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Research article

“There is no carnival without samba”: Revealing barriers hampering biodiversity-based R&D and eco-design in Brazil

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ABSTRACT

Considering the unique relevance of Brazilian biodiversity, this research aims to investigate the main barriers to biodiversity-based R&D and eco-design development in a leading national company which has been commended for its innovation and sustainability. The methodology for this research was based on on-location visits, in-depth interviews, and consensus building among R&D, sustainability, and quality managers. A multi-criteria decision-making (MCDM) approach was adopted through interpretive structural modelling (ISM), a method that assists decision makers to transform complex models with unclear data into structural models. Some of the most influential barriers to biodiversity-based eco-design initiatives are “lack of legal incentive”, “not enough demand from the market”, and “not enough available knowledge/scientific data.” The most relevant barrier was “no legal incentive” from government. Consequently, managers should concentrate their efforts in tackling those barriers that may affect other barriers known as ‘key barriers’. Government should work decisively toward promoting a framework of legal incentives for bio-based eco-design; otherwise, metaphorically, “there is not carnival without the samba singer who pushes the rhythm”. The results given here reveal the barriers for bio-based eco-design in a Brazilian leading company, and this is the first work combining ISM to barriers to biodiversity R&D and eco-design.

1. Introduction

Eco-design, also known as environmental product design, environmentally-friendly design, or green design, has emerged as an important subject in the development of a more sustainable society. Eco-design is a subject within the emerging field of sustainable entrepreneurship (Shepherd and Patzelt, 2011) and innovation for sustainability (Seebode et al., 2012). Eco-design integrates environmental issues during the process of product development (Luiz et al., 2016; Park and Tahara, 2008) in order to provide low-impact products (Karlsson and Luttropp, 2006). The adoption of eco-design principles is a proactive approach to corporate environmental management and, as a consequence, a myriad of authors and managers have encouraged companies to integrate eco-design into their efforts when working towards sustainability (Wijethilake, 2017). Some authors name eco-design as the most relevant approach to bolster corporate greening (Brones and Carvalho, 2015).

The literature has highlighted a range of benefits that can come from the adoption of eco-design, such as improving sales and profit (Plouffe et al., 2011; Fujimoto et al., 2009), improving corporate reputation (Sanyé-Mengual et al., 2014; Vercalsteren, 2001), improving innovative capacity (Hellström, 2007), and improving organizational performance in terms of operational and environmental performance (Jabbour et al., 2015). However, eco-design is not a simple method of corporate greening and its implementation

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will face similar challenges to those that any other environmental management initiative might face (Poulikidou et al., 2014). These challenges, labeled as "barriers for environmental management", have been studied by scholars and practitioners for some time (Chan, 2011; Kehbila et al., 2009; Studer et al., 2006; Hillary, 2004).

However, after analyzing the current literature on eco-design, it is apparent that most available works have not discussed the effects of the barriers on its implementation. Addressing barriers for implementing eco-design remains as a critical research gap (Paramanathan et al., 2004; Dekoninck et al., 2016). Additionally, the majority of works that discuss barriers to green initiatives have neglected eco-design as a focus of their study (Murillo-Luna et al., 2011; Chan, 2008; Shi et al., 2008; Hillary, 2004; Post and Altma, 1994), and most of them are conceptual (Brones and Carvalho, 2015; Hillary, 2004; Post and Altma, 1994). Moreover, there are research avenues for developing studies about emerging economies (Murillo-Luna et al., 2011) and only a few articles have discussed the reality of eco-design in the context of an emerging economy (Jabbour et al., 2015). Scrutinizing the impact of the barriers on eco-design initiatives is particularly relevant in emerging economies (Mittal and Sangwan, 2014). Emerging markets demonstrate an impressive growth rate of nearly 7%, and this rapid forward development exceeds what is typically found in developed nations. Still, emerging markets face significant challenges as they try to implement modern sustainable strategies, because in some cases even basic definitions remain unclear (Tseng et al., 2016).

