Strategic Dimensions of Eco-Innovation Adoption in Manufacturing SMEs in the Context of Mexico City

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Article

Strategic Dimensions of Eco-Innovation Adoption in Manufacturing SMEs in the Context of Mexico City

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Abstract: This paper delves into the strategic dimensions influencing the adoption of environmental innovations (EIs) in small and medium-sized manufacturing enterprises (SMEs) in Mexico City. Employing a mixed-methods approach combining documentary analysis and expert interviews, the study aims to provide a comprehensive understanding of integrating EI practices in the context of manufacturing SMEs. Qualitative methodology was chosen to explore experiences, perceptions, and practices related to EI adoption, acknowledging its ability to capture the complexity and richness of data. Through systematic literature review and semi-structured interviews with Corporate Social Responsibility experts, causal relationships and key factors influencing EI adoption were identified. The data analysis involved constructing causal maps and applying the Viable System Model to comprehend the interactions and dynamics within the organizational systems.

Keywords: complex adaptive systems; eco-innovations; manufacturing; small and medium-sized enterprises (SMEs); strategic dimensions

1. Introduction

The planet is facing an exponential increase in the challenges associated with climate change. This situation generates deep concern about the environmental repercussions of production and consumption activities, including the depletion of natural resources, the reduction of biodiversity and the pollution of water, soil, and atmosphere. Among the most worrisome aspects are the emissions of global pollutants that contribute to global warming [1], [2]. The IPCC Special Report "Global Warming of 1.5 °C" evidence that the impact of climate change increases in line with the increase in average temperature [3]. It highlights that upon reaching 2 °C, drastic consequences could be experienced globally. According to this report, to limit the temperature increase to 1.5 °C, it is necessary to achieve net zero emissions of carbon dioxide (CO2) globally by 2050, and neutrality in terms of other greenhouse gases later in this century. However, the report "Climate Change 2022: Impacts, Adaptation and Vulnerability" points out that the effective implementation of climate measures and the management of trade-offs between mitigation, adaptation, and sustainable development demand urgent action to meet key deadlines, such as those set by the Sustainable Development Goals and the Paris Agreement by 2030 [4].

In addition, environmental awareness has been progressively gaining ground in discussions on ecological and green management. As ecological awareness has developed, environmental issues have gained significant relevance. Customers of companies, as stakeholders, show increasing concern about the ecological footprint and environmental impact of these companies [5]. But beyond highlighting the importance of sustainable development and green management, the scarcity of resources and higher levels of pollution are progressively leading to cleaner production [6]. This has generated a growing interest on the part of environmental and innovation researchers in the idea of sustainable innovation [7], [8]. Academics and practitioners increasingly recognize EI as an important source of competitive advantage for companies; companies that possess unique technological

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competencies and resources are more likely to introduce new environmentally friendly products and processes and substantially improve their productivity [9].

SMEs, as key economic actors, play a fundamental role in the transition to a sustainable economy. To achieve this goal, it is crucial that these companies restructure and combine their resources and capabilities effectively, adapting to environmental requirements without compromising their competitiveness [10]. However, the ability of SMEs to balance environmental and economic objectives has been the subject of debate in the specialized literature. Given the resource constraints they often face, it is argued that these firms often face significant challenges when trying to develop sustainable capabilities. This is because implementing sustainable practices can generate additional costs, complicating the task of maintaining their competitiveness in the market [11].

Consequently, the adoption of eco-innovations by manufacturing SMEs is influenced by several factors. The application of EI and traditional environmental management practices can lead to performance improvements, with different effects on environmental and economic performance [12]. Hansen (2002) proposed an analytical framework, the "dynamic triangle", which emphasizes the role of competencies, network relationships and strategic orientation in driving the adoption of environmental innovations. However, it was found that a self-directed online sustainability and eco-innovation toolkit was not sufficient to drive SMEs to address environmental issues [14]. To overcome barriers to eco-innovation adoption, it is important to study demand uncertainty, financial risks, and lack of funds, and to analyze the potential benefits and risks of applying innovative products and technologies [15].

In Mexico, the implementation of EI practices has been shown to positively impact the business performance of small and medium-sized enterprises, especially in the manufacturing sector [16]. This assertion is further supported by research conducted in Oaxaca, Mexico, which identified a significant connection between eco-innovation and environmental performance in the hotel industry [17]. However, even though the topic has been examined from various levels, perspectives and interests, the integration of eco-innovation into business operations remains rare. This underscores the urgency of continuing research, not only to broaden the understanding of this process, but also for the purpose of developing tools that facilitate the incorporation of innovation as an integral part of the enterprise [18].

Taking all these aspects into consideration, the primary purpose of this paper is twofold. First, it seeks to understand and discern the fundamental strategic dimensions that define the implementation of eco-innovation within small and medium-sized enterprises (SMEs) engaged in manufacturing, within the context of Mexico City, conceived as an adaptive system of a complex nature. Secondly, it is proposed to examine how these business entities can manage the configurations and complexities inherent to the incorporation of eco-innovative practices in their operational processes.

To achieve this objective, this research adopts a qualitative research paradigm, characterized by its in-depth, flexible, and naturalistic approach, is particularly suitable for studying human experience and meaning [19], [20]. This method, frequently used in the social sciences, focuses on non-quantifiable aspects, such as attitudes and values [21]. For data collection, documentary and field tools are proposed. Documentary research is a key component of social sciences, involving the analysis of existing data within a variety of documents [22]. On its side field research, through interviews, is a crucial tool in business research, as it provides a rich insight and a deeper understanding of the subject [23]. Interviews go beyond oral communication and allow researchers to observe behavior, personality, and beliefs, as well as to verify the accuracy of information [24]. Data analysis will be explained in more depth in the methodology section.

The paper is organized as follows. Section 2 presents the theoretical background of EMC, eco-innovation, complex adaptive systems, and the relationship of eco-innovation to strategic dimensions in manufacturing SMEs. Section 3 describes each of the research hypotheses. Section 4 describes the method adopted in this study. Section 5 presents the results of the desk study, the field study, and

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the causal map. Section 6 discusses the theoretical implications of the results and the validation of the hypotheses. Section 7 presents conclusions and perspectives for future research.

1.2. Underpinning theory

1.2.1. Sustainable competitive advantage (SCA)

The SCA is based on the resource-based view (RBV) theory. This strategic management theory holds that an organization's competitive advantage is based on its unique and valuable resources and capabilities [25], [26]. Resources are an organization's assets, capabilities, knowledge, information, and skills. Capabilities are how the organization combines its resources to create value [27]. According to this theory, a firm's resources must possess; valuable, rare, inimitable, and non-substitutable attributes to develop a new capability that leads to competitive advantage. The RBV recognizes two types of resources: tangible resources, such as physical assets, and intangible resources, such as organizational culture and reputation [28].

According to the Resource-Based View (RBV), the achievement of a Sustainable Competitive Advantage (SCA) is made difficult for competitors due to the complexity of imitation, attributable to factors such as the rarity, inimitability and non-substitutability of an organization's resources and capabilities. Consequently, Chain Value Added (CVA) has been the subject of extensive discussion in strategic management and sustainability research, being considered crucial for long-term success and business survival in an environment of intense global competition and rapid change [29]. For this reason, it is argued that organizations must adopt sustainable business models that generate long-term value and contribute to the three fundamental pillars of sustainability: economic, social, and environmental [30].

