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(Article begins on next page)

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A conceptual framework for the eco-efficiency assessment in small- and medium-sized enterprises

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The mitigation and prevention of environmental impacts is still a challenge for most companies, especially for small- and medium-sized enterprises (SMEs). The literature shows that researchers are paying attention to the concept of eco-efficiency, revealing companies' significant efforts to develop sustainable methodologies due to consumer pressure or government enforcement. However, concrete initiatives implemented at SMEs remain scarce. The aim of this paper is to present a conceptual framework to examine how SMEs understand the concept of eco-efficiency and implement other sustainability strategies through the identification of the following four specific factors: availability of an environmental management system, environmental knowledge, organizational culture, and environmental monitoring and control. In this paper, limitations and research gaps in the specific context are analyzed, and a conceptual framework allowing the eco-efficiency implementation to be assessed is proposed. An exploratory study has been carried out in17 SMEs of the wood industry in Bogotá, Colombia. The results show that most SMEs are unaware of existing sustainability strategies and environmental practices. Nevertheless, all SMEs agreed that the environment requires more attention and thus are interested in sustainability strategies to help decrease the negative impact of companies and increase their cost-effectiveness and competitiveness.

Keywords: conceptual framework; eco-efficiency; small and medium-sized enterprise; sustainability strategy; wood industry

1. Introduction

The world's industrial and economic activities have focused on the exploitation of renewable and non-renewable natural resources, causing constant and growing contamination to the environment and creating a negative impact on both society and nature. Therefore, different governmental organizations, companies, and researchers continue to search for mitigation or prevention strategies and measures to avoid and reduce environmental impacts.

Initially, one of the most significant movements in the search for environmental strategies began at the Conference of the United Nations on the Human Environment held in Stockholm, Sweden, in 1972. At this conference, the relationship between development and environmental protection was defined with the term 'eco-development'. This concept represents the commitment to reconciling increases in production with a respect for ecosystems necessary to maintaining world habitability conditions (Brundtland, 1987; Mebratu, 1998). While the term 'eco-development' had been widely disseminated, in the 1980s, the International Union for the Conservation of Nature (IUCN) defined 'conservation' as a means of establishing the stratification of the extinction of the species, ecosystems and environmental resources (Kates et al., 2005).

Following this definition, the expression 'sustainable development' was not universalized until the World Commission on Environment and Development (CMMAD) published a document known as the 'Brundtland Report' in 1987, which defines 'sustainable development as meeting the needs of the present generation without compromising the ability of future generations to meet their own needs' (Brundtland, 1987; Holden et al., 2014; Kates et al., 2005). Different useful strategies have been designed to achieve and put into practice sustainable development, such as the case of eco-efficiency, which establishes the relationship between economy and ecology (Ct et al., 2006). Several definitions of eco-efficiency can be found in the literature, given the wide range of applications (Besné et al., 2018; Jové-Llopis and Segarra-Blasco, 2018). ISO 14045 (International Organization for

Standardization, 2012) define eco-efficiency strategies as a quantitative management tool which enables the study of life-cycle environmental impacts of a product system along with its product's system value for the stakeholders. In this paper, eco-efficiency has been recognized to be necessary for achieving a balanced use of resources through the adoption of more sustainable strategies by employees. This implies that eco-efficiency represents an essential strategy for the decision making of the leaders with respect to the sustainable value chain.

In order to examine how SMEs understand the concept of eco-efficiency and implement other sustainability strategies, a review of the state-of-the-art concerning the eco-efficiency concept has been carried out. Then, some gaps in the development and application of eco-efficiency in SMEs have been identified. For example, the discrepancy between 'efficiency' and 'eco-efficiency' terms in theoretical, practical and empirical studies is not clearly understood. Also, some biased measurement of efficiencies due to the unsuitable orientation of eco-efficiency measure models still exist in recent related studies (Ho et al., 2018; Huang et al., 2018; Jové-Llopis and Segarra-Blasco, 2018).

Several researches provide quantitative measures of economic and environmental benefits (Agita et al., 2017; Huang et al., 2018; Jové-Llopis and Segarra-Blasco, 2018). Nevertheless, these contributions focused on individual economic and environmental indicators. One of the major restrictions when analyzing several single indicators separately is that analysts cannot draw economic inferences (Ho et al., 2018). Therefore, an integrated indicator might better reflect the economic performance of productive sectors. Additionally, the comprehensive assessment of sustainability should include environmental management, environmental knowledge, control system, and other social aspects that have not yet been embedded in the concept of eco-efficiency in practical applications (Huang et al., 2018; Koskela, 2015; Müller et al., 2015; Ullah et al., 2016).

Moreover, SMEs make up the majority of businesses in most countries, making them hugely important for economic growth and innovation. However, the impact of eco-strategies on the SMEs' performance has received less attention in the literature in comparison to that of large firms (Jové-Llopis and Segarra-Blasco, 2018). Based on these gaps, for organizations to incorporate eco-efficiency into their production activities, it is necessary to take into account other essential factors for their successful implementation.

Considering the above mentioned context, an eco-efficiency conceptual framework has been designed by using the Design Science Research Methodology (Chan et al., 2014; Dresch et al., 2015; Weber, 2017), and four factors to be examined were included: the environmental management systems, the environmental knowledge, the sustainable organizational culture, and the control and monitoring of environmental indicators. Each factor is composed of different elements that are based on strategies and tools that have not been taken into account in theoretical and practical eco-efficiency models. This framework could be used by SME managers, process owners, academic researchers and government analysts, who are interested in using this framework to analyze the results of the reference sector, to improve the process and to design and implement effective environmental laws and policies.

Finally, the conceptual framework has been translated into an evaluation tool, which has been applied in SMEs of the wood furniture industry in Bogotá, Colombia, to examine how SMEs understand the concept of eco-efficiency and interpret the four factors previously established. In general, the results disclose different opinions and perceptions about the sector, leading to the definition of further hypothesis and future researches.

The paper contributes to the previous literature in several ways. First, few SMEs are able to invest large amounts of resources to undertake multiple eco-strategies (Jové-Llopis and Segarra-Blasco, 2018). SMEs in Latin America have difficulties in enforcing their industry to more sustainable and eco-efficient processes, so this research contributes to the existing debate about the strengths and weaknesses of the SMEs in the sustainability context. Second, the analyses of eco-efficiency here proposed are still scarce in emerging countries. In general, empirical studies are performed in rich industrialized countries, while this study is focused on one emerging market that faces significant challenges when addressing sustainable development (Rauch et al., 2016, 2015). Finally, the present study is expected to be relevant for business leaders, as it indicates whether current eco-strategies are sufficient or whether adjustments are needed.

The paper is organized accordingly to the following structure: Section 2 introduces the literature review regarding the eco-efficiency models that have been applied in small- and medium-sized enterprises. Section 3 presents the research gaps to design a conceptual framework. Section 4 details the proposed methodology. Section 5 describes

the eco-efficiency conceptual framework, whereas Section 6 shows its application. The results are discussed in Section 7. Section 8 summarizes the main conclusions and some ideas for future researches.

2. Eco-efficiency in SMEs: an overview

An emerging market is a country that has some features of a developed market but does not meet the standards to be called a developed market. Therefore, industrial leaders are considering emerging market economies as important markets in their own right (Rauch et al., 2016). They offer clear opportunities for economic growth, but this implies new challenges for different industrial companies. One of the main industrial goal is to achieve sustainable manufacturing by introducing the Distributed Manufacturing System (DMS) (Rauch et al., 2016, 2015; Senvar and Bulkan, 2017; Srai et al., 2016).

DMS is defined as system autonomous agents, which are mutually dependent on each other. Namely, companies will focus on decentralizing production units to establish a global market and meet local needs. Reasons for the trend towards DMS are the increasing importance of sustainability, the rise in logistic costs, the mass customization, the democratization of design and open innovation, the market and customer proximity, the well-aimed use of resources and regionalism and authenticity (Senvar and Bulkan, 2017). Sustainability is part of the optimization of the overall efficiency of enterprises' products and processes (Rauch et al., 2016, 2015). For this reason, responsible companies and consumers have just reacted to the challenge of sustainability by examining alternatives to their usual business (Heikkurinen et al., 2019). Different strategies, such as eco-efficiency, have been used to contribute to the achievement of DMS in SMEs.

Eco-efficiency was globally promoted in 1991 by the World Business Council for Sustainable Development (WBCSD), which declared that 'eco-efficiency is achieved through the delivery of competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing environmental impacts of goods and resource intensity throughout the entire life-cycle to a level at least in line with the Earth's estimated carrying capacity' (WBCSD, 2009). Also, eco-efficiency has been popularized as a management philosophy that encourages companies to balance their environmental and economic performances by promoting innovation, growth and competitiveness, namely a sustainable change in business and consumption. The basic notion of eco-efficiency prescribes a win-win strategy to target at less damaging use of natural resources along with financial savings for the company (Besné et al., 2018; Heikkurinen et al., 2019). There are many definitions about eco-efficiency, however, all the studies agree that eco-efficiency aims to generate more value in products and services while using less material and energy (Ct et al., 2006).

Several authors believe that eco-efficiency can help sustainable development by integrating activities in any type of business, regardless of the firm's size or economic situation. However, other researchers show that eco-efficiency is particularly useful in SMEs of emerging countries (Besné et al., 2018; Catarino et al., 2016; Fernández-Viñé et al., 2013; Jové-Llopis and Segarra-Blasco, 2018), because it has achieved economic savings in maintenance, savings in water consumption, reduction in raw material usage and/or energy consumption, as well as some changes in the properties of the products.

On the other hand, according to the traditional process in the supply chain, there are different management problems and wastes that do not add value to the customer: overproduction, waiting time, transportation and inventory. Companies that develop their products by engineer-to-order present difficulties in communication between the engineering, manufacturing, and installation departments (Dallasega et al., 2015). Besides, the lack of activities synchronization between those departments is the main cause of big levels of inventory, expenditures for operations and environmental waste. For this reason, eco-efficiency helps to eliminate the reprocessing of activities (Besné et al., 2018; Pardo et al., 2012).