To accompany discussions of environmental issues and eco-design, ideally, academia should discuss another important subject: biodiversity. As affirmed by Boiral and Heras-Saizarbitoria (2017), the mainstream of the literature on corporate greening has neglected issues on biodiversity; however, the conservation of natural ecosystems and indigenous biodiversity are core principles of eco-design (Yang et al., 2004). Under the conceptual and practical umbrella of eco-design, barriers for eco-design, biodiversity-based eco-design and the context of emerging economies, searches for articles on ISI Web of Knowledge and Scopus were conducted and it was noted that there is no work integrating all of these issues while providing useful and practical evidence. Thus, we aimed to discover the relationships between the barriers to biodiversity-based eco-design in a leading Brazilian company which has economic activities in the field of bio and natural products.

The efforts undertaken in emerging economies such as Brazil to expand their industry seeking more intense economic growth have side effects, including resource rarefaction and environmental problems (Lopes and Azevedo, 2014). Furthermore, as observed by Pedrollo and Kinupp (2015), although Brazil has some advantages in developing natural products, the country also faces a variety of challenges, such as bureaucratic obstacles and legislative delays by the public administration bodies (Pedrollo and Kinupp, 2015). In Brazil, we can understand the complexity of bio-based eco-design as "organising the carnival party" and this expression is frequently used to refer to very complex processes of everyday life, and is based on full-collaboration of a variety of stakeholders. However, these processes can be worthy. Therefore, a better understanding of the potential barriers to corporate environmental management, in particularly in the context of emerging economies, as mentioned before, can be useful during decision making processes and can help decision-makers prioritize the issues that deserve the most attention to work towards a more sustainable society.

This work is organized as follows. After this Introduction (Section 1), a theoretical background defining the main concepts of the research is provided (Section 2). Section 3 presents the research methodology and the procedures adopted to collect and analyze data. Section 4 presents research findings and its discussion. Finally, Section 5 registers final remarks.

2. Literature review

2.1. Eco-design

Due to the fact that there are currently high levels of concern among governments and consumers regarding the development of environmentally sustainable products (Dalhammar, 2016; Jabbour et al., 2015; Sanye-Mengual et al., 2014), there is a growing amount of research that highlights the need for companies to incorporate environmental sustainability in their product project (Dekoninck et al., 2016; Pigosso et al., 2013). Within this scope, recent works (e.g., Brones and Carvalho, 2015; Brones et al., 2014) have advocated for the application of eco-design as a practical way to integrate environmental concerns into product design decisions.

In product designs that are based on eco-design, quality assurance and customer satisfaction should be considered and integrated with the necessary environmental requirements. These factors should be acknowledged in order to implement greener solutions throughout the product's life cycle (Hur et al., 2005) in terms of extraction of raw materials, manufacturing, packaging, usage, spare parts, maintenance, disposal, reuse, and end of life (Park and Tahara, 2008; Zhu et al., 2010).

Luchs et al. (2012) emphasize that the application of eco-design can help to overcome the traditional trade-off that many companies face between the development of environmentally sustainable products and production costs. In terms of practicality, Byggeth and Hochschorner (2006), Luttropp and Lagerstedt (2006), Pigosso et al. (2010), Finksel (2012), and Bovea and Pérez-Beliz (2012) propose to apply different eco-design methods, such as environmental-quality function deployment (EQFD), environmental failure mode effects analysis (E-FMEA), and a checklist of eco-design, among others, in order to facilitate the choice of production processes, materials to be used, and other environmentally sound features that would subsequently support firms in their eco-design approaches.

Many positive effects result from the application of eco-design principles, including an increase in sales volume and profitability (Fujimoto et al., 2009; Plouffe et al., 2011), an improvement in image within the market, an improvement of the quality and technological capacities of products and processes, and a greater alignment to various legal requirements (Sanye-Mengual et al., 2014; Vercalsteren, 2001). Poulikidou et al. (2014) noted that real and practical implementations of eco-design are still not very widespread among companies. The lack of current research emphasizes the importance of expanding research considerations within the area of eco-design in order to identify problems and alternatives for researchers and practitioners involved. Identifying barriers to eco-design is an essential part of this process.