Thus, the main objective of SCA is to outperform competitors in terms of decisions on the allocation of resources and capabilities to achieve an organization's objectives [31], [32]. However, achieving a competitive advantage in the marketplace is often more complex because business models and competitive patterns in the marketplace have changed dramatically due to increasingly stringent environmental regulations and stakeholders [33], [34]. Some authors, such as Porter [35], predicted this trend by suggesting that companies will only gain advantages when the green idea is implemented throughout the product life cycle. For this reason, environmental sustainability has generated increased interest as a research topic and focus among practitioners to understand whether a commitment to sustainable practices creates comparative advantages from an environmental point of view [36].

Thus, in a competitive environment, where resources are scarce, innovation is an effective way to stand out from the competition [37], [38]; that is, the most successful companies are those that constantly innovate their products and services to meet changing customer needs [39]. SMEs can also contribute to their competitiveness through eco-innovation through its positive effect on the market, sales, market share, sales, and profitability, including their green image [40]. However, the literature also shows that SMEs have difficulties in converting sustainable practices into competitive advantages through innovation [41]. Specific studies are still needed to understand how eco-innovation helps to promote environmentally friendly practices [42].

1.2.2. Eco-innovation

The concept of eco-innovation has evolved over time in response to the emergence of the concept of sustainable development in the late 1980s to reconcile economic growth with environmental preservation [43]. One of the first authors to address this concept was Fussler and James in 1996 in their work "Driving eco-innovation: a breakthrough discipline for innovation and sustainability", where eco-innovation is defined as actions aimed at preventing environmental damage, involving new or modified processes, techniques, systems, and products [44]. Since then, the concept has acquired a variety of definitions that focus on the "new" and that, in simple terms, seek to mitigate environmental impact.

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Eco-innovation, in its broadest sense, represents a collaborative process among diverse stakeholders with the purpose of generating innovative solutions to environmental problems, thus contributing to the advancement of sustainability [45], [46]. According to the Eco-Innovation Action Plan (2011), his concept encompasses any process aimed at developing new innovative solutions to environmental challenges. Such solutions can range from reducing environmental impact to strengthening resilience to environmental pressures, as well as improving efficiency and responsibility in the use of natural resources. Therefore, eco-innovation has been consolidated as a proactive environmental strategy by fulfilling two complementary functions: promoting sustainability and fostering innovation, considered sources of competitive advantage [48], [49].

1.2.3. Eco-innovation as a complex adaptive system

Systems thinking, as described by Jackson (2004), is an approach to analyzing and understanding complex systems. It is a way of thinking that seeks to understand the interactions between the parts of a system and how these interactions affect the system. Rather than analyzing each component in isolation, systems thinking focuses on understanding the relationships, connections, and patterns that emerge from the system. Thus, the systemic approach to eco-innovation is based on industrial symbiosis that seeks to improve the economic and environmental performance of companies through collaboration among them [51]. This strategy is based on the exchange of resources, such as materials, energy, and water, between companies in the same region.

When examining eco-innovation from the theory of complex adaptive systems (CAS), it becomes a system that adapts and evolves in an increasingly changing environment [52]. For this reason, adaptation and co-evolution of all systems is necessary for innovations to be successful [53]. Eco-innovation behaves as a complex system built on a set of IE components that involve different types of activities, resources, tools, and strategies within the company, in a clear systemic relationship with external social, environmental, socio-technical and transitional systems where the company experiences generate strategies under the influence of changes in its environment [54].

1.2.4. Relationship of eco-innovation to strategic dimensions in manufacturing SMEs

The strategic dimensions of manufacturing SMEs to adopt IE are related to both external and internal factors. External factors impact competitiveness including innovation and financial management [55]. On the other hand, internal factors play an important role in supplier collaboration, on-time delivery, and short- and medium-term strategies [56]. Thus, the combination of external and internal factors becomes a catalyst for EI integration in manufacturing SMEs.

Several studies have examined the role of external factors in stimulating eco-innovation in small and medium-sized enterprises (SMEs). According to Cecere (2018), public funding and tax incentives can significantly improve a firm's ability to implement eco-innovations, especially when combined with substantial internal or external resources. Klewitz (2012) highlighted the importance of intermediaries such as local authorities and consultancies to facilitate eco-innovation in SMEs, especially those with limited absorptive capacity. Triguero (2013) pointed out the relevance of collaboration with research institutes, agencies, and universities, as well as the increase in market demand for green products, as key drivers of various types of eco-innovation.

Internal strategic dimensions play a fundamental role in the development and adoption of eco-innovations [57]. These dimensions, which encompass environmental awareness, knowledge, resources, and capabilities, are shaped by corporate philosophy and culture [58]. In addition, specific capabilities that enhance eco-innovation performance in manufacturing firms focus on organizational culture, structure, and performance evaluation [59]. Also, previous experiences in eco-innovation emerge as the most influential factor, underlining the importance of learning and knowledge transfer within the firm [60].

1.3. Research hypotheses

1.3.1. The competitive environment

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The competitive environment plays a fundamental role for the development of eco-innovations because an eco-innovative design or process generates improved product design, increased productivity, reduced inputs, process design, and reduced product costs [61]. Consequently, an SME's understanding of the competitive environment leads to a better understanding of the competitive capabilities that can contribute to the achievement of sustainable business performance and competitive advantage. Companies should seek out and integrate resources with a competitive advantage, such as assets, skills, processes, information, and experience, to develop business capabilities that provide a competitive advantage [62].

H1: The competitive environment influences the adoption of eco-innovations by manufacturing SMEs in Mexico City.

1.3.2. The economic environment

The economic environment influences the way in which the SME has the skills to attract financing and investment to carry out sustainable projects. Eco-innovation can be considered a relevant instrument to make economic growth and environmental protection compatible. However, to be viable, eco-innovative investments require adequate financial resources in terms of quantity, quality, typology, and availability [63]. To achieve the above, acquiring resources lies in the organization's ability to plan environmental performance and related costs, or the organizational capabilities of companies for better performance of eco-innovative investments, to obtain the value demanded by stakeholders [64].

H2: The economic environment influences the adoption of eco-innovations by manufacturing SMEs in Mexico City.

1.3.3. The technological environment

The technological environment is influenced market instruments are more effective than command and control instruments in promoting the cost-effective adoption and diffusion of new technologies competitive conditions, market instruments tend to work better than command and control instruments [65]. For this reason, to respond to constant technological changes and the shortening of product life cycles, companies must increase their investments in environmental innovations to improve their competitiveness. To justify financial investments for the development and implementation of innovative environmental solutions, there must be the prospect of expanding the company's market share [66].

H3: Technological environment influences the adoption of eco-innovations by SMEs in Mexico City.

1.3.4. Political Environment

The political environment is related to environmental policy, its influence on the adoption of EI is complex and is determined by several factors. The first is the provision of incentives by public entities for environmental technology innovation, especially effective instruments such as economic instruments and R&D subventions [67]. The second aspect is environmental policy to promote EI, whether market-based or voluntary, command and control policies [68]. The third is taxation, as it becomes a more effective way than customer information [69]. The fourth is a greater focus on the use of public instruments and increased spending on R&D [70].

H4: The political environment influences the adoption of eco-innovations by manufacturing SMEs in Mexico City.

1.3.5. Social environment

The social environment stems from customer and societal requirements [71]. This is because innovations improve environmental performance and process IE helps to improve material efficiency [72]. In addition, individuals are social drivers of IE, as their environmental awareness induces the

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transition to a circular economy [73]. Thus, business models are motivated to enable a transition in the way they develop their product to achieve resource efficiency [74].