A review of eco-efficiency in SMEs has been carried out using databases from 2012 to 2019. It can be highlighted that research has been focusing on different industry sectors, the most prominent being manufacturing industries (Alves and de Medeiros, 2015; Charmondusit et al., 2014; Fernández-Viñé et al., 2013; Jové-Llopis and Segarra-Blasco, 2018; Rattanapan et al., 2012; Zurano-Cervelló et al., 2018), construction (Tatari and Kucukvar, 2011), mining (Catarino et al., 2016; Henriques and Catarino, 2015), agriculture (Ho et al., 2018; Müller et al., 2015; Ullah et al., 2016), and petrochemicals (Alkaya and Demirer, 2014; Besné et al., 2018; Changwichan et al., 2018; Gómez

et al., 2018). The results of this review are classified according to techniques of eco-efficiency evaluation and implementation in SMEs.

Following recent studies, Müller et al. (2015) conducted an analysis on eco-efficiency among different kiwi growers in New Zealand by gathering data through surveys to analyze the specific handling of crops. The authors evaluated sustainability in crops by comparing environmental performance and productivity and demonstrated that the eco-efficiency metric can enhance product differentiation for customers and can also assist orchardists to find the most sustainable management system. In addition, Ho et al. (2018) used the frontier-based eco-efficiency model to assess whether coffee farmers with sustainability certification are more eco-efficient than non- certified farms by data envelopment analysis (DEA) and factorial regression, evidencing that sustainability-certified farms are found to be more eco-efficient than conventional farms. In this study, the lack of strategies and social indicators is evident, so the socioeconomic aspects relevant to the welfare of coffee income and poverty should be incorporated. Similarly, it has been studied the economic environmental results of cotton crop systems in Pakistan; their evaluation was carried out using (DEA) and product lifecycle analysis by Ullah et al. (2016), who concluded that the use of pesticides and fertilizers, the deficiency in field operations, and irrigation are the primary sources of environmental impact and so proposed substantial changes in the production chain.

In addition, some researches reflect the concern of high volumes of pollution and the excess of energy used in developed countries. Xiong et al. (2017) measured eco-efficiency indicators in the industrial sector in China from 2006 to 2013 using the DEA technique to determine which are the most efficient regions in economic and environmental terms. However, DEA does not account for data uncertainties, which is important because eco-efficiency scores are highly sensitive to data errors (Gómez et al., 2018). Another methodology applied for eco-efficiency assessment is the use of environmentally extended input/output (EEIO) and multiregional input and output models (MREEIO) (Zurano-Cervelló et al., 2018).

Furthermore, one of the best ways to evaluate eco-efficiency is by designing indicators. Thus, a study was carried out to measure eco-efficiency in the Finnish forestry industry from an economic and environmental perspective (Koskela, 2015). This research concludes that the levels of eco-efficiency are not optimized. Thus, it is necessary to find the proper sustainability tools so that these types of companies can increase their productivity and competitiveness, emphasizing how they would benefit from applying eco-efficiency. Similarly, another study proposed models for economic, energy and environmental efficiencies to analyze the performance of Chinese provinces (Huang et al., 2018), showing that some provinces perform better in economic terms than in energy and environmental efficiencies.

It is evident that researchers use theoretical and mathematical eco-efficiency models for metric measurement and indicator identification, mainly to make comparisons in industrial behavior around the world. However, as far as national and local data are concerned, there are some difficulties in data collection at the regional level (Huang et al., 2018; Liu et al., 2018). The lack of mechanisms for the control, the collection of environmental information, and eco-innovation are evident, which entails effectively promoting public policies (Jové-Llopis and Segarra-Blasco, 2018).

About the implementation eco-efficiency model, one of the pioneer companies in implementing eco-efficiency was the Chemical Corporation (BASF), which developed a methodology in 1996 that integrates environmental and economic behavior in chemical processes, and products during its cycle of life, based on the evaluations of ISO 14040:2006, 14044:2006 and ISO 14045:2012 standards. This methodology was validated in 2016 by the Organization for Health and Public Safety (NSF International), and hence the eco-efficiency analysis carried out by this company can be applied to support the sustainable development of the customer throughout the value chain by reducing the energy and resources used (BASF, 2015; Caiado et al., 2017).

In another implementation study, is developed a project with multiple marble extraction and transformation companies, implementing strategies for cleaner production and sustainable value (SV), which aim to optimize the industrial processes (Catarino et al., 2016). Since eco-efficiency alone cannot address every problem in a company, its focus is on cleaner production strategies and life cycle analysis. For example, a methodological framework of eco-efficiency based on fuzzy logic and life cycle assessment was applied to Mexican SMEs to improve the eco-efficiency analysis and facilitate the decision making process (Besné et al., 2018).

Besides, it has been developed the cleanest eco-efficiency and production program supported by the European Commission, resulting in SMEs in a coating sector in Turkey making substantial changes in their use of paint materials for less toxic products for the environment and human health, in addition to achieving water and energy savings by promoting a sustainable approach to environmental and economic aspects (Alkaya and Demirer, 2014).

From a life-cycle analysis for supply-chain improvement approach, the potential for improved eco-efficiency in SMEs is detected when the key stakeholders of the chain are identified, which should not only be emphasized in environmental performance but also in the evaluation of the products, recognizing the critical processes that need to be improved. Although SMEs are classified as companies with limited resources (Besné et al., 2018; Fernández-Viñé et al., 2013, 2010), they are higher in the chain due to the potential influence of the elaboration of the final product. For example, it has been evaluated the environmental and economic sustainability of bioplastic production together with end-of-life options, the combination of economic and environmental indicator showed that environmental and economic sustainability could be enhanced 100% by mechanical recycling all kinds of the studied plastics (Changwichan et al., 2018).

In the literature review, some elements that allow the implementation of eco-efficiency in various studies have been identified. Table 1 shows some components that research studies have included to apply eco-efficiency; for example, indicators, simulation tools, and statistics.

Focus found	(Ho et al., 2018)	(Zurano-Cervelló et al., 2018)	(Huang et al., 2018)	(Besné et al., 2018)	(Jové-Llopis and Segarra-Blasco, 2018)	(Xiong et al., 2017)	(Ullah et al., 2016)	(Koskela, 2015)	(Sproedt et al., 2015)	(Charmondusit et al., 2014)	(Fernández-Viñé et al., 2013)	(Rattanapan et al., 2012)
Process analysis	x	x	X	x	x	x	x	x	x	x	x	x
Standardization of resources			X				x		x	x		x
Production control	x		X	x					x			
Simulation	x	x		x		x			x			
Resource consume accounting		x	X		x		x	x	x	x	x	
Analysis of economic indicators	x		X	x	x	x	x	x	x	x	x	x
Analysis of environmental indicators	x	x	X	x	x	x	x	x	x	x	x	x
Analysis of social indicators								x		x		
Analysis of statistical data				x	x		x	x		x	x	
Analysis of data envelopment (DEA)	x	x	X			x	x					

Table 1. Focus found in the eco-efficiency models

Some commonalities found in the above studies include a productive process, resources used, and a measure of consumption, the development of eco-efficiency and social models, and analysis of the model using statistical tools. In addition, those elements explain the following advantages for a company in developing eco-efficiency:

- Increase economic growth. One of the most noteworthy benefits of applying eco-efficiency in SMEs is the positive economic results in the indicators that demonstrate reliability with shareholders and customers (Caiado et al., 2017).

- Reduce pollutant emissions. Eco-efficiency allows a diagnosis of all the company's processes, identifying the points with the greatest environmental impacts and proposing substantial changes in the company's production processes (Henriques and Catarino, 2015).

- Comply with environmental regulations. Within the common processes in SMEs, the production, maintenance, marketing, and other processes are carried out so that environmental management can use strategies linked to compliance with environmental laws and regulations in a particular environment (Fernández-Viñé et al., 2013).

- Compare performance and production levels in the company. With eco-efficiency, one can evaluate the effectiveness of an SME, which also serves as a set of elements for making decisions related to business sustainability. The results of eco-efficiency make it possible to compare processes in companies in the same sector and to identify barriers to business competitiveness (Ullah et al., 2016).

- Monitor economic, social and environmental aspects. Control and measurement tools allow for the evaluation of water consumption, materials, energy, solid waste emissions, and greenhouse gas emissions; thus, a drop in these values is a positive result for the system, since it indicates an improvement in the eco-efficiency in the company. In this way, the monitoring of the processes will allow for continuous improvement; for example, checking if economic, social and environmental objectives are being achieved or identifying the significant deviations between expectations and results to make appropriate modifications (Sproedt et al., 2015).

3. Limitation of the eco-efficiency concept in SMEs

To connect the purpose of this research with the collection and data analysis, a conceptual framework for eco-efficiency has been designed, which is an abstract representation of factors that have not been taken into account to develop eco-efficiency in SMEs. Table 2 provides a synthetic overview of the shortcoming obtained from the literature review.