2.2. Barriers to eco-design

As any other initiative of environmental improvement in companies, eco-design tends to face several barriers to its implementation. Barriers to environmental management within companies have been studied by several authors over the years (Chan, 2011; van Hemel and Cramer, 2002; Kehbila et al., 2009; Studer et al., 2006). Studying barriers to environmental management is particularly important in the context of emerging economies (Mittal and Sangwan, 2014), because the majority of knowledge on this subject often represents the reality of more developed countries. A better understanding of the potential barriers to corporate environmental management can be useful during decision making processes and decisions regarding the prioritization of issues that deserve attention from managers and policy makers towards a more sustainable society. In this work, we use the barriers to corporate environmental management as a foundation for understanding the barriers to biodiversity eco-design since this area has been understudied.

The discussion about barriers to incorporating environmental management in business intensified during the 1990s. Post and Altma's (1994) pioneering work divided barriers into two different and complementary groups: industrial barriers (capital costs, competitive pressures, industry regulations, technical information) and organizational barriers (employee attitude, inadequate top management leadership, poor communication, past practice, uncertainty about potential results). Industrial barriers correspond to external challenges to firms, whereas organizational barriers are internal to the firm.

Building on that initial classification, many contemporary works have divided the barriers of environmental management into two groups (Murillo-Luna et al., 2011; Shi et al., 2008; Chan, 2008; Hillary, 2004): internal barriers or external ones. Internal barriers start inside organizations and are firm-specific issues that hinder the achievement of planned environmental initiatives, such as limited financial capabilities for environmental investment and low employee involvement in decision-making (Murillo-Luna et al., 2011). External barriers emerge from the external context of organizations (Hillary, 2004) and cannot be completely controlled by organizational efforts (Murillo-Luna et al., 2011).

Some recent research results demonstrate that:

- Walker et al. (2008) discovered that the barriers to environmental supply chain management that were experienced by organizations tended to be both internal and external;
- Based on Lebanese companies, Massoud et al. (2010) discovered that a lack of government support and incentives, a lack of clear benefits, and a lack of legal requests formed the main barriers to ISO 14001 certification. Along the same line, Veugelers (2012) and Kesidou and Demirel (2012) affirm that governmental intervention is crucial for promoting eco-innovation;
- Based on a study of Spanish firms, Murillo-Luna et al. (2011) discovered that internal barriers were predominant;
- Recently, Zhu and Geng (2013) studied barriers to the implementation of sustainable supply chains in China. Internal barriers, such as the lack of monetary gains, resources, and capability, are the main obstacles for the implementation of sustainable customer cooperation;
- Abdulrahman et al. (2014) identified four key categories of barriers to the adoption of reverse logistics in China;
- Küçüksayraç (2015) analyzed Turkish companies in order to discuss the barriers to sustainable design, and market demand and legislation were found to be the main issues;
- Polzin et al. (2016) emphasized that barriers for eco-innovation tended to change along with product development research, and the common barriers to eco-innovation were technological, regulatory, cooperative, and a fundamental lack of knowledge or information.

The majority of the aforementioned barriers can hamper the environmental performance of companies by reducing the success of objectives such as the adoption of ISO 14001 certification. These barriers can be more complex in emerging economies. As highlighted by Tseng et al. (2016), the barriers can co-exist with an expansive economic growth in emerging economies, creating structural issues that will re-emerge as potential problems in the future. When we specifically focus on barriers for eco-design, one of the most relevant works was done by van Hemel and Cramer (2002), who studied the factors that can hamper small and medium Dutch enterprises when it comes to eco-design. These authors listed eleven barriers: no clear environmental benefit; not perceived as responsibility; not yet required by legislation; not yet required by customers; commercial disadvantages; conflicts with functional product requirements; no innovation opportunities; no alternative solutions available; investment is fruitless; insufficient time; and insufficient knowledge. The authors discovered the relevance of stimuli and stated that the implementation of eco-design does not only rely on finding the best technical solutions but also on securing the economic and social factors of eco-design, such as the success of green products in the current market and society. They also identified that three barriers, 'not perceived as responsibility,' 'no clear environmental benefits,' and 'no alternative solutions available' were ranked as the worst for reducing the potential of eco-design initiatives.