H5: The social environment influences the adoption of eco-innovations by manufacturing SMEs in Mexico City.

1.3.6. Strategic orientation and focus

Strategic orientation involves the way in which an organization uses strategy to adjust or modify elements of its environment to achieve a more favorable alignment. It is also a fundamental element for profitability, both in manufacturing companies, as it influences business decisions through its effects on overall profitability [75]. Responses to the operating environment reflect firms' strategic orientations; strategic orientations largely determine their choices, establish their strategic positioning, affect their performance, involve multiple functions, are highly complex and ambiguous, and require significant resource commitments [76].

Strategic guidelines are vital to drive the different departments of a company towards the established management objectives. These strategic guidelines have the potential to elevate business competence and contribute to corporate performance growth. The implementation of environmental management best practices can improve the competitive advantage of companies [77], [78]. Strategic green orientation involves a company's long-term sustained commitment to manufacturing environmentally friendly products and services through the implementation of goals to improve its environmental performance. The adoption of environmentally friendly products can contribute to a company's overall economic success by fostering internal integration and external coordination with key stakeholders, such as customers and suppliers [79].

H6: Strategic orientation influences the adoption of eco-innovations by SMEs in Mexico City.

1.3.7. Internal and organizational capabilities

The consideration of internal factors in companies to make the decision to embark on eco-innovation has led to the concept of innovation capabilities. These capabilities comprise organizational routines and processes that seek to achieve innovation as the goal for the firm [80] From the dynamic capability perspective, innovation experience and innovative capabilities have been identified as crucial elements influencing a firm's determination to innovate. It is highlighted that the decision to pursue eco-innovation is based on the experience accumulated in previous eco-innovation processes, which exerts a considerable impact on the future direction of eco-innovation [81].

Entrepreneurial capabilities are configured as resources that, through their repeated application, generate routines or processes. When these capabilities are adjusted and adapted according to changes in the business environment, they are transformed into what are called dynamic capabilities. In the context under consideration, this distinction is significant, since employees involved in activities related to environmental protection are prioritized as organizational resources, while investment in environmental certifications is perceived as a form of organizational capabilities [82]. In this perspective, dynamic capabilities can play a crucial role in the creation of new knowledge-based capabilities or in the transformation of existing ones, with the purpose of generating solutions to sustainability challenges. This, in turn, contributes to improving environmental performance [83].

H7: Internal and organizational capabilities influence the adoption of eco-innovations by SMEs in Mexico City.

1.3.8. Adsorption Capabilities

The incorporation of innovative practices in manufacturing or service environments demands that a company possesses the ability to acquire, disseminate and apply knowledge both internally and externally. A company's absorptive capacity drives its ability to generate green innovations, such as sustainable goods, services, or work processes [84]. Consequently, companies seek to incorporate external knowledge related to the negative impact of their operations on the environment, such as

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pollution, waste, and other environmental outcomes. By integrating this new information with their existing knowledge base, they facilitate the adoption of green innovation practices in their processes and operations [85].

H8: Absorption capabilities influence the adoption of eco-innovation by Mexican manufacturing SMEs.

To demonstrate the hypothesis in a more integrated way, the following figure is presented:

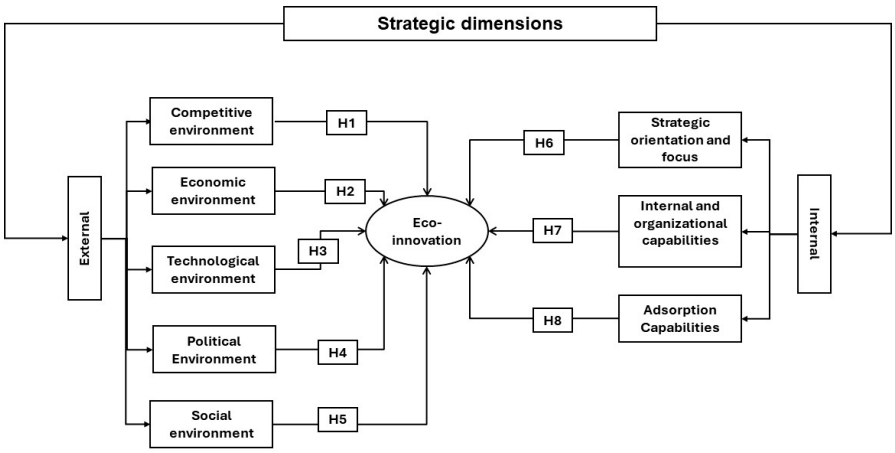

Figure 1. Theoretical framework

2. Materials and Methods

2.1. The Research design

To achieve the objective of the study, this paper focuses on the strategic dimensions of IE adoption in small and medium-sized manufacturing enterprises (SMEs) in Mexico City as a context. The research was conducted using a documentary and field methodology, i.e., literature review and interviews with experts in the field. Through this mixed approach, an in-depth understanding was obtained in integrating IE-related practices in manufacturing SMEs in Mexico City. The choice of a qualitative methodology for the study is justified by the need to explore and understand experiences, perceptions, and practices to encourage manufacturing SMEs to adopt eco-innovations. Accordingly, several studies highlight the importance of qualitative methodology to explore and understand experiences as well as perceptions and practices.

In this sense, several studies highlight the importance of qualitative methodology to explore and understand experiences, as well as perceptions and practices [86], [87]. This approach is relevant to capture the complexity and richness of data in expert interviews and documentary analysis [88]. Data collected through this approach are holistic, rich, and nuanced, allowing themes and findings to emerge through careful analysis [89]. For its part, the importance of correlational research lies in its role in determining and prevalence of prevalence and relationship between variables thanks to the complex and multifaceted nature that characterizes it which allows for a nuanced understanding of the factors that influence it [90]. And field research, in organizational sciences, allows identifying correlations and variables that affect each other to contrast theoretical data with field data to determine relaxations and correct irregularities [91], [92].

In field studies, interviews are social interactions in which researchers ask people questions to collect data for social research [93]. Interviews are crucial components of social research because they provide rich qualitative data and information about participants' perspectives [94], [95], [96]. In this sense, the role of the interviewer is important, and more attention needs to be paid to their experiences and the support they need (Morris 2012). For this research study, 2 Corporate Social

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Responsibility expert who understand the dynamics of adopting environmental practices in companies were interviewed. The research process is detailed below.

2.2. Data collection

To achieve the proposed objective, documentary research was carried out with a systemic and field approach through semi-structured interviews with experts in Corporate Social Responsibility and experience in the adoption of environmental technology for SMEs. A traditional literature search was conducted in the Web of Science (WOS) and SCOPUS, following the steps described in Table 1. The 24 selected papers were simultaneously reviewed and coded with the support of the ATLA.ti version 23 program. Each causal relationship identified in the literature on strategic dimensions and EI was coded based on the criteria of functionality of the subsystems of the ESM described in the data analysis section. The systematic review is a methodological approach that seeks to identify, select, evaluate, and synthesize previous studies in an organized manner, to present the evidence in a way that allows informed conclusions to be drawn about existing knowledge, highlighting what is known and what remains to be explored [97]. For the literature review, the steps proposed by Denyer and Tranfield (2009):

- Step 1: formulation of the research question.
- Step 2: location of studies.
- Step 3: selection and evaluation of studies.
- Step 4: analysis and synthesis.
- Step 5: reporting and use of research results.