Factors	Shortcoming
Environment management system	The development of a simplified eco-efficiency implementation methodology that does not require extended periods of time to assess the investment benefits (Catarino et al., 2016; Fernández-Viñé et al., 2013). Limited management experience in environmental management and operations issues (Ct et al., 2006). Lack of policies for environmental management and strategies for the acquisition of economic and environmental data in SMEs (Charmondusit et al., 2014). Few SMEs are able to either invest large amounts or undertake a large number of eco-strategies (Jové-Llopis and Segarra-Blasco, 2018).
Knowledge of internal and external customers about the environment	The lack of methodologies for standardizing the implementation of eco-efficiency (Catarino et al., 2016; Fernández-Viñé et al., 2013). Some greenhouse gas emissions and waste mitigation are not considered (Alves and de Medeiros, 2015; Caiado et al., 2017; Charmondusit et al., 2014). Lack of design of methodological guidelines for the implementation of eco-efficiency aimed especially at SMEs (Caiado et al., 2017; Jové-Llopis and Segarra-Blasco, 2018). Lack of validation of the proposed models for the implementation of eco-efficiency (Ct et al., 2006).
Organizational culture	The comprehensive assessment of sustainability should include social aspects; however, this dimension is mostly not considered nor evaluated (Changwichan et al., 2018; Koskela, 2015; Müller et al., 2015; Ullah et al., 2016). Strengthening of learning and communication programmed to implement eco-efficiency among actors in the value chain (Charmondusit et al., 2014; Michelsen and Fet, 2010; Ullah et al., 2016). Difficulty in promoting environmental compensation through the inclusion of eco-efficiency policies and incentives (Fernández-Viñé et al., 2013; Ullah et al., 2016).
Monitoring and environmental control	Specify if the eco-efficiency indicators are sufficient, suitable and aligned with the missionary strategies of the organization (Koskela, 2015; Müller et al., 2015; Ullah et al., 2016). Lack of development of a software tool for the management and monitoring of eco-efficiency in SMEs (Fernández-Viñé et al., 2013; Müller et al., 2015).

Table 2. Factors and significant shortcoming

The frameworks and methodologies are quantitative models since the eco-efficiency assessment is strictly related to a quantification. According to the previous researchers, it is noticeable that the eco-efficiency models include common elements such as process analysis, resource consumption and economic and environmental indicators analysis. Nevertheless, elements in production management, simulation, and social indicator analysis are the least studied. To move towards the more sustainable use of resources while improving the productivity and minimizing environmental impacts, organizations need a sustainability model with eco-efficiency methodology that integrates environmental strategies, technologies and information systems for extract data, value chain, and relevant knowledge to support a wide array of operational and strategic business decisions. In the following section, the methodology used for the conceptual framework is explained.

4. Methodology

As described in the "Design Science Research" (Dresch et al., 2015; Henver, 2007; Weber, 2017), the methodology to define a framework which contributes in a novel way to research has to follow a sequence of phases. Such a novel framework has to solve a problem that has not yet been solved or provide a more effective solution. The proposed methodology is already used in different areas of engineering and it is based on three cycles: relevance cycle, rigor cycle, and design cycle. Fig 1. shows how the three cycles have been developed in the present paper. The details on each cycle are explained in detail in the next subsections.

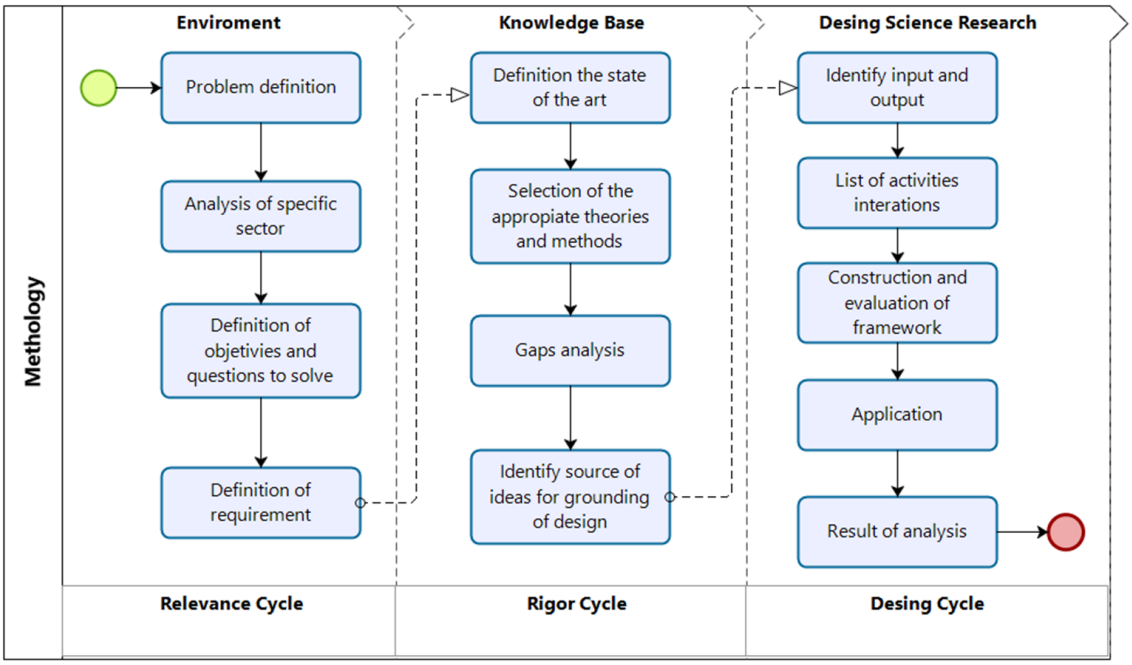

Fig. 1. Steps followed in design science research methodology

4.1. First stage: environment

The relevance cycle deals with the analysis of the environment. It connects the contextual environment of the research project with the design activities. It defines the research problem and justifies the value of the solution. The main objective of this stage is to understand the problem relevance, the current available solutions and their weakness in the sector of interest. The problems highlighted by SMEs of the specific sector have been analyzed through the competitiveness studies, strategic plans of government and direct communication with people in charge. The objective and questions to be solved have also been defined. In the end, based on the previous results, the final requirements have been defined.

4.2. Second stage: knowledge base

The rigor cycle connects the design activities with the knowledge base of scientific foundations and experience. In this stage, the literature review available in the sector previously defined has been analyzed. Based on the literature review, different theories, methods, models, and frameworks related to the eco-science have been analyzed. Therefore, the factors and elements associated with the research gap have been defined. Finally, the elements needed for developing the proposed framework have been selected. The collection of information and data from research are essential raw materials for creating a useful framework.

4.3. Third stage: design science research

The design cycle connects the core activities of building and evaluating the design framework with the processes of the research. A visual structure can help organizing information and ideas, so companies could benefit from it. The proposed conceptual framework provides a set of elements which are listed in a visual way to improve the understanding and focus on the content that is intended to be examined. The chosen application tool was an examination survey dispensed to company leaders, and the results of the survey were analyzed using a quantitative verification method.

In the following section, the proposed framework is described.

5. Design of the eco-efficiency conceptual framework

Following the three cycles described in Section 4, an empirical conceptual framework has been designed with the aim of having an overview of how SMEs understand the concept of eco-efficiency and interpret other sustainability strategies. Particularly, the methodologies, the tools, and the environmental strategies available in SMEs have been analyzed in order to determine the strengths and the weaknesses of each SME in the context of sustainability.

The framework has several contributions. First, the framework could generate a statistics report from set manufacturing companies about the analysis of their operation, identification and evaluation the environmental impacts, integration of their management system, environmental knowledge, eco-efficiency measurement, and an action plan for improving the environment. Second, the conceptual framework could include a methodology for sustainability to involve the elements, steps, tools and different techniques to apply eco-efficiency within the company. In addition, the advantages of the proposed frameworks could be the design or redesign of strategic indicators and operative indicators to make decisions.

The limitations were necessary for designing the conceptual framework with the different elements proposed. Through these elements, the factors of acceptance or eco-efficiency development in companies can be analyzed to identify the tools and techniques needed for their implementation. The proposed conceptual framework is shown in Fig. 2 it has four categories and in each one different aspect are examined, as described in the following subsections.

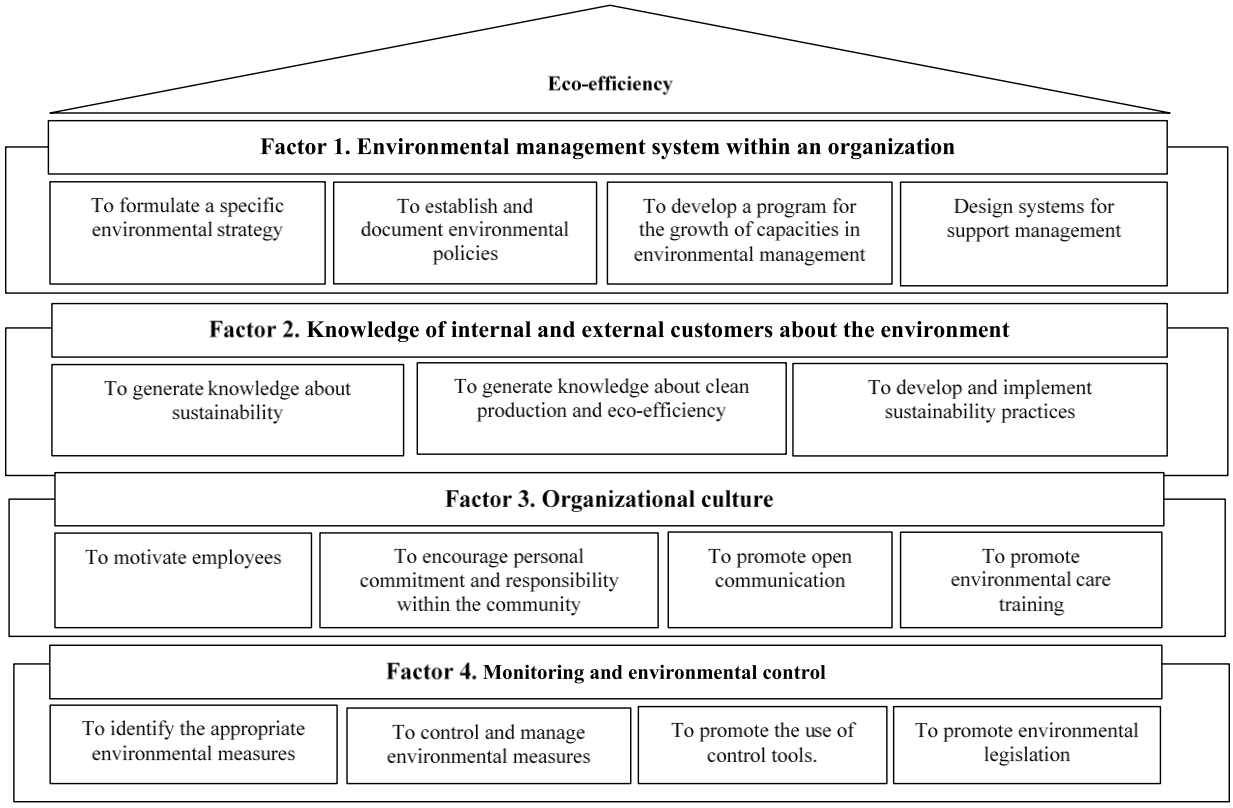

Fig. 2. Conceptual Framework of the Eco-efficiency Factors

5.1 Environmental management system within an organization

The environmental management system is a set of internal rules, which are defined by a collection of policies, processes, and procedures that ensure interaction among the principal activities of the company in relation to the environment. The Environmental Protection Agency in the United States defines the Environmental Management System (EMS) as a group of processes and practices that allow an organization to reduce its environmental impacts and increase its operative efficiency (Systems, 2004). The objective of an EMS is to decide "how to do" what eco-efficiency proposes.

