertise and concentrate only on their most essential interests.

The present study sought to help SMEs correctly develop circular-economy initiatives or solve problems related to this economy. The main objective was to design an analysis system that combines cognitive mapping and ISM in order to identify circular-economy drivers in SMEs and analyze the causal relationships among these determinants. Companies can use this decision-support system to decide which drivers are more important and organize them into focus areas as it divides the drivers into five clusters: *Products*; *Processes*; *Policies/Regulations*; *Attitudes/Behaviors*, and *Communication/ Awareness*.

The analysis system also provides a hierarchy according to the significance of the determining factors within each cluster. In this way, SMEs can ascertain which drivers they should work on first and which are more important within each focus area. Firms should concentrate first on the least important determinants (*i.e.*, at the bottom of the hierarchy). Then these companies can go on to harness more fully the most significant drivers (*i.e.*, at the top of the hierarchy). When all the factors are of equal importance (*i.e.*, a one-level hierarchy) in a cluster, firms can choose where they prefer to start. Notably, the collaborative nature of the study, involving both circular-economy experts and the United Nations' International Labor Organization, underscores the potential for knowledge transfer and global best practices, fostering a community-driven approach to sustainable decision-making. Ultimately, the significance of this knowledge lies in its capability to contribute to a more sustainable and socially responsible business ecosystem, with SMEs playing a pivotal role in driving positive change.

The proposed analysis system has several limitations. The main shortcoming of the procedures followed was the difficulty in recruiting the expert panel. In general, expertise in the circular economy is scarce, making it challenging to find true specialists in this field. Furthermore, the resulting analysis system is context-dependent, indicating that caution must be exercised before attempting to generalize it to other contexts.

The analysis system developed is unique in that it combined cognitive mapping and ISM and used them to analyze the causal relationships between circular-economy drivers. This research can thus serve as the basis for future studies. The methodologies applied were new to the experts who participated in the development of the analysis system and those who validated the findings, although the specialists were all able to see their great potential. This type of analysis should be used in further research to help companies implement circular-economy initiatives more efficiently.

Additional future studies could take three different forms. The first is to develop similar investigations but apply other methodologies (*i.e.*, techniques that differ significantly from cognitive mapping and ISM). The second option is to replicate the present research using another panel of experts with unquestionable know-how and experience in the circular economy. The last suggestion is to develop a similar study at the international level. Additionally, the structured breakdown of circular-economy drivers into five clusters and the exploration of causal relationships and prioritization based on relative importance provide a valuable methodological foundation that could be cited for future studies seeking to understand and address similar complexities in circular-economy projects within the SME sector. These avenues of research should contribute further insights into how SMEs can best implement circular-economy strategies.

CRediT authorship contribution statement

Pedro S.P.C. Oliveira: Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Fernando A.F. Ferreira:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Methodology, Investigation, Data curation, Conceptualization. **Marina Dabić:** Writing – review & editing, Supervision, Investigation, Conceptualization. **João J.M. Ferreira:** Writing – review & editing, Supervision, Investigation, Conceptualization. **Neuza C.M.Q.F. Ferreira:** Writing – original draft, Software, Methodology, Investigation, Data curation.

Declaration of competing interest

None.

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