To answer the research question: what are the strategic dimensions and relationships that influence the adoption of eco-innovations by manufacturing SMEs in Mexico City as a complex adaptive system? In this, it prioritizes the literature that presents causal evidence between the relationships of eco-innovation, manufacturing, and SMEs, thereby reducing to 24 papers.

Table 1. Steps to search for traditional literature.

Step. 1	Conceptual limits for document search in WOS and SCOPUS: 1. Search equation: (eco-innovation OR ecological innovation OR environmental innovation) AND (manufacturing OR manufacture) AND (smes OR small Business). 2. Search period: the last five years from the date of the most recent publication (2019-2024), the search date was May 23, 2024. A total of 37 documents were obtained.
Step 2	Definition of criteria for document search in WOS and SCOPUS: 3. Selected fields: Article title, Abstract, Keywords. 4. Documents: articles
Step 3	Definition of exclusion criteria for the documents found: 5. Review articles. 6. Exclusion for duplicity. 7. For not being research in EI. 8. For not presenting causal relationships. 9. A total of 24 documents were reviewed.

In the case of the interviews, two experts were interviewed: one a specialist in corporate social responsibility and the other a senior sustainability consultant in Mexico City. The interviews were semi-structured, conducted in Spanish through virtual means and distributed in 16 questions with strategies, challenges, opportunities, strengths, business strategy, regulations, etc... and later translated into English, these interviews were conducted on January 24, 204 and February 7, 2024, respectively. Semi-structured interviews are a valuable tool in various research fields, as they offer a

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conversational approach that can reveal unexpected insights [99]. They are particularly useful for exploring complex issues and allowing flexibility in data collection [100].

Textual transcripts were loaded into the data analysis program ATLA.ti version 23. All transcripts were analyzed and coded word by word using an open coding system. Then, open codes were classified, interrelated, and grouped using axial coding [101]. Thematic analysis was then applied based on the themes addressed in the semi-structured interviews. Non-participant observation was used to conduct the interviews, this refers to a research method in which the observer does not directly participate in the interaction but observes it from an outside perspective. Non-participant observation, a method of data collection, has been used in several fields, including online behavior analysis [102], nursing research [103], and classroom teaching [104]. It has been found to provide unique information about individual behaviors and mechanisms [105]. In this interview, the questions were previously asked, and the participant answered the question without intervention from the interviewer.

2.3. Data analysis

The causal map and the model of viable systems were considered for the data analysis. A causal map consists of a network of nodes (statements) and directed arrows whose direction implies causality, i.e. "may lead to" [106]. The construction of the map must be done starting from a general question or statement. First, the objectives or gaps are written from the question, with complete statements. Second, all relationships between them are sought, resulting in a causal map. In this way, a graphical representation shows the complexity of a problem, showing, for example, how the objectives or problems are interconnected, as well as detecting emerging patterns. When interpreting a map this helps to understand the reading of information [107].

From the methodological point of view, the raw causal maps [108] are organized in three steps: The first is to identify conceptually salient coding categories. The second step consists of developing construct operationalizations that capture the coding categories. Finally, the concepts and constructs are tested for validity using the limb checking procedure recommended by Lincoln and Guba (1985). The standard causal map reflects the relationships between certain vertices of mentioned information blocks (Figure 2). The arcs between vertices should reflect the causal relationships. Concept A can be cause or effect of Concept B, Concept C, Concept D, Concept E, Concept F; Concept B can be cause or effect of Concept A, Concept C, Concept D, Concept E, Concept F and so on (presented in any form).

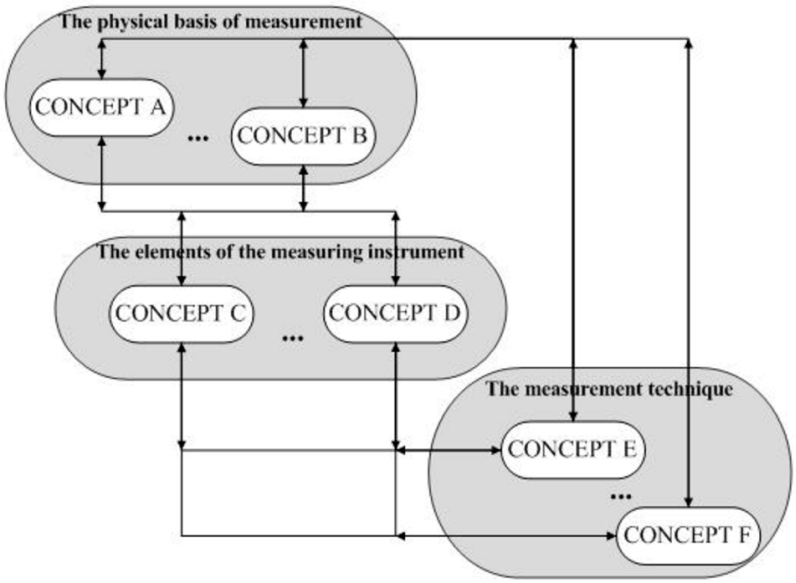

Figure 2. A theoretical model of the causal map [110].

A causal map displays the causal relationships indicating that from any concept in any of the blocks, there is the ability to connect to at least two additional concepts from other blocks, or at least

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two more concepts from the same block, or at least one other concept within the same block (Figure 3).

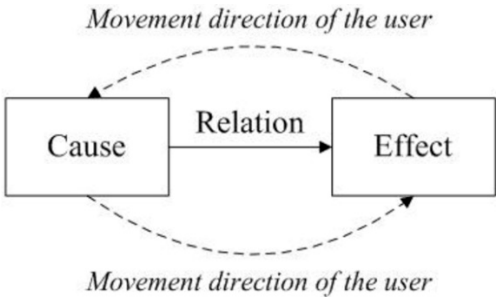

Figure 3. Possible directions of movement through the causal map [110].

To understand the interactions of one of the variables involved in greater depth, the Viable System Model (VSM), a tool for designing and managing complex systems used in various applications, will be used [111]. In the business field, it is used to diagnose organizational weaknesses and design management systems [112]. In creating the Viable System Model (VSM), Stafford Beer sought to establish a "science of organization" based on cybernetic and systemic principles. His goal was to understand how organizations generate viability, i.e., the ability to survive and thrive in often unpredictable and turbulent environments [113], [114]. This model is based on three key principles: viability, recursiveness and autonomy. Viability implies that a company must adapt effectively to internal and external changes to ensure its continuity. Recursiveness implies organizing the organization's systems in such a way that they reflect themselves at different levels [115]. Thus, a viable system is composed of interlocking systems that are also viable. Within this context, autonomy means that a system can operate independently if it conforms to the rules set by its higher systems [116].

The Viable System Model is described as a visual diagram representing a series of fundamental elements (five subsystems and an environment) interconnected in a specific way, all of them essential for viability (see Figure 4).