However, the EMS includes Environmental Management Practices (EMP), which can be described as the systematic application of company management to environmental management. These practices manage the impacts on the environment, formulate plans and politics to implement actions for the protection of the environment and integrate the daily operations of a company with environmental activities. The most common systems include ISO 14001, Balance Score Card and the Total Qualities Management focused on cleaner production (Goosen, 2012; Ibrahim and Jaafar, 2016).

The EMS can also be used to deal with non-regulated problems; for example, conservation of energy and the factors affecting global warming. Nevertheless, the EMS by itself does not mitigate the environmental damage that a company could generate. In fact, it defines a planning frame to increase environmental awareness and provides the essential measures for decision-making, thus facilitating a company's compliance requirements.

Based on the literature research, this factor has been characterized by designing rules or working methods to discover mitigating techniques to maintain environmental balance. The objectives of this factor in the conceptual framework of eco-efficiency are to establish a series of environmental guidelines in a company, to define the strategies, documented support and policies integrated into the quality systems and capacity development program for the management of the environment.

5.2 Knowledge of internal and external customers about environment management

Knowledge in the enterprise is defined as intangible assets that generate value for an organization, and knowledge management is the process of organizational learning in companies which generates value from its intellectual capital and assets based on knowledge (Atia et al., 2017; Bruno et al., 2018; Jelenic, 2011). Value can be obtained by improving administrative management practices using stakeholders (Atia et al., 2017; Sarkis et al., 2010).

The relation between knowledge management and environmental sustainability in a company is associated with the action of the organizations that acquires knowledge and uses it effectively to obtain a sustainable competitive advantage in the market. In addition, to increase the different possibilities for success in the innovation of a product, it improves the processes and increases profit and uses environmental practices that are influenced by the culture of knowledge management (de Guimarães et al., 2018).

In this way, this factor proposes an ability to acquire, use, confront and transform the knowledge of environmental issues in a company in order to encourage and use different environmental strategies to improve its competitiveness and sustainability.

5.3 Corporate culture of sustainability

The corporate culture of sustainability is a relevant topic for organizations and researchers looking to explore this issue. Nonetheless, establishing this concept and putting it into practice remains a challenge for company managers (Linnenluecke and Griffiths, 2010). Some authors suggest initially defining the basis for a corporate culture to comply with the function of sorting out companies, generating a sense of identity, orientating the behaviour of employees towards an institutional goal and accepting change (Carro-Suárez et al., 2017; Carro Suárez et al., 2017).

Despite the difficulties in establishing an organizational culture in SMEs, SMEs make efforts to develop networks in different segments and regions, allowing access to market information, visibility, possibilities to execute projects and sustainable programs. In addition, sharing the knowledge through collaborations among companies, as well as between companies and other knowledge owners, such as universities and research centers, is essential to strengthen the economy. A network of SME can behave in the market as a single larger company, with the purpose of creating competition in the market (Antonelli et al., 2015; Antonelli and Taurino, 2011).

The relationship between corporate culture and sustainability can be defined in several ways. The Network for Business Sustainability establishes that corporate culture occurs when members of an organized exchange idea about the importance of seeking a balance among the pillars of eco-efficiency, social justice, and responsibility, with the goal of supporting a healthy atmosphere while operating successfully in the long term (NBS, n.d.). The model proposed by (Carro Suárez et al., 2017) suggests that a corporate culture of sustainability is based on reinforcing the search and acquisition of better social development in and out of companies, improving one's sustainability image within society, and establishing habits and new ways of behaviour and education. Also, the

This factor is based on incentives to motivate company employees, identify responsibilities in the company, and improve the levels of communication and training based on the principles linked to eco-efficiency strategies and sustainability.

5.4 Monitoring and environmental control

There are different methods to assess and measure the impacts of companies on the environment. In this study, analyzing eco-efficiency is a constant strategy to help in the transition to sustainable development, and different methods are proposed for their evaluation. Some methods that measure the impacts to the environment have been associated with the Delphi Method (Fernández-Viñé et al., 2013; Koskela, 2015), Data environment analysis (DEA) (Ullah et al., 2016), and Life Cycle Assessment (LCA) (Müller et al., 2015). Nevertheless, to carry out the analysis and measurement of eco-efficiency, various authors emphasize that initially, it is essential to have qualitative and quantitative information about what is to be measured, knowing how to measure it and the types of possible indicators (Agita et al., 2017).

This factor proposes a mean for identifying which are the right actions to measure the environmental impacts in SMEs, i.e., to be able to identify the indicators and essentials elements that help analyze the environmental, to establish the support tools that help the follow up in environmental analysis and to identify the regulations that may directly affect SMEs. The quantitative elements and requirements are involved in this factor, as the inputs and outputs in the process.

The quantitative elements to analyze the input material, energy and water, and at the same time the outputs, waste and emissions. Hence, there are two essential classes of inputs from nature for evaluating the eco-efficiency: the supply of resources (energy and water) and nature's function as a sink for the discharge of residuals and pollutants (Agita et al., 2017; Gómez et al., 2018). It has been pointed out that environmental pressure (impact) indicators such as emissions, land use and resource extractions can be used to monitor the changes in environmental effects.

6. Application of the conceptual framework

The productivity dynamic in SMEs is due to their importance in the industrial tissues, even if a SME is often characterized by having few resources, especially financial and human. In addition, the survival of the SMEs is closely dependent on its capacity to acquire new knowledge and share it with other SMEs (Besné et al., 2018; Valdez-Juárez et al., 2018). The economic, social and environmental problems of Colombian SMEs are partially due to a lack of mechanisms to overcome competitive barriers in an emerging market. Only SMEs that focus their learning, knowledge, and product and process innovation on the market attain a strong competitive advantage, outrun competitors, and survive in highly competitive environments(Valdez-Juárez et al., 2018).
Considering the importance of Colombia's biodiversity, which has a strong presence in the wood furniture industry, this sector was selected for the analysis. Also the fact that many companies are working in the transformation and fabrication of wood products prove the significance of the sector.

6.1 The Colombian wood sector scenario

Around the forty-nine percent of Latin America and the Caribbean is covered by forests; these 891 million hectares represent 22% of the world's forests. This region has 57% of the primary forests in the world, the most important from a biodiversity and conservation perspective. While 18% of the area is protected, 14% is available for production purposes, and the carbon stored comprises 104 gigatons of forest biomass (FAO, n.d.).Colombia had 59,558,064 hectares (52.2% continental land) of forest in 2015, according to the Environmental Information System. The loss of forest for that year was 124,035 hectares (Ministerio de Ambiente y Desarrollo Sostenible de Colombia, 2015).

The furniture industry was classified by the International Standard Industrial Classification (ISIC): forestry and logging (Division 02 of the ISIC, Rev. 4), the manufacture of wood (Division 16 of the ISIC Rev. 4) and the manufacture of paper and paper products (Division 17 of the ISIC, Rev. 4) (Departamento Administrativo Nacional de Estadística, 2012).

The wood industry in Colombia includes companies producing furniture, chipboards, plywood and sawmilling wood; this sector does not focus on the commercial reforestation to obtain the primary raw material. The wood industry is a significant sector in Colombia; according to the Superintendence Association, Colombia has approximately 2,000 companies working in the transformation and fabrication of wood products, which is 4% of the country's companies, and Colombian exports of wood products have not developed positively in recent years, as they represent only 3% of the national production of these products (Marín, 2013; PROFOR, 2017).

The most important consumers of wood are paper producers (2 million m^3), construction companies (1.8 million m^3), furniture manufacturers (0.5 million m^3), and packing manufacturers (0.3 million m^3) (Herrera, 2015). SMEs consume 430,000 m^3 of wood, mostly chipboards and boards for furniture and carpentry. The furniture industry also has an artisanal component that is exclusively for the national market, with most companies in the group of SMEs which design a number of models for offices and homes.

The industrial production of furniture in Colombia, according to the data of the Departamento Administrativo Nacional de Estadistica (DANE), during the fourth trimester of 2017 showed a drop of 13.6% and a decrease in sales of 5.9%, which translates into unemployment (Departamento Administrativo Nacional de Estadística, 2018). Among

the most important cities in Colombia that produce wooden furniture is Bogotá, with more than 40% of companies located in this city, followed by Medellin, Cali, Barranquilla, Bucaramanga, Pereira, and Manizales.