2.3. Biodiversity-based eco-design

A clear understanding of barriers will help organizations to prioritize better and to manage their resources in an efficient and effective way (Luthra et al., 2011). However, understanding the organizational barriers to adopting biodiversity-based eco-design has been an overlooked subject in the literature. Boiral and Heras-Saizarbitoria (2017) affirmed that the literature on environmental management has neglected issues on biodiversity. This lack of research is surprising because, according to Yang et al. (2004), the conservation of natural ecosystems is a principle of ecological design.

Biodiversity is represented by ecosystems, wide and diverse kinds of species and genetic material that are available on the earth (Earthwatch Institute, 2002). Some factors may affect biodiversity, such as a change of habitats, pollution, climate change, invasive species, and overexploitation (Englund and Berndes, 2015; Polomé, 2016).

According to the IUCN (2014), biodiversity is relevant for supporting production processes and supply chains. On the other hand, companies should manage ecosystems carefully in order to not affect them negatively. Therefore, companies need to know how to extract natural resources in a way that has a low impact on biodiversity and how to request permission from Government officials and stakeholders (local communities, indigenous populations, etc.) to gain access to ecosystems (Earthwatch Institute, 2002). As a consequence, product development processes from companies should consider those aspects when using an eco-design approach.

Some studies addressed the field of biodiversity through the lens of business. Boiral and Heras-Saizarbitoria (2017), for example, discussed the impact of different stakeholders on biodiversity management. They highlighted that indigenous stakeholders and traditional knowledge management were important in managing biodiversity. Further, Englund and Berndes (2015) analyzed whether or not sustainability certifications have considered biodiversity as a criteria of their assessment, eventually concluding that they have.

3. Materials and methods

3.1. Object of analysis

Brazil is a country which is well known globally for its abundant natural resources, its vivid biodiversity, and its unique culture — as represented by the carnival (Chasteen, 1996). Brazil is positioned as the richest country in terms of biodiversity, occupying the top of many global rankings. For example, it is the number one country for the ranking "Countries with the highest biological biodiversity" (Mongbay, 2016) and it holds a high position in the table of "Top 10 countries in biodiversity" (SustainabilityForAll, 2016). Therefore, Brazil has a great opportunity to invest in biodiversity-based eco-design, mainly because this kind of business generates income and jobs for poor communities, while at the same time protects the natural environmental. Thus, a Brazilian company was selected to be analyzed in terms of barriers to biodiversity-based eco-design initiatives.

The studied company is genuinely Brazilian, was founded in the 1950s, has approximately 400 employees, operates in the botanical extracts market, and has exported its products to more than 70 countries. It has four fully certified industrial plants in Brazil, commercial offices, an agricultural unit complete with a farm and has a cutting-edge Research & Development Department focused on biodiversity-based eco-design. The company also has a special Innovation Unit supporting and analysing all the necessary steps to introduce new biodiversity products into the market. The company produces plant extracts, dehydrated pulps, essential oils, and active ingredients extracted from plants in order to meet customer health sectors (pharmaceutical), food, beverages, and personal care products (cosmetics). As such, many barriers can emerge that might hamper the process of innovation. The Innovation Unit plays a major role in supporting compliance with regulatory issues and approvals and certifications of its products. The Innovation Unit also takes care of issues related to intellectual property licensing, regulatory support, and innovation management.