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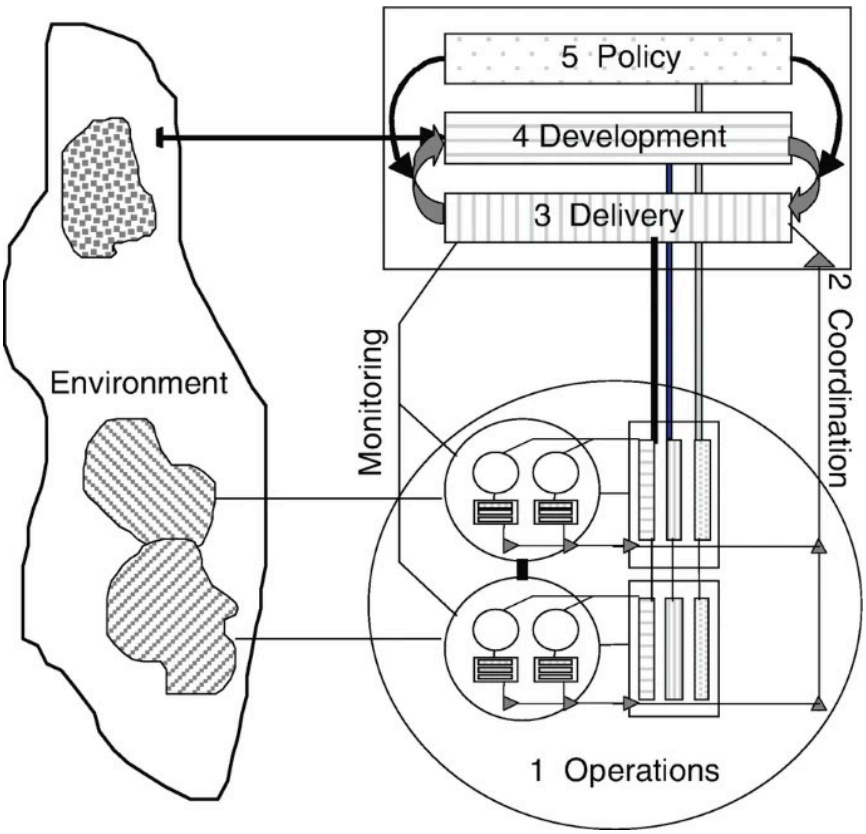

Figure 4. Viable systems model.

System 1 is the set of activities performed by the organization that provide value to its external environment, the primary operations and comprises elementary operating units that may be divisions of a company, sub-organizations, among others. The main function of System 2 is to ensure the coordinated operation of the organizational units that make up System 1 (represented by the triangles on the right side of the diagram). System 3 is responsible for optimizing the overall functioning of System 1, i.e. management activities related to resource allocation and present and immediate operations. System 4's main task is to monitor the organization's environment, keeping an eye on its environment and future changes to keep it always prepared. Finally, System 5 makes policy decisions and defines the vision and identity of the organization. The environment is represented as external to the system in question and is commonly visualized as an undifferentiated mass.

Ithink version 8.0 was used to prepare the causal maps. Ithink is a business modeling and simulation application developed by isee systems. This tool is used to build business process models and scenarios for the purpose of evaluating various policies and gaining a better understanding of the operation of complex systems. Several ethical considerations were considered for the interviews. These included the need to ensure a safe environment and equal attention for all participants [117]. Principles of business ethics, such as preparedness, openness, honesty, and power relations as a guide to interviewer and interviewee behavior[118]. Privacy, informed consent, and the potential for emotional harm [119].

3. Results

3.1. Literature review

In an initial review of the 24 articles, they were classified by dimensions and categories. As shown in Figure 1, 8 categories were found that are related to the eco-innovation option in manufacturing SMEs: social capital and eco-innovation, knowledge and expertise for eco-innovation, internal environmental capabilities, external pressures and regulations, sustainable business

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performance, sustainable competitive advantage, eco-innovation, and non-technological innovation. These articles arise from different methodologies, both quantitative and qualitative, where most documents lead to the construction of a model. Additionally, due to the chosen period, you can find articles related to the resilience of SMEs against covid19 in relation to eco-innovation. The location where the studies were conducted is in Malaysia, Ghana, Netherlands, Pakistan, Egypt, Italy, and Taiwan.

Table 2. General dimensions/categories of the articles studied.

Overall dimensions/categories	Study
Social capital and eco-Innovation	Assessing the influence of social capital and innovations on environmental performance of manufacturing SMEs [120].
Knowledge and expertise for eco-Innovation	Ecolabnet service packages as a response to the needs of manufacturing enterprises in the SME sector of the Baltic Sea Region [121].
	Eco-innovation of food processing and manufacturing SMEs [122].
	Innovation in manufacturing SMEs during the COVID-19 pandemic: How does environmental dynamism reinforce employee proactive behavior [123].
	Manufacturing SMEs doing it for themselves: developing, testing and piloting an online sustainability and eco-innovation toolkit for SMEs [124].
Internal environmental capabilities	Linking internal environmental capabilities to sustainable competitive advantage in manufacturing SMEs [125].
	The role of CSR oriented organisational culture in eco-innovation practices [126].
	On the growth impact of different eco-innovation business strategies [127].
	Institutional pressure and eco-innovation: The mediating role of green absorptive capacity and strategically environmental orientation among manufacturing SMEs in Egypt [128].
External pressures and regulations	Environmental pressures and eco-innovation in manufacturing SMEs [129].
	Effects of the Fit between Size and Environmental Uncertainty on Manufacturing SMEs' Innovation Activity [130].
	Adoption of green innovations by SMEs: an investigation about the influence of stakeholders [131].
	Determinants of eco-innovation initiatives toward sustainability in manufacturing SMEs: Evidence from Bangladesh [132]
	Institutional pressure and eco-innovation [133]
Sustainable business performance	Eco-Innovation Capabilities and Sustainable Business Performance during the COVID-19 Pandemic [134]

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	Corporate sustainability and firm performance in small and medium enterprises in Ghana: Mediating role of green innovation [135].
	Green manufacturing practices and SMEs' sustainable performance: a moderated mediation mechanisms of green innovation and managerial discretion [136].
	Determinants of eco-innovation capabilities adapted by Malaysian SMEs during the COVID-19 pandemic [137].
	Innovative Green Initiatives in the Manufacturing SME Sector in Poland [138].
Sustainable competitive advantage	Drivers of multiple eco-innovation and the impact on sustainable competitive advantage [139].
Eco-marketing and digital innovation	An Analysis of Eco-Innovation Capabilities among Small and Medium Enterprises in Malaysia [140].
	Environmental and technological factor diffusion with innovation and firm performance: Empirical evidence from manufacturing SMEs [141].
	Unraveling the transformation: the three-wave time-lagged study on big data analytics, green innovation and their impact on economic and environmental performance in manufacturing SMEs [142].
	Digital technology and circular economy practices [143].
Non-technological Innovation	Environmental objectives and non-technological innovation in Spanish manufacturing SMEs [144].

3.2. Causal map

To generate the causal map resulting from the literature review, an axial coding is performed considering the examples of Hoare (2012) and Brown (2002) emphasizing the interaction between coding and categorization. In addition, the techniques and methods of axial coding were considered [147], [148]. In the initial phase an open coding was done considering the articles reviewed for the determination of the hypotheses. With a total of 164 codes, then, axial coding the codes were analyzed, resulting in 6 main categories, from which subcategories resulted as shown in Figure 5. For more information see Appendix 1 containing the report of the codes.