6.2 Value chain description

There are several stages in manufacturing furniture, as shown in Fig. 3. The first begins in the forest crop and in the natural forest where the principal raw materials are obtained (Lucia Castañeda, 2016). Next, the raw materials are turned into different kinds of wood. The second stage is to identify better techniques and new trends in the market, and the quality of the product is established to satisfy the customer. Lastly, the third stage is to assemble, pack and deliver or exhibit the finished product. The following flowchart illustrates the operational sequence for the fabrication of furniture, although this particular chart could change depending on the product:

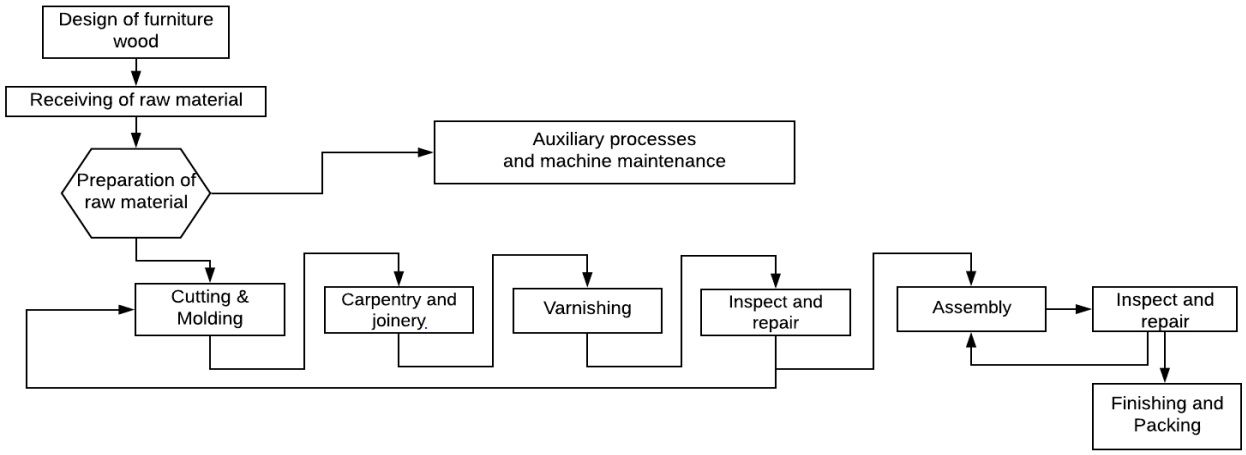

Fig. 3. General wood transformation flow chart by the National Federation of Wood Industries

The value chain of the furniture is a dynamic function, characterized by the relations or links among the interested participants. It is a modular chain in which providers build products according to the specific requirements of customers, where all responsibility is assumed and machinery and technology are used (Gereffi and Humphrey, 2005). Despite complex interactions among buyers and providers, the information flows both ways to satisfy customers' needs. Table 3 shows the actors taking part in the chain.

Factories before the process	First, production in the wood transformation.	Next, sale and distribution of the wood.	Second, transformation of the wood.	Finally, customers
Dedicated to forest plantation.	Companies dedicated to the transformation of raw wood into cut wood, chips, and natural cork to then turn it into accessories such as boards and chipboards.	Companies dedicated to distributing the wood to customers or to locate the wood where customers can buy it (furniture factories). This is their raw material.	Designing companies and furniture factories (carpentry, cabinet making) and build according to specifications from the customer's market trends.	Offices, homes, construction, and commerce in general.

Table 3. Principal members in the value chain

This research is focused on the second transformation of the wood, which assumes risks and generates profit. These members incorporate new production techniques and add innovation to the production and marketing processes.

6.3 Set of analyzed SMEs

A set of SMEs in the wood furniture sector for home and industry of the city of Bogotá, Colombia, were selected for the analysis. Among all the available companies, the selected ones participated to the Cleaner Production Project developed by the Bogotá city hall in 2018. Furthermore, the selected companies are found in the commercial registry of the chamber of commerce and comply with the minimum requirement of being companies

with legal existence. In addition, they are family companies and have from 10 to 20 employees. After the application of these criteria, a total of 17 SMEs were selected.

Considering the proposed model, SMEs are analyzed using a questionnaire with four sections (one for each factor) to examine how they consider the concept of eco-efficiency and interpret other sustainability strategies of development. The results obtained by the survey were analyzed using a quantitative verification method, as described in the following section.

7. Results and Discussion

The framework defined in Section 5 has been used to develop a survey to collect the answers of the 17 selected SMEs to the questions related to the four factors. The following subsections report the answers of SMEs to the four sections of the questionnaire applied. The possible answers were rated as 4 for "definitely yes" (DS), 3 for "probably yes" (PS), 2 for "probably not" (PN), and 1 for "definitely not" (D).

For each factor, a radar chart has been used to compare the SME answers. It allows to easily identify which SMEs have similar values and which of them are outliers. The radar charts are also useful for seeing which company scores high or low according to its answers. Each SME in the radar chart is provided with an axis that starts from the center. The highest level is 4 and the lowest is 1. All the axes are arranged radially. The axis-to-axis lines are used as a guide to determine the score of each answer. Each of the answers' value is plotted and connected together to form different figures that highlight the behaviour of the factor under study.

7.1 Environmental management system

An environmental management system can facilitate the development of eco-efficiency, as it provides adequate information for its measurement and monitoring (Passetti and Tenucci 2016). The environmental management is related to the use of efficient material, reducing environmental impacts and risks, and other implied measures related to reducing costs and generating new revenues. Companies shown a great interest in establishing their environmental management system, which facilitates the development of eco-efficiency strategies.

Fig. 4 shows the answers to the questions related to the environmental management systems, which is the first factor of the proposed framework. Three questions have been proposed "Does your company have an environmental management system?", "Are the environmental problems important for your company?", and "Is your company interested in implementing an environmental management system?".

From the radar chart, it is evident that all the considered SMEs did not use environmental management systems, environmental guidelines or environmental plans within their mission and operational strategies. In fact, according to the results, 80% of SMEs affirm that they have no environmental management system inside the company, which would allow them to develop rules and environmental objectives. The companies that did adopt an environmental management system affirm that it was a requirement from their customers, even though they were not aware of the benefits of implementing an environmental management system. The results show that only the 10% of companies tried to develop the elements that the factor proposes. However, around the 50% of companies show a high interest in developing an environmental management system, especially the ones that consider environmental problems highly significant.

To summarize, it can be observed that several SMEs show high values for all the questions, at least the half indicating interest in having an environmental management system. Nevertheless, some results were conflicting because some SMEs had a low interest in the system but recognize its high importance.

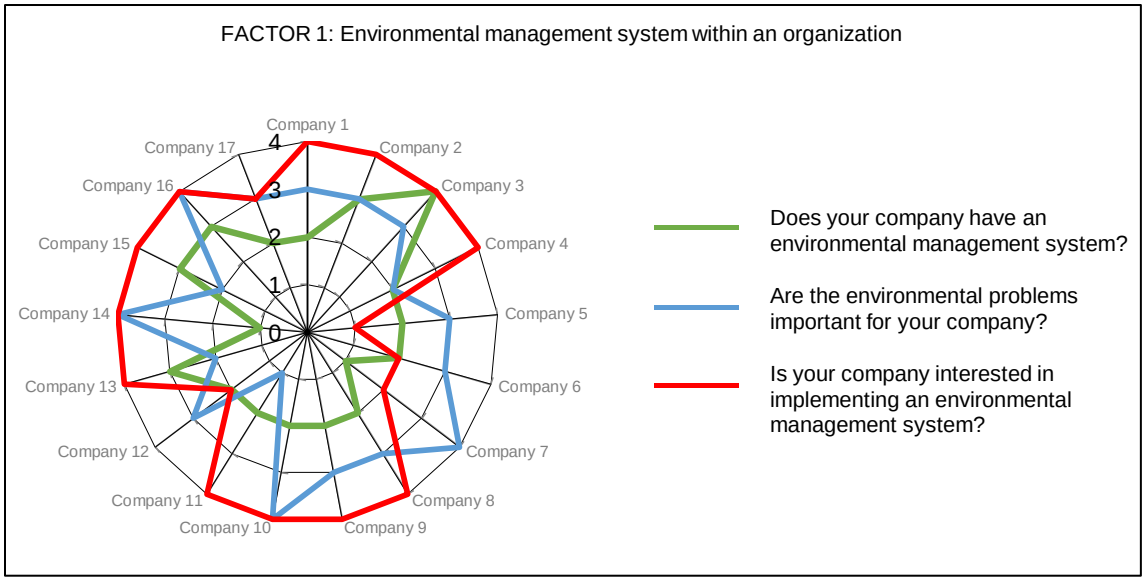

Fig. 4. Environmental management system

7.2 Effect of management of environmental knowledge on stakeholders

The second factor analyses the management of environmental knowledge. The management of such knowledge is intended to show that members of a company can carry out good practices in their operations and can, therefore, contribute to eco-efficiency in reducing costs, while at the same time watching the environmental performance of their company increase (Cagno et al., 2012; Passetti and Tenucci, 2016).

The results of the analysis are shown in Fig.5. Four questions have been proposed: "Does your company have any knowledge on the Sustainable Development topic?", "Does your company have any knowledge on the environmental practice?", "Does your company have any knowledge on the Eco-efficiency topic?", and "Has your company implemented environmental practices?". Approximately 58% of companies consider that they are not aware of sustainable development issues. In addition, their knowledge of environmental practices is low. When asked about strategies related to cleaner production and eco-efficiency, approximately 29% and 35%, respectively, considered they may be aware of the topic but are insecure handling it.

The percentage of companies that implement environmental practices is low. The chart shows that only 10% of the analysed companies felt secure in implementing them in their operations; this is interesting, considering that SMEs that apply environmental tools or techniques had links with large companies that require their suppliers to use some environmental tools.