The name of the company will not be made public in this work, as formally agreed between the research team and the company's participants. The chosen company is well known for its innovative approach, and consistently considers its impact on poor communities, environmental conservation, and biodiversity care. The company has received a number of awards for its efforts in promoting Brazilian biodiversity through sustainable products. For instance, the company has received the prestigious “National Biodiversity Award” carried out by the Ministry of Environment of Brazil, which is given to acknowledge the merit of initiatives that promote the improvement or maintenance of the conservation status of species from Brazilian biodiversity.

3.2. Research method

The main objective of this study is to explore the most influential barriers to biodiversity-based eco-design initiatives, with the results to be considered when future decisions are made. Therefore, this study adopts a multi-criteria decision making (MCDM) approach in order to satisfy the objective. Although there are several MCDM techniques that could be used, some techniques are better suited to explore the interrelationship and influences among factors. Interpretive structural modelling (ISM) is a method which is highly valuable in assisting decision makers in dealing with and transforming complex models of unclear data to create structural models (Venkatesh et al., 2015; Sushil, 2012). ISM makes clear to decision-makers their own ideas due to the complexity of human beings' rationality by transforming their opinions and perceptions, which are subjective, into a structured basis using maths.

The first ISM model was proposed by Warfield in 1973 with the intention of investigating socioeconomic complex systems (Govindan et al., 2015; Sage, 1977; Warfield, 1974), and the method eventually became popular among researchers due to its advantages. Several studies (Farris and Sage, 1975; Khan and Rahman, 2015; Thakkar et al., 2008; Warfield, 1974) suggest that ISM is one of the best suited methodologies for acknowledging the interrelationships among various factors with dynamic capabilities.

According to Lendaris (1980) and Poduval and Pramod (2015), ISM is the methodology which projects the problem as geometric and focuses upon relationship modelling instead of simply considering calculative mathematical output. Considering these outstanding advantages, many studies have successfully applied ISM to various fields of application. For instance, ISM was used when studying automobiles (Azevedo et al., 2013; Govindan et al., 2012; Kannan et al., 2014), management (Sharma et al., 2012), sustainable strategies (Govindan et al., 2013, 2015; Kumar, 2013; Mathiyazhagan et al., 2013; Mathiyazhagan and Haq, 2013), supply chains (Venkatesh et al., 2015; Jindal and Sangwan, 2013), manufacturing (Dubey and Ali, 2014; Haleem et al., 2012), energy (Ansari et al., 2013), mining (Bouzon et al., 2015; Jia et al., 2015; Muduli et al., 2013), pharma (Gupta and Ramesh, 2015), tourism (Debata et al., 2013) and education (Mehta et al., 2014; Mahajan et al., 2014; Mitra Debnath and Shankar, 2012). This study seeks to apply ISM methodology in order to analyze the influential barriers of biodiversity in Brazilian context.

The ISM methodology was applied as a methodological approach in order to achieve the study's objective, and the general steps involved in ISM methodology is briefly discussed below (Diabat and Govindan, 2011).

Step 1: Identification of the common criteria (barriers) involved in the implementation of biodiversity-based eco-design initiatives (this step is contextualized for this study)

The common barriers involved in the implementation of biodiversity should be collected from various reliable sources, including existing literature, experts' opinions and case industry managers' notions. From the combined effects, the criteria for the problem are finalized. Experts and case industry managers' responses are generally obtained by conducting workshops, seminars, telephonic enquiries, and so on.

Step 2: Conceptual relationship development and development of structural self-interaction matrix (SSIM)

An SSIM matrix is developed with the assistance of the conceptual relationship that emerges from the collected common criteria. This relationship is developed with the assistance of case industrial managers (decision makers). The common collected barriers will be given to decision makers, who will detail their conceptual relationship using the linguistic symbols V, A, X and O. Each of the symbols has its own significance with “if” conditions, which are as follows.

“V” – Barrier i will help to achieve Barrier j;
“A” – Barrier j will help to achieve Barrier i;
“X” – Barriers i and j will help to achieve each other; and
“O” – Barriers i and j are unrelated.