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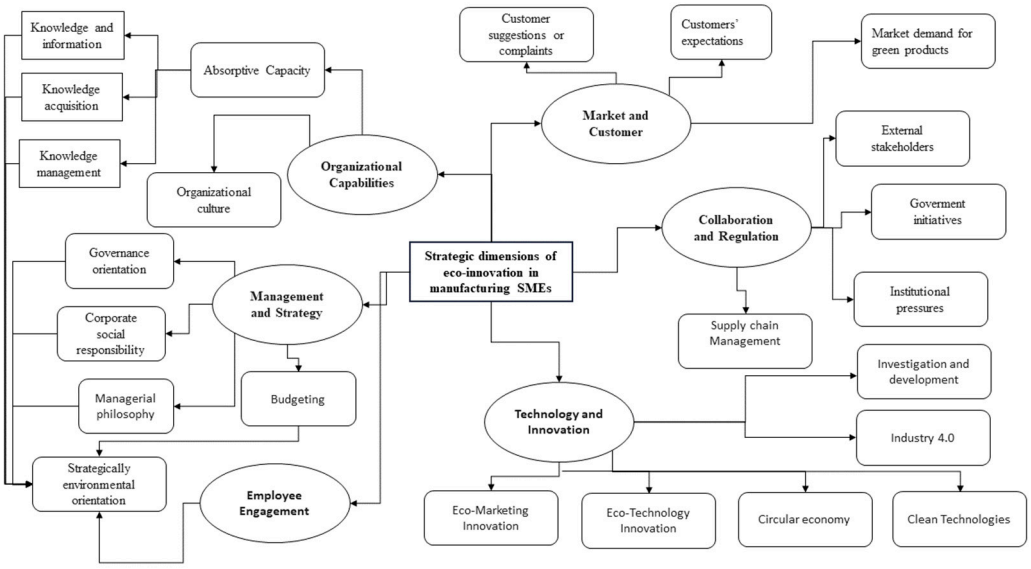

Figure 5. Literature review causal map.

With a total of 55 codes after translating and coding the interviews, 8 categories are generated as shown in Figure 6. Both in the literature review and in the interview, the strategic dimensions of eco-innovation are related to management, planning and the strategy that is worked from the management. In addition, it relates that environmental innovation, and the adoption of environmental practices is linked to the pressure exerted by the parties on the SME. However, differences can be observed, such as the issue of financing and infrastructure; while the literature review highlights that in each country where eco-innovation is studied the financing is given, in the interviews, it is mentioned that it is necessary to generate strategies so that the SMEs can take advantage of the financing and that it is necessary to work on infrastructure issues at an external level so that the SMEs can take advantage of it. Each of these considerations will be discussed below in the viable system model.

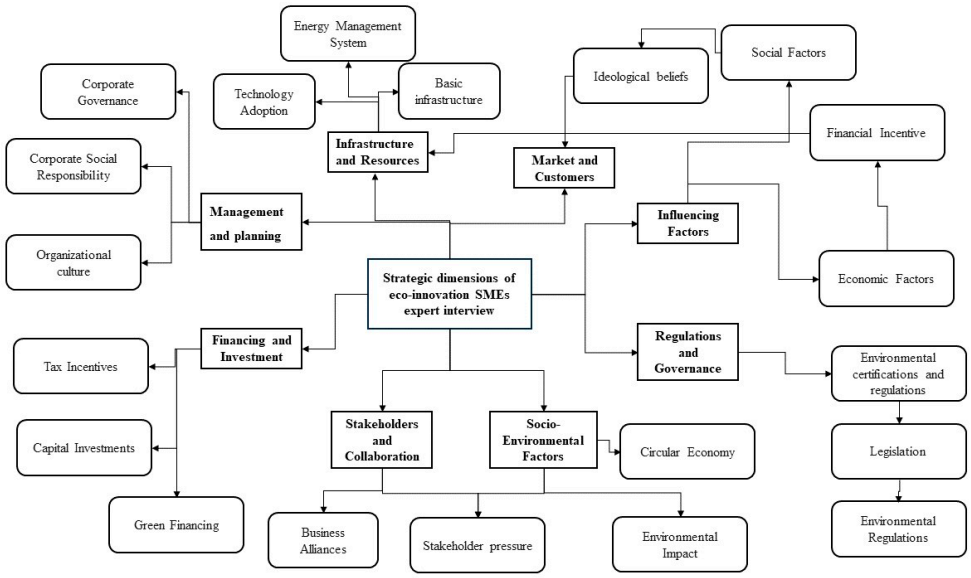

Figure 6. Causal map of interviews.

3.3. viable system model

For the realization of the viable system model, a conceptual model was considered, which is built from the axioms, principles, and laws of the viable organization, considering the dynamic

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structure that determines the adaptive connectivity of the parts of the organization or organism, which is what allows it to adapt and survive in a changing environment. For the construction of the system, represented in Figure 7, both the codes from the literature review and those from the interview were considered, with emphasis on the relationship between the variables.

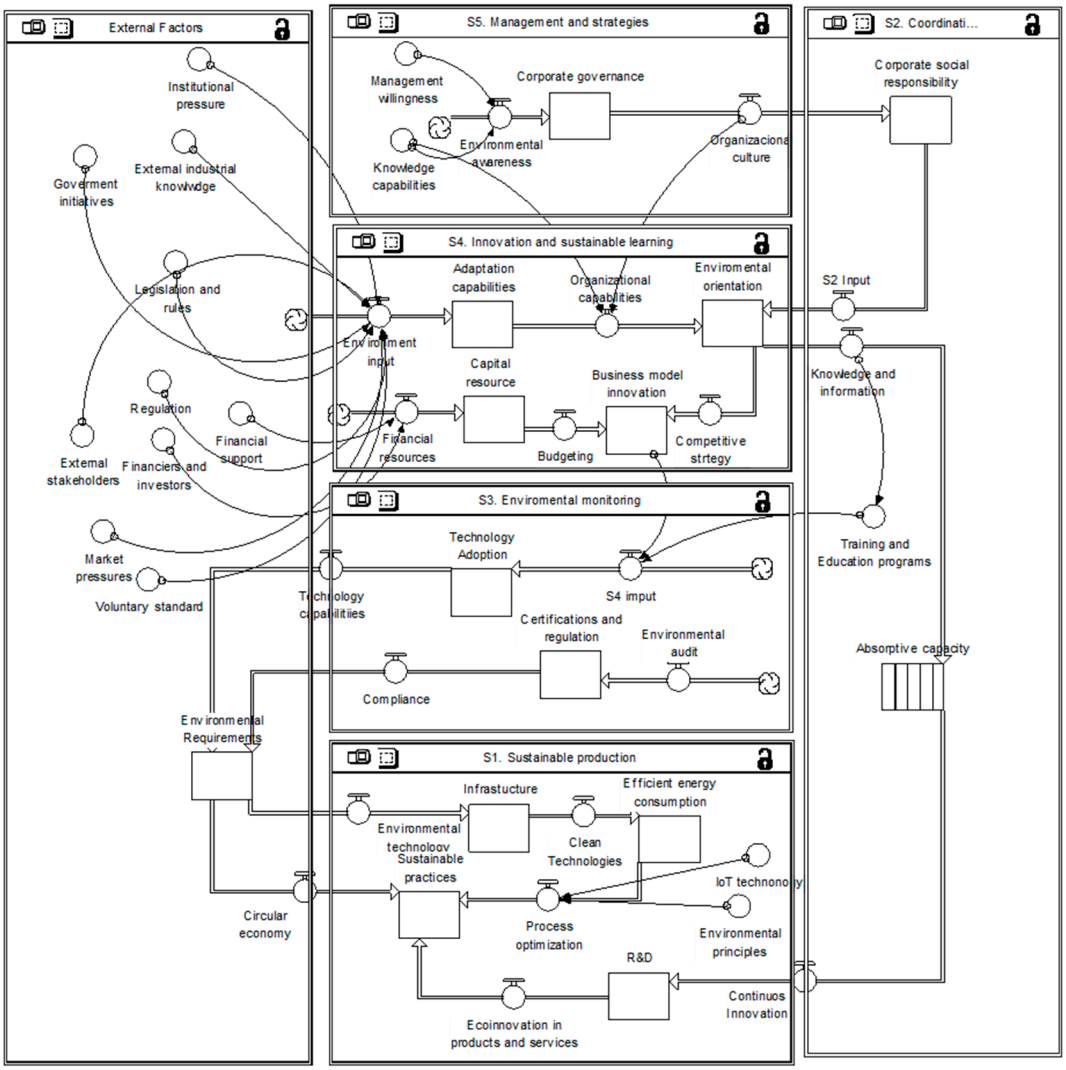

Figure 7. Viable eco-innovation model system for manufacturing SMEs in Mexico City.