From these results, it is evident there is a deficiency in issues related to the knowledge of environmental practices and its development. Thus, it is relevant to show the importance of introducing these issues in the internal and external operations of companies by developing their members' awareness. The internal and external processes, when linking them with sustainability and knowledge management, are focused on encouraging the participation of all company members through the implementation of their ideas, reducing unnecessary processes, and optimizing time and resources, to show that employees' knowledge and efforts are valued.

To summarize, it can be observed that all the SMEs have a low knowledge regarding sustainability strategies. Thus, it is necessary to develop an environmental culture through specific training, awareness and communication, which may assist organizations in improving their environmental performance.

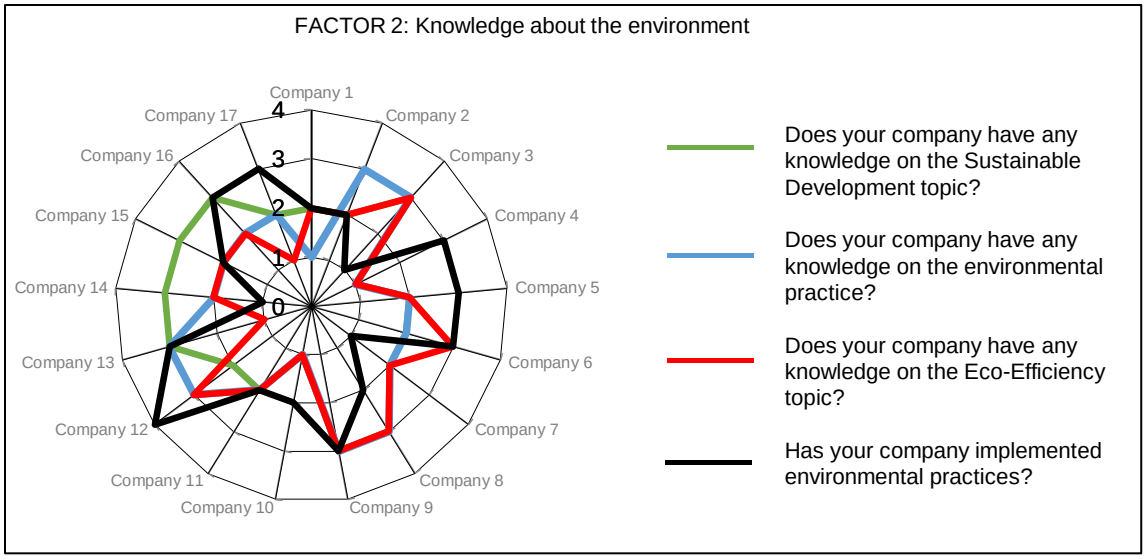

Fig. 5. Management of environmental knowledge

7.3 Organizational culture

The third factor analyses the understanding of the company's corporate culture regarding environmental issues. This factor has been associated with environmental training, open communication about the company's current situation, and staff motivation. According to the literature reviewed, different world organizations promote people as the center that provides great value in achieving sustainability. The International Labour Organization encourages sustainable enterprises by improving the productive actions of people and their working conditions, together with good working relationships and environmental practices (IOL, 2017). In this way, a sustainable corporate culture is challenged by the beliefs and changes stemming of thoughts that contribute positively to the company, because it is expected to adjust to the culture, to the new needs of the environment and to the preparations involved in dealing with economic, social and environmental challenges, as this is a difficult task that requires a commitment from all company members (Carro-Suárez et al., 2017).

Three questions have been proposed: "Are your employees concerned about the care for the environment?", "Have your employees received an environmental care training?", and "Are your employees informed about the environmental situation within the company?". Based on the results reported in Fig. 6, it should be noted that 50% of SMEs inform their employees about their company's environmental situation. However, the chart also shows that employees are not receiving enough environmental care training.

In fact, Fig. 6 highlights a high percentage of environmental commitment: 82% of companies consider that environmental issues involve all employees and that this is not an issue only for the CEO. However, the chart shows that only 17% of SMEs inform their employees about environmental awareness during their everyday activities. Even if the scores are low, the empowerment that employees have in carrying out environmental actions is high because of their commitment to the organization, showing that responsibility is not only focused on the leaders but also on everyone taking part in the organization.

The leaders in the organizations are responsible for communicating with their employees about the environmental situation of the company, however, the lack of training in environmental practices means that environmental problems might increase.

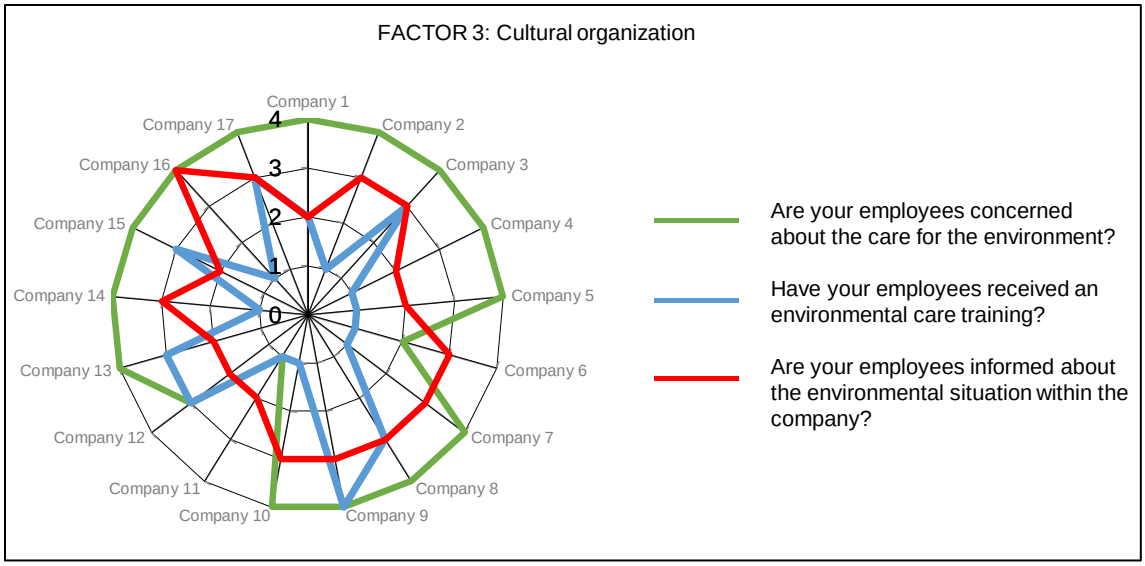

Fig. 6. Cultural organization

7.4 Monitoring and environmental control

The last factor analyses the company monitoring and environmental control. Three questions have been proposed: "Does your company buy raw material with the green seal?", "Does your company have environmental indicators or other tools for the environmental control?", and "Are you aware that the Colombian legislation for the environment is being applied to your company?". In Fig. 7, results show that 35% of companies are sure to buy their raw materials with environmental seals because some large companies require that small companies have an environmental 'green stamp'. In addition, the radial line shows that 52% of companies consider that environmental regulations are not clearly understood, and so few laws are applied within the company. Moreover, energy, water, and waste data, etc., are not updated and therefore are not regulated. Some SMEs have not considered the benefits or incentives that they could obtain from the government.

In terms of the tools and techniques for environmental monitoring and control, 71% of SMEs declare that they have no indicators or other measurement tools. This result emphasizes the importance of developing decision-making tools. The data obtained to evaluate the environmental monitoring and control factor are a cause for concern because some companies should be required to buy the raw material certified for forest systems, while others have had no opportunity to purchase wood to make furniture.

However, when asking SMEs about the clarity of the implementation of environmental policies, a lack of knowledge and management is perceived. Therefore, in reviewing some of the laws associated with sustainability in Colombia, it is found that the Ministry of Environment and Sustainable Development has proposed the sustainable production and consumption policy for companies to conduct green transactions. This policy aims to help the culture change its consumption process, increase production efficiency, take responsibility for the use of raw materials and natural resources, the consumption of products and the disposal of waste, and contribute to the improvement of Colombia's environmental quality and the quality of products for consumption by national markets (Ministerio de Ambiente y Desarrollo Sostenible, 2014). With this policy in mind, the SMEs evaluated consider that the ways to achieve it require a great effort and contributions from the state, companies, and universities.

In addition, the lack of planning and control mechanisms in the evaluated SMEs leads to check measurement tools, which runs counter to eco-efficiency, since this sets the development of measurement indicators that help to quantify energy efficiency, pollution, waster, material usage and environmental productivity, concentrating on capturing different aspects of the production process and covering important elements of economic value (Caiado et al., 2017; Passetti and Tenucci, 2016; Rattanapan et al., 2012).

To summarize, it can be stated that most of the analyzed companies are aware of purchasing their certified raw material. However, there are deficiencies in establishing environmental indicators and understanding environmental laws. Thus, the lack of current environmental reports as well as the lack of planning and breach of regulations could result in the suspension of companies.