The following statements illustrate the use of symbols in an SSIM matrix.

- E.g. “No legal incentive” barrier will help to achieve “Not enough available knowledge/scientific data” (V); and
- E.g. “Require more available time for R&D” barrier will be achieved by “Not enough available knowledge/scientific data” barrier (A).

Step 3: Reachability matrix

From the SSIM, an initial reachability matrix is derived based on the following rules:

- If the (i, j) entry in the SSIM is V, the (i, j) entry in the reachability matrix is set to 1 and the (j, i) entry is set to 0.
- If the (i, j) entry in the SSIM is A, the (i, j) entry in the reachability matrix is set to 0 and the (j, i) entry is set to 1.
- If the (i, j) entry in the SSIM is X, the (i, j) entry in the reachability matrix is set to 1 and the (j, i) entry is set to 1.
- If the (i, j) entry in the SSIM is O, the (i, j) entry in the reachability matrix is set to 0 and the (j, i) entry is set to 0.

Once the initial reachability matrix is developed, then the transitivity from the initial reachability must be removed to form a final reachability matrix. However, this transformation does need to mind the rule of transitivity. The transitivity rule states that if a variable 'A' is related to 'B' and 'B' is related to 'C', then 'A' is necessarily related to 'C'.

Step 4: Level partitions

The reachability matrix obtained from previous step is partitioned into different levels. For this step, three different sets are found in the final reachability matrix namely, the reachability set, antecedent set, and intersection set. The reachability set for an individual barrier consists of itself and the other barriers which it may help to achieve. The antecedent set consists of the barriers themselves and the other barriers which may help in achieving it. The intersection of both these sets is also derived for all barriers. With the assistance of these three sets, level partitions are made. For instance, barriers in Level I are those criteria which are the same on both the reachability and intersection sets; they must be assigned to the top level of the ISM hierarchy with great influence. However, all of the previous formulations are based on level of influence. After this partition, this iteration continues until the last barrier appears, but after every iteration, the previous level of barriers is discarded for next level of iteration. Once the iteration levels of all barriers are concluded, each level's influence can be determined. Simply put, barriers in higher levels are more influential than those in lower levels.

Step 5: Formation of ISM model

ISM model can be formulated based on the obtained driving and dependence power of each barrier (identified in step 4). Based on this ISM model, driving and depending barriers were identified. A check for further inconsistencies is made, and if anything is identified, necessary modifications are made and the process is repeated.

3.3. Data collection based on ISM methodology

The research team visited the company twice, and the company's Head of R&D met the researchers once in order to attend a workshop on challenges of R&D in Brazil. During the first visit, the Head of R&D received the research team and spent around 6 hours highlighting aspects regarding new products development, R&D, and the common challenges this company faces. This first on-location visit was fruitful not only because it motivated an open conversation based on in-depth reflections, but also for allowing the research team to get to know all the facilities. The research team visited the research labs for natural products, the manufacturing area, the warehouse, and other managerial areas, such as human resources and sustainability. Documents such as sustainability reports were collected by the research team.

During the in-depth conversations, respondents of the company explained that the Brazilian legislation to regulate the extraction and marketing of biodiversity assets is in transition, but they repeatedly emphasized that the current version and the version that is likely to be approved by the Government both represent challenges to the sector. The company wanted to better understand its main barriers in order to overcome challenges and to have a more relevant role and market share in biodiversity eco-design. This question – about the main barriers – was the trigger for deciding to apply ISM methodology. The first visit was followed by frequent contacts between the research team and the Head of R&D by email and phone calls, in order to secure details regarding the study.

A second visit to the company took place for a more detailed discussion on eco-design and the potential barriers the company has faced. During the second visit, a questionnaire containing a list of all barriers recommended by van Hemel and Cramer (2002) was applied to the participants. Questionnaires were distributed to the Head of R&D, the environmental manager, a senior staff in chemical engineering, and the manager for corporate sustainability. As it will be developed further, four questionnaires were obtained, followed by a consensus questionnaire developed after brainstorming and discussion among the participants. The consensus questionnaire was used as a foundation for the multi-criteria decision making (MCDM) approach.