System 5 or policy system in the context of eco-innovation was called management and strategies. In the context of SMEs, it is necessary to consider the willingness of management and knowledge capabilities to generate environmental awareness on the part of the organization's managers and thus generate a corporate governance with ideals towards eco-innovation and the emergence of an organizational culture linked to corporate social responsibility. According to interviewee 1, the lack of an organizational culture linked to environmental issues is one of the main problems for SMEs to adopt eco-innovations:

"The rigid structure is a disadvantage for SMEs that want to adopt environmental practices. SMEs can allocate a couple of resources, even hire someone specialized, but it takes time to change the structure with which they are doing things, if you ask an organization to implement an environmental management system, they have been operating for 20 years without formalizing environmental management, because it is part of the organizational culture, it is part of the organizational culture, It is a matter of the organizational culture, of the organizational culture, that the people in charge accept it, that there are processes, procedures and internal controls to adopt it, that they really follow it, that they really give it importance, that the management says yes it is worth it, that the operators say we understand it and that there is follow-up and monitoring, it is moving a huge mass for large companies, so that is where the most common problems can normally be found".

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For interviewee number 2, he comments something similar: "*It cannot be established whether it is just a fashion or an imposition, it has to be something voluntary, there has to be total awareness that this is the way to work and focus efforts to achieve that goal, as long as that does not happen, it will not work*".

The literature, for its part, agrees with the authors that eco-innovation is closely related to governance orientation and a strategic vision: *"In its continuous evolution, today sustainable development has adopted a governance orientation that includes the ethical and environmental implications of business choices within a strategic vision, according to a global approach that goes beyond the mandatory behaviors imposed by legislation to assume a unique and distinctive feature"* [131, p. 46]even going so far as to speak of an eco-organizational innovation: *"First of all, eco-organizational innovation involves the development of a corporate culture and new organizational methods that contribute to updating management processes and managing the environmental impact of the organization, such as eco-training programs, eco-auditing and eco-learning techniques"* [139, p. 41]

The intelligence system or system 4 is given by innovation and sustainable learning. This system engages with the environment: on the one hand, with the pressures exerted by stakeholders and society in the generation of eco-friendly products and services and the financing opportunities offered by the environment. For the interviewee one, the business model responds to this demand from the environment: *"There are studies on the subject that have been widely accepted worldwide because it has been seen as a business strategy that has an impact, as I mentioned, on the image of the company in the fact that we as consumers, the population in general, as consumers become more aware of the implications of a company that cares for the environment, of a company that cares for its workers and the society with which it interacts, and of a company that has responsible economic management and also, for the benefit of society."* It is also the environment that provides financing, due to the fact that SMEs have limited use of resources, according to interviewee 2: *"I believe that the greatest financial incentives are this part of the guidelines for private institutions, that is, banks have an approach that if you do an environmental activity or a practice that helps solve an environmental problem, you will have a special credit, many speak of credits. with a lower rate are not clear but there is talk that they can be credits that are loans that are capital investments with a much lower rate because they seek not only a financial performance but also an environmental impact"*.

For the literature, it is relevant to consider a business plan that considers eco-innovation: *"SMEs can incorporate eco-innovation into their business plans, so that companies are able to transform environmental constraints into opportunities to improve their financial situation and their reputation in the existing or emerging market"* [137, p. 182].

System 3 or control system was called environmental monitoring, which is linked to system 4, which seeks to comply with environmental regulations and is based on compliance with environmental standards and certifications. For interviewee 1, in Mexico, there are certifications that require companies to be clean industry: "*The main trend that I have been able to observe is the maintenance of certifications. In Mexico there is a certification from the Ministry of the Environment and Natural Resources, which is that of a clean industry company and at the end of the day it is a seal that companies have and carry, and there is also the part in terms of corporate social responsibility of a distinctive that is called socially responsible company*". For interviewee 2 in Mexico City there are also specific certifications: *"Many are working with an emissions trading system that is also going to be important and in Mexico are also beginning to develop laws or regulations with help because in Mexico there is a certificate of sustainable building of Mexico City where if you* have a building if it is considered live Edge or not".

The literature agrees with the experts regarding certifications, *"To reduce environmental impacts, business owners should engage in information gathering, provide training and education programs to guide their company's management in implementing green practices and obtain environmental certification"* [140, p. 7]. Other papers in the literature consider specific certifications that improve the management and research capabilities of SMEs and boost eco-organizational innovations, such as adherence to ISO 14001 or the adoption of life cycle assessment methods [139].

System 2 or coordination system integrates the activities of System 1, ensuring the coherence and efficiency of the work and establishes communication and collaboration mechanisms between the different parts of the system. This is composed of corporate social responsibility, the transmission of knowledge that translates into absorption capabilities to ensure continuous innovation. In relation

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to absorptive capacities, the literature makes an extensive list of this capacity and considers it as an advantage of SMEs compared to large companies, contrary to the interviews that do not explicitly indicate it. In this sense, the adoption of eco-innovations in SMEs is closely linked to their level of understanding and processing of environmental concepts. The continuous development of knowledge through various learning processes can enhance and streamline a company's green capabilities. Thus, the apparent superiority of large companies in implementing environmental management practices is not necessarily due to exclusive tools, but to the vast accumulation of knowledge they possess [139].

In addition, absorptive capacity serves as an internal mechanism in the connection between institutional pressures and the implementation of environmental practices. Absorptive capacity helps mediate institutional pressures through knowledge acquisition, an organizational capability that enables firms to provide and exploit knowledge in the external environment [129]. Similarly, the literature comments: "*green absorptive capacity has been shown to facilitate the diffusion of environmentally friendly knowledge within firms and to help identify and prioritize key environmental initiatives"* [125, p. 3]. Although the interviews do not explicitly mention absorptive capacities, they do mention the training that occurs when an SME is a supplier of a larger company that involves environmental issues, interviewer 2 comments *"The SMEs probably have an external consultant who works with the multinational, they will train the SMEs on how to implement environmental activities or initiatives and at the same time the suppliers have to start generating information that the large companies have to report in their annual reports".*

Interviewer 1 highlights the importance of the knowledge given by private entities and government: "*Well look, I agree, the fact that there is participation in various forums, organized by the same private initiative, by the academy, by the government, definitely helps to begin to filter these concepts, to begin to generate awareness..."* However, he considers that this knowledge acquired by the members of the organization becomes useless if it is not adopted by the SME management.

System 1 or implementation system where the basic activities of the system are performed, transforming inputs into outputs and produces the goods or services that the system offers to its environment. For the case of manufacturing SMEs in Mexico City is called sustainable production, this system relates to the environmental requirements demanded by the environment and requires the acquisition of technologies such as infrastructure for efficient energy use and process optimization, also linked to research and development and support of technology 4.0. for continuous innovation. 0. for continuous innovation of this system is important system 2 in relation to absorption capacities.