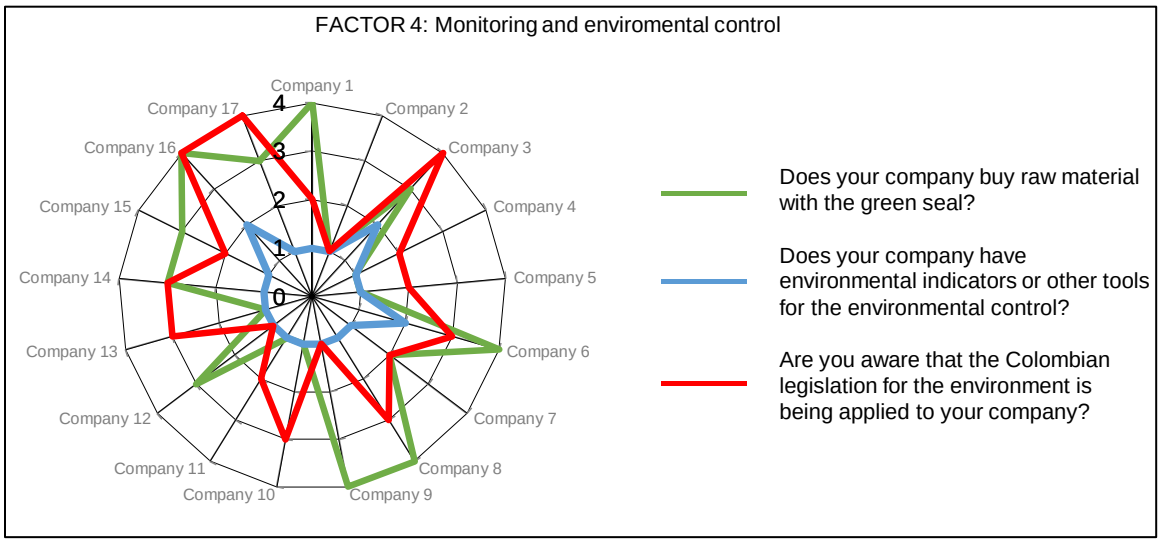

Fig.7. Monitoring and environmental control

8. Conclusions and future research

Eco-efficiency is a strategy that guides companies to achieve sustainable development by means of economic savings and a reduction in environmental impact. This strategy is used by SMEs to assist leaders of organizations in making strategic and operational decisions. Therefore, eco-efficiency can be considered the most convenient and understandable metric for small businesses which are part of emerging countries to advance in sustainability activities.

This research was based on an analysis of the eco-efficiency models of several industrial sectors. A series of elements and limitations have been identified and were included in the elaboration of a conceptual framework of factors whose purpose was to examine how SMEs understand the concept of eco-efficiency and interpret other sustainability strategies.

The factors of this framework can be adapted to the different environments of SMEs, according to the research preferences. The integration factors are one more advantage of the proposed framework. The factors can be easily implemented within a company's various processes, such as, for example, incentives to motivate employees, identify responsibilities within the company, and improve the levels of communication and training based on the principles linked to eco-efficiency strategies and sustainability.

The assessment result of each factor indicates the low use of environmental management systems or planning methodologies, a lack of knowledge about environmental actions to carry them out in companies due to low training on this issue, as well as the few mechanisms in place to apply environmental policies, monitoring, and control of resources. However, the group of evaluated companies has demonstrated the necessity to develop environmental protection, as well as the motivation to continue their search for measures to prevent environmental impacts.

The results obtained in this research suggest that companies make sustained efforts to strengthen environmental synergy, generate networking opportunities, innovate in their activities or services, strengthen knowledge in their activities, implement environmental improvement techniques, perform strategic planning regarding environmental policies, conduct training for business leaders, support associations between universities, companies and the state, familiarize themselves with Colombian environmental regulations, and seek strategies for the evaluation and control of environmental impacts.

From the results, the following hypotheses can be formulated. First, the environmental management system factor is positively related to eco-efficiency in SMEs. Second, the sustainable knowledge management factor determines the

development of eco-efficiency in SMEs. Third, the sustainable corporate culture factor is of high importance for the development of eco-efficiency in SMEs. Lastly, the monitoring and environmental control factor are essential.

In future research, answers for each of the above hypotheses have to be provided. Furthermore, it has to be ascertained if the proposed factors of environmental management, environmental knowledge, corporate culture, and control and monitoring influence or affect the development of eco-efficiency in SMEs. Additionally, appropriate mechanisms should be established for the adoption of an eco-efficiency framework in SMEs to develop them in a flexible and efficient manner.

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References

Agita, G., Jelena, P., Marika, R., Dagnija, B., 2017. Evaluation of agriculture eco-efficiency in Latvia, in: Energy Procedia 128. Elsevier Ltd., Riga, Latvia, pp. 309–315. https://doi.org/10.1016/j.egypro.2017.08.318

Alkaya, E., Demirer, G.N., 2014. Improving resource efficiency in surface coating/painting industry: practical experiences from a small-sized enterprise. Clean Technol. Environ. Policy 16, 1565–1575.

Alves, J.L.S., de Medeiros, D.D., 2015. Eco-efficiency in micro-enterprises and small firms: a case study in the automotive services sector. J. Clean. Prod. 108, 595–602.

Antonelli, D., Bruno, G., Taurino, T., Villa, A., 2015. Graph-based models to classify effective collaboration in SME networks. Int. J. Prod. Res. 53, 6198–6209. https://doi.org/10.1080/00207543.2015.1038368

Antonelli, D., Taurino, T., 2011. Identifying and exploiting the collaboration factors inside SMEs networks. Int. J. Netw. Virtual Organ. 9, 382. https://doi.org/10.1504/IJNVO.2011.043805

Atia, C., Lopes, M., Scavarda, A., Hofmeister, L.F., Onio, A.^, Arcio, M., Thom E D, T., Luís, G., Vaccaro, R., 2017. An analysis of the interplay between organizational sustainability, knowledge management, and open innovation. https://doi.org/10.1016/j.jclepro.2016.10.083

BASF, 2015. Eco-Efficiency Analysis [WWW Document]. BASF. URL https://www.basf.com/en/company/sustainability/management-and-instruments/quantifying-sustainability/eco-efficiency-analysis.html (accessed 10.29.17).

Besné, A.G., Luna, D., Cobos, A., Lameiras, D., Ortiz-Moreno, H., Güereca, L.P., 2018. A methodological framework of eco-efficiency based on fuzzy logic and Life Cycle Assessment applied to a Mexican SME. Environ. Impact Assess. Rev. 68, 38–48. https://doi.org/10.1016/j.eiar.2017.10.008

Brundtland, G.-H., 1987. Our Common Future: The World Commission on Environment and Development: Oxford University Press. New York.

Bruno, G., Taurino, T., Villa, A., 2018. An approach to support SMEs in manufacturing knowledge organization. J. Intell. Manuf. 29, 1379–1392. https://doi.org/10.1007/s10845-015-1186-6

Cagno, E., Micheli, G.J.L., Trucco, P., 2012. Eco-efficiency for sustainable manufacturing: an extended environmental costing method. Prod. Plan. Control 23, 134–144. https://doi.org/10.1080/09537287.2011.591628

Caiado, R.G.G., de Freitas Dias, R., Mattos, L.V., Quelhas, O.L.G., Leal Filho, W., 2017. Towards sustainable development through the perspective of eco-efficiency - A systematic literature review. J. Clean. Prod. 165, 890–904. https://doi.org/10.1016/j.jclepro.2017.07.166

Carro-Suárez, J., Sarmiento-Paredes, S., Rosano-Ortega, G., 2017. La cultura organizacional y su influencia en la sustentabilidad empresarial. La importancia de la cultura en la sustentabilidad empresarial. Estud. Gerenciales 33, 352–365. https://doi.org/10.1016/J.ESTGER.2017.11.006

Carro Suárez, J., Reyes Guerra, B., Rosano Ortega, G., Garnica González, J., Pérez Armendáriz, B., 2017. Modelo De Desarrollo Sustentable Para La Industria De Recubrimientos Cerámicos. Rev. Int. Contam. Ambient. 33, 131–139. https://doi.org/10.20937/RICA.2017.33.01.12

Catarino, J., Henriques, J., Maia, A., 2016. Eco-efficiency in Portuguese companies of marble sector. Int. J. Sustain. Eng. 9, 35–46. https://doi.org/10.1080/19397038.2015.1050479

Cecere, G., Mazzanti, M., 2017. Green jobs and eco-innovations in European SMEs. Resour. Energy Econ. 49, 86–98. https://doi.org/10.1016/J.RESENEECO.2017.03.003