From the list of barriers to eco-design presented by van Hemel and Cramer (2002) and the previous studies, six barriers were selected as most relevant both by academics and managers from the company. They were described by the code letter "B" ("barrier") and were numbered as follows:

- "B1 – Biodiversity-based eco-design initiatives find no legal incentive"
- "B2 – Biodiversity-based eco-design initiatives find insufficient demand from the market"
- "B3 – Biodiversity-based eco-design initiatives find technical conflicts with other functional features of product development projects"
- "B4 – Biodiversity-based eco-design initiatives find that the necessary technological solutions are not completely available"
- "B5 – Biodiversity-based eco-design initiatives would require more available time for R&D"
- "B6 – Biodiversity-based eco-design initiatives find insufficient available knowledge/scientific data"

The questionnaire was structured by putting the barriers (B1-B6) into columns and lines, forming a matrix. Thus, the participants were able to check the relationship among variables. Finally, the research team started a discussion based on their responses in order to achieve a consensus regarding the main barriers. This consensus was used to generate the quantitative analysis. The questionnaire was based on a typical matrix used in MCDM problems. A decision making technique was applied in order to support the company in discovering the interrelationships among the cited barriers. In order to operationalize the MCDM approach, respondents of the company analyzed the potential relationships between the variables (barriers) and considered the following options for each pair of variables: (i) the first barrier influences the second; (ii) the second barrier influences the first; (iii) the barriers have mutual influence; (iv) there is no relationship between the two barriers. The questionnaire had no open questions, but as explained earlier, an in-depth conversation was sustained between the research team and the respondents. Additionally, documents (sustainability reports) were collected. Although the secondary data was not used to feed the MCDM methodology, the information collected was very useful for better understanding the company and for helping the respondents to come up with the consensus questionnaire used in ISM analysis.

Thus, data to fulfil steps 1 and 2 from the ISM methodology respectively, 'Identification of the common criteria (barriers involved in the implementation of biodiversity-based eco-design initiatives)' and 'Conceptual relationship development and development of structural self-interaction matrix (SSIM)' were collected by means of the procedures explained above.

4. Results and discussion

This section presents the means by which steps 2 to 5 from the ISM methodology were fulfilled (4.1) as well as the main research results through ISM methodology (4.2) and its analyses (4.3).

4.1. ISM's steps

Step 1: Data collection as Section 3.3

Step 2: A Structural self-interaction matrix (SSIM) is developed based on the pair-wise comparison with the assistance of the replies from managers. Table 1 presents the results from this stage.

Step 3: Once the SSIM is developed, then it is necessary to validate the transitivity. Simply put, it must follow the rule that if a variable 'A' is related to 'B' and 'B' is related to 'C,' then 'A' is necessarily related to 'C.'

Step 3: Different levels of divisions were made from the obtained reachability matrix. Table 2 presents the results from this stage.

Step 3: Based on the obtained levels, a diagraph is drawn and, furthermore, with the assistance of the reachability matrix, the transitive links are removed based on the relationship. Table 3 presents the results from this stage.

Step 4: The resulting digraph is converted into an ISM by replacing the variable nodes with statements. Table 4 presents results from this stage.

Step 5: Finally, the conceptual inconsistencies were checked in the ISM, and if any are found, relevant corrections are made.

4.2. ISM's results

Based on the analysis with the assistance of ISM, a relationship model was framed among the barriers, shown in Fig. 1 (based on Table 5), which demonstrates that "No legal incentive" is in the lower tier of the hierarchy. This result projects that this factor highly influences all the other barriers. The next level of hierarchy in the ISM model contains "Not enough demand from the market" and "Not enough available knowledge/scientific data," both of which have a significant influence and interrelationship on other top level factors. The top level hierarchy in the ISM model is "Technical conflicts with other functional features of product development," "Necessary technological solutions are not completely available," and "Require more available time for R&D."