From the experts, they consider that technology acquisition is relevant, however, for SMEs it can be complex due to their financial constraints, that is why interviewer 2 considers that SMEs should perform a risk and opportunity analysis: *"One way to look at it is always from a perspective of risks and opportunities, there are risks for not doing something environmental, for example legislation, change in market behavior, costs and the other way to look at it as opportunities, diversify a product or service for another market, see the incentives, changes in technology that can make it much easier to appropriate environmental practices, make this double vision of risks and opportunities for each environmental issue, then let's talk about energy, let's talk about water, let's talk about emissions, let's talk about waste and materials. Each topic will have its own risks and opportunities and then we will know where to start, what to adopt first and what will be more worthwhile".*

For interviewer 1, he considers that although for SMEs the process of moving to eco-innovation can be costly and a slow process, this can be achieved with circular economy activities: *"It is not such a fast process either, you have to invest as a company, you have to invest in the dissemination part that allows the positioning of the image. Now, in fact, if you and the companies follow practices such as circular economy or other types of benefits, that is where you can measure the impact more quickly because instead of and this is more of nothing, you see it in the environment".*

From the literature, eco-innovation for manufacturing SMEs becomes a valuable component given that *"at the macro level, it has been found that green innovations, on average, are associated with a higher degree of technological novelty as they are more likely to arise from combinations of new and/or existing technologies that belong to 'distant' fields of knowledge"* [127, p. 660]. In turn, the recent literature shows

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that Industry 4.0 also helps to transit towards eco-innovation: *"In addition to emission deduction, digital innovation enables an optimal allocation of resources and is expected to unlock the full environmental performance potential of the firm. Based on the current sustainability trend, it is hypothesized that digital innovation can improve the environmental performance of SMEs"*[120, p. 5].

4. Discussion

4.1. The competitive environment

The competitive environment significantly influences the adoption and performance of eco-innovation in SMEs [149]. This is particularly true for environmentally oriented firms, where eco-innovation has a positive impact on business performance, especially when combined with environmental orientation and resource commitment [150]. In the case of manufacturing SMEs in Mexico City, according to the experts interviewed, most SMEs are part of the value chains of large companies and multinationals, which obliges them to comply with certain environmental standards, in which, if they do not meet them, they will be replaced by other SMEs that comply with these standards, therefore H1 is accepted.

4.2. The economic environment

The technological environment significantly influences eco-innovation in SMEs, with the incorporation of "ecotechnologies" being viewed as a traditional innovation process [151]. However, SMEs face several challenges in this regard, including lack of awareness, outdated equipment, and limited resources [152]. However, as the literature studied shows, policymakers, and top-tier manufacturing SMEs in building an exceptional innovation platform that SMEs can rely on for assistance and support to preserve their business performance in the future and beyond [153]. For the experts, Mexico City has done very little work in ensuring a technological environment for manufacturing SMEs to adapt their production processes towards eco-innovative practices. H3 is accepted.

4.3. The technological environment

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4.4. . Political Environment

In the political context and eco-innovation emerging as a relevant factor, it is essential that small and medium-sized enterprises (SMEs) focus on developing environmental technologies to promote sustainable development and environmental protection. Since the market alone cannot effectively manage environmental resources, it is necessary for the government to provide support to SMEs through the implementation of laws, policies and fiscal measures that encourage innovation in this specific area [154]. Government incentives, such as public financing, tax incentives, and tax exemptions, play a crucial role in promoting eco-innovation in SMEs [155], [156]. However, the effectiveness of these incentives can be influenced by factors such as financial constraints [157], accessibility of funds [158], and the optimal range of subsidies [159]. For experts, in Mexico City, it is relevant to consider incentives through subsidies or tax reductions for SMEs that carry out environmental practices. For this reason, H4 is accepted.

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4.5. Social environment

The growth environment of innovative SMEs is determined by various ecological factors, including policy, finance, and market [160]. However, the impact of eco-innovation on sustainability performance varies; eco-processes and eco-organizational innovation show a significant association [161]. The role of environmental strategy in driving green innovation and environmental performance is also highlighted [162]. Despite these positive influences, SMEs face barriers to eco-innovation, including financial limitations and lack of awareness. Therefore, an enabling social environment is crucial to promote eco-innovation in SMEs. In the specific case of Mexico City, market pressures are not evident, however, according to experts, understanding social dynamics in relation to customer requirements allows taking advantage of potential market segments. Therefore, H5 is true.

4.6. Strategic orientation and focus

According to the literature, strategic orientation encourages SMEs to engage in waste management, recycling or reuse of resources, research, and development, producing sustainable products that take advantage of customer requests, and using machines. of environmental management [163]. Furthermore, market orientation and value co-creation positively affect green product innovation in the context of small and medium-sized enterprises. Regarding the interviews, the experts consider that the basis for implementing eco-innovations is that managers have a strong awareness of environmental care and thus guide the company towards sustainable practices [164]. Therefore hypothesis 6 is accepted.

4.7. Internal and organizational capabilities

Internal capabilities such as organizational learning and dynamic capabilities help overcome resource constraints and improve eco-innovation performance. Additionally, the role of competencies, network relationships, and strategic orientation in driving the adoption of environmental innovations and improving corporate performance[165]. These internal capabilities are influenced by regulatory, supply and demand factors, as well as shared vision, stakeholder management and strategic proactivity, in the promotion of different types of eco-innovation and environmental protection [166]. In the case of SMEs in Mexico City, experts agree that they must strategically consider the implications of adopting eco-innovation in their organizations to take advantage of the economic and efficiency benefits that it implies. For this reason, H7 is accepted.

4.8. Adsorption Capabilities

Research has consistently demonstrated the important role that knowledge plays in driving eco-innovation. On the one hand, the dissemination and use of knowledge to improve process innovation, and the latter also emphasizes the role of knowledge diffusion between companies [167] or on the other, the superiority of knowledge-intensive companies in eco-innovation [168]. Therefore, SMEs must consider specific strategies to acquire and use external knowledge, the first highlighting the role of R&D cooperation and the second the importance of knowledge management [169]. Thus, H8 is accepted.

5. Conclusions

By identifying multiple dimensions and categories, it provides a solid foundation for future research and practice in this field. Overall, the Viable eco-innovation system model in Mexican manufacturing SMEs reveals the interconnectedness and dependence among various systems that drive the adoption of eco-innovative practices. From policy formulation to implementation in production, each system (management, intelligence, control, coordination, and implementation) plays a crucial role. Management preparedness, knowledge absorption capacity and understanding of environmental impacts are critical to the transition to sustainable practices. Organizational culture, environmental certification, and the integration of technologies such as Industry 4.0 emerge as key

pillars. This comprehensive approach recognizes the complexity of the process and highlights the need for strategic vision, sectoral collaboration, and government support to catalyze eco-innovation in manufacturing SMEs in Mexico.

In relation to future research, it is suggested to deepen the understanding of the dynamics of eco-innovation as a complex adaptive system, exploring new theories and approaches that help to better explain this phenomenon in the specific context of manufacturing SMEs in Mexico City. In addition, it would be desirable to develop and validate specific measurement instruments to assess eco-innovation in this context, as well as to explore the application of qualitative approaches to understand in depth the experiences and perceptions of firms. In addition, future research could focus on the design and implementation of specific policies and programs to promote eco-innovation in manufacturing SMEs in Mexico City, as well as on the evaluation of their effectiveness in different business contexts.

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