Chan, H.K., Wang, X., Raffoni, A., 2014. An integrated approach for green design: Life-cycle, fuzzy AHP and environmental management accounting. Br. Account. Rev. 46, 344–360. https://doi.org/10.1016/j.bar.2014.10.004
Changwichan, K., Silalertruksa, T., Gheewala, S.H., 2018. Eco-efficiency assessment of bioplastics production systems and end-of-life options. Sustain. 10, 952. https://doi.org/10.3390/su10040952
Charmondusit, K., Phatarachaisakul, S., Prasertpong, P., 2014. The quantitative eco-efficiency measurement for small and medium enterprise: a case study of wooden toy industry. Clean Technol. Environ. Policy 16, 935–945. https://doi.org/10.1007/s10098-013-0693-4
Ct, R., Booth, A., Louis, B., 2006. Eco-efficiency and SMEs in Nova Scotia, Canada. J. Clean. Prod. 14, 542–550.
Dallasega, P., Rauch, E., Matt, D.T., 2015. Sustainability in the Supply Chain through Synchronization of Demand and Supply in ETO-Companies. Procedia CIRP 29, 215–220. https://doi.org/10.1016/J.PROCIR.2015.02.057
de Guimarães, J.C.F., Severo, E.A., de Vasconcelos, C.R.M., 2018. The influence of entrepreneurial, market, knowledge management orientations on cleaner production and the sustainable competitive advantage. J. Clean. Prod. 174, 1653–1663. https://doi.org/10.1016/J.JCLEPRO.2017.11.074
Departamento Administrativo Nacional de Estadística, 2018. Boletín técnico - Producto Interno Bruto PIB -Cuarto trimestre de 2017. Bogotá D.C.
Departamento Administrativo Nacional de Estadística, 2012. Clasificación Industrial Internacional Uniforme de Todas las Actividades Económicas.
Dresch, A., Lacerda, D.P., Antunes, J.A.V., 2015. Design science research : a method for science and technology advancement, 1st ed. Springer International Publishing. https://doi.org/10.1007/978-3-319-07374-3
FAO, n.d. Manejo forestal sostenible en América Latina y el Caribe | Oficina Regional de la FAO para América Latina y el Caribe | Organización de las Naciones Unidas para la Alimentación y la Agricultura [WWW Document]. URL http://www.fao.org/americas/prioridades/bosques/es/ (accessed 3.22.18).
Fernández-Viñé, M.B., Gómez-Navarro, T., Capuz-Rizo, S.F., 2013. Assessment of the public administration tools for the improvement of the eco-efficiency of Small and Medium Sized Enterprises. J. Clean. Prod. 47, 265–273.
Fernández-Viñé, M.B., Gómez-Navarro, T., Capuz-Rizo, S.F., 2010. Eco-efficiency in the SMEs of Venezuela. Current status and future perspectives. J. Clean. Prod. 18, 736–746.
Gereffi, G., Humphrey, J., 2005. The governance of global value chains. Rev. Int. Polit. Econ. 12, 78–104. https://doi.org/10.1080/09692290500049805
Gómez, T., Gémar, G., Molinos-Senante, M., Sala-Garrido, R., Caballero, R., 2018. Measuring the eco-efficiency of wastewater treatment plants under data uncertainty. J. Environ. Manage. 226, 484–492. https://doi.org/10.1016/j.jenvman.2018.08.067
Goosen, M.F.A., 2012. Environmental management and sustainable development. Procedia Eng. 33, 6–13. https://doi.org/10.1016/j.proeng.2012.01.1171
Heikkurinen, P., Young, C.W., Morgan, E., 2019. Business for sustainable change: Extending eco-efficiency and eco-sufficiency strategies to consumers. J. Clean. Prod. 218, 656–664. https://doi.org/10.1016/J.JCLEPRO.2019.02.053
Henriques, J., Catarino, J., 2015. Sustainable value and cleaner production–research and application in 19 Portuguese SME. J. Clean. Prod. 96, 379–386.
Henver, A.R., 2007. A Three Cycle View of Design Science Research. Scand. J. Inf. Syst. 19.
Herrera, G., 2015. COLOMBIA: Potencial de Reforestación Comercial.
Ho, T.Q., Hoang, V.-N., Wilson, C., Nguyen, T.-T., 2018. Eco-efficiency analysis of sustainability-certified coffee production in Vietnam. J. Clean. Prod. 183, 251–260. https://doi.org/10.1016/J.JCLEPRO.2018.02.147
Holden, E., Linnerud, K., Banister, D., 2014. Sustainable development: our common future revisited. Glob. Environ. Chang. 26, 130–139.
Huang, J., Xia, J., Yu, Y., Zhang, N., 2018. Composite eco-efficiency indicators for China based on data envelopment analysis. Ecol. Indic. 85, 674–697. https://doi.org/10.1016/J.ECOLIND.2017.10.040
Ibrahim, I. bin, Jaafar, H.S. binti, 2016. Factors of Environment Management Practices Adoptions. Procedia - Soc. Behav. Sci. 224, 353–359. https://doi.org/10.1016/j.sbspro.2016.05.387
International Organization for Standardization, 2012. ISO 14045:2012 - Environmental management -- Eco-efficiency assessment of product systems -- Principles, requirements and guidelines [WWW Document]. 2012. https://doi.org/13.020.60
IOL, I.L.O., 2017. Sustainable Enterprises.
Jelenic, D., 2011. The Importance of Knowledge Management in Organizations – With Emphasis on The Balanced Scorecard Learning and Growth Perspective, in: International School for Social and Business Studies, S. (Ed.),

International Journal of Management, Knowledge and Learning. Celje, Slovenia, p. 11.
Jové-Llopis, E., Segarra-Blasco, A., 2018. Eco-efficiency actions and firm growth in European SMEs. Sustain. 10. https://doi.org/10.3390/su10010281
Kates, R.W., Parris, T.M., Leiserowitz, A.A., 2005. What is sustainable development? Goals, indicators, values, and practice. Environ. DC) 47, 8–21.
Koskela, M., 2015. Measuring eco-efficiency in the Finnish forest industry using public data. J. Clean. Prod. 98, 316–327.
Linnenluecke, M.K., Griffiths, A., 2010. Corporate sustainability and organizational culture. J. World Bus. 45, 357–366. https://doi.org/10.1016/J.JWB.2009.08.006
Liu, W., Zhan, J., Li, Z., Jia, S., Zhang, F., Li, Y., 2018. Eco-efficiency evaluation of regional circular economy: A case study in Zengcheng, Guangzhou. Sustain. 10, 453. https://doi.org/10.3390/su10020453
Lucia Castañeda, M.F., 2016. Informe Anual Cadena Forestal 2015. Bogotá, Colombia.
Marín, C., 2013. 20 Datos Económicos del Mueble y la Madera [WWW Document]. Rev. M&M. Edi. 81. URL https://revista-mm.com/economicos/20-datos-economicos-del-mueble-y-la-madera/ (accessed 4.4.18).
Mebratu, D., 1998. Sustainability and sustainable development: historical and conceptual review. Environ. Impact Assess. Rev. 18, 493–520.
Michelsen, O., Fet, A.M., 2010. Using eco-efficiency in sustainable supply chain management; a case study of furniture production. Clean Technol. Environ. Policy 12, 561–570. https://doi.org/10.1007/s10098-009-0266-8
Ministerio de Ambiente y Desarrollo Sostenible, 2014. Plan Nacional de negocios verdes, 2014. Bogotá D. C, Colombia.
Ministerio de Ambiente y Desarrollo Sostenible de Colombia, 2015. Superficie de bosque natural. Bogotá, D.C.
Müller, K., Holmes, A., Deurer, M., Clothier, B.E., 2015. Eco-efficiency as a sustainability measure for kiwifruit production in New Zealand. J. Clean. Prod. 106, 333–342.
NBS, n.d. Systematic Review: Organizational Culture.
Pardo, R.J.H., Bhamra, T., Bhamra, R., 2012. Sustainable product service systems in small and medium enterprises (SMEs): opportunities in the leather manufacturing industry. Sustainability 4, 175–192.
Passetti, E., Tenucci, A., 2016. Eco-efficiency measurement and the influence of organisational factors: evidence from large Italian companies. J. Clean. Prod. 122, 228–239. https://doi.org/10.1016/J.JCLEPRO.2016.02.035
PROFOR, 2017. Current situation and future potentials of commercial forest plantations in Colombia: English Summary. Bogotá, Colombia.
Rattanapan, C., Suksaroj, T.T., Ounsaneha, W., 2012. Development of eco-efficiency indicators for rubber glove product by material flow analysis. Procedia-Social Behav. Sci. 40, 99–106.
Rauch, E., Dallasega, P., Matt, D.T., 2016. Sustainable production in emerging markets through Distributed Manufacturing Systems (DMS). J. Clean. Prod. 135, 127–138. https://doi.org/10.1016/J.JCLEPRO.2016.06.106
Rauch, E., Dallinger, M., Dallasega, P., Matt, D.T., 2015. Sustainability in Manufacturing through Distributed Manufacturing Systems (DMS). Procedia CIRP 29, 544–549. https://doi.org/10.1016/j.procir.2015.01.069
Sarkis, J., Gonzalez-Torre, P., Adenso-Diaz, B., 2010. Stakeholder pressure and the adoption of environmental practices: The mediating effect of training. J. Oper. Manag. 28, 163–176. https://doi.org/10.1016/J.JOM.2009.10.001
Senvar, O., Bulkan, S., 2017. Conceptual Overview to Distributed Manufacturing Systems. Int. J. Information, Bus. Manag. 9, No. 4, 41–52.
Sproedt, A., Plehn, J., Schönsleben, P., Herrmann, C., 2015. A simulation-based decision support for eco-efficiency improvements in production systems. J. Clean. Prod. 105, 389–405.
Srai, J.S., Kumar, M., Graham, G., Phillips, W., Tooze, J., Ford, S., Beecher, P., Raj, B., Gregory, M., Tiwari, M.K., Ravi, B., Neely, A., Shankar, R., Charnley, F., Tiwari, A., 2016. Distributed manufacturing: scope, challenges and opportunities. Int. J. Prod. Res. 54, 6917–6935. https://doi.org/10.1080/00207543.2016.1192302
Systems, E.M., 2004. Environmental Management Systems [WWW Document]. URL https://www.epa.gov/ems (accessed 3.13.18).
Tatari, O., Kucukvar, M., 2011. Eco-efficiency of construction materials: data envelopment analysis. J. Constr. Eng. Manag. 138, 733–741.
Ullah, A., Perret, S.R., Soni, P., 2016. Eco-efficiency of cotton-cropping systems in Pakistan: an integrated approach of life cycle assessment and data envelopment analysis. J. Clean. Prod. 134, 623–632. https://doi.org/10.1016/j.jclepro.2015.10.112
Valdez-Juárez, L.E., Solano-Rodríguez, O.J., Martin, D.P., 2018. Modes of learning and profitability in Colombian and Mexican SMEs. J. High Technol. Manag. Res. 29, 193–203.

https://doi.org/10.1016/J.HITECH.2018.09.007
WBCSD, 2009. Learning Module [WWW Document]. URL http://www.wbcsd.org/Projects/Education/Resources/Eco-efficiency-Learning-Module (accessed 10.5.17).
Weber, R., 2017. Chapter 11. Design-science research. https://doi.org/10.1016/B978-0-08-102220-7.00011-X
Xiong, B., Li, Y., Santibanez Gonzalez, E.D.R., Song, M., 2017. Eco-efficiency measurement and improvement of Chinese industry using a new closest target method. Int. J. Clim. Chang. Strateg. Manag. 9, 666–681. https://doi.org/10.1108/IJCCSM-08-2016-0112
Zurano-Cervelló, P., Pozo, C., Mateo-Sanz, J.M., Jiménez, L., Guillén-Gosálbez, G., 2018. Eco-efficiency assessment of EU manufacturing sectors combining input-output tables and data envelopment analysis following production and consumption-based accounting approaches. J. Clean. Prod. 174, 1161–1189. https://doi.org/10.1016/j.jclepro.2017.10.178