According to Warfield (1990), MICMAC analysis (a cross impact matrix multiplication applied to classification) is used to structure complex problems into clear levels of priorities. Since it was developed by Duperrin and Godet (1973), it has gained many positive reviews from the academics. Generally, it consists of four clusters, in which dependence power acts on the x-axis and driving power is on the y-axis. The four quadrants of the graph can be considered as four clusters, in which first cluster generally contains the factors which have weak dependence power and driving power, frequently called "autonomous factors." Next to that, in cluster II, the factors which have high dependence power but weak driving power, are called "dependent factors." The factors in cluster III are named "linkage factors" owing to the nature of having high driving power and high dependence power. Finally, cluster IV consists of factors which have low dependence power and high driving power and these are called "independent factors." Based on these assumptions, in this study, the factors are categorized based on their position in the graph.

According to the MICMAC analysis shown in Fig. 2, in cluster IV "No legal incentive" (B1), "Not enough demand from the market" (B2), and "Not enough available knowledge/scientific data" (B6) can be seen; it is clearly evident that these factors have high driving power and less dependence power. It can be concluded, therefore, that these three factors are the most influential barriers to biodiversity-based eco-design. No factors lie in cluster III, suggesting that there are no linkage factors. Only one factor, "Necessary technological solutions are not completely available" (B4), falls in cluster I, which highlights that this factor has weak driving and dependence power and therefore it can be designated as an autonomous factor. Finally, cluster II presents only two factors that include "Technical conflicts with other functional features of product development projects" (B3) and "Require more available time for R&D" (B5); these barriers have more dependence power and weak driving power making them dependent factors.

Table 2
Initial reachability matrix.

Element	1	2	3	4	5	6
1	1	1	0	0	0	1
2	0	1	1	0	0	1
3	0	0	1	1	0	0
4	0	0	1	1	0	0
5	0	0	0	0	1	0
6	0	1	0	0	1	1

Table 3
Final reachability matrix.

Element	1	2	3	4	5	6	Driving Power
1	1	1	1	0	1	1	5
2	0	1	1	1	1	1	5
3	0	0	1	1	0	0	2
4	0	0	1	1	0	0	2
5	0	0	0	0	1	0	1
6	0	1	1	0	1	1	4
Dependence	1	3	5	3	4	3	

4.3. Analysis of ISM's results

From the results presented in Fig. 1, it can be inferred that the lack of legal incentive ("no legal incentive") is the barrier with the greatest influence on others to the adoption of eco-design. The results indicate that the lack of legal incentive for the adoption of eco-design influences the lack of market demand for green products. In the same vein, Fig. 1 indicates that the lack of legal incentive influences other barriers, such as the lack of knowledge and scientific data to the adoption of eco-design. These barriers will also exacerbate the fact that "necessary technological solutions are not completely available."

Additional evidence from our MICMAC analysis suggests that:

Table 1
Structural self-interaction matrix (SSIM).

Element	Barrier	6	5	4	3	2
1	No legal incentive	V	O	O	O	V
2	Not enough demand from the market	X	O	O	V	
3	Technical conflicts with other functional features of product development projects	O	O	X		
4	Necessary technological solutions are not completely available	O	O			
5	Require more available time for R&D	A				
6	Not enough available knowledge/scientific data					

Table 4
Level partition.

S. No	Barriers	Reachability Set	Antecedent set	Intersection	Level
1	No legal incentive	1, 2, 3, 5, 6	1	1	III
2	Not enough demand from the market	2, 3, 4, 5, 6	1,2,6	2,6	II
3	Technical conflicts with other functional features of product development projects	3,4	1, 2, 3, 4, 6	3,4	I
4	Necessary technological solutions are not completely available	3,4	2,3,4,	3,4	I
5	Require more available time for R&D	5	1, 2, 5, 6	5	I
6	Not enough available knowledge/scientific data	2,3,5,6	1,2,6	2,6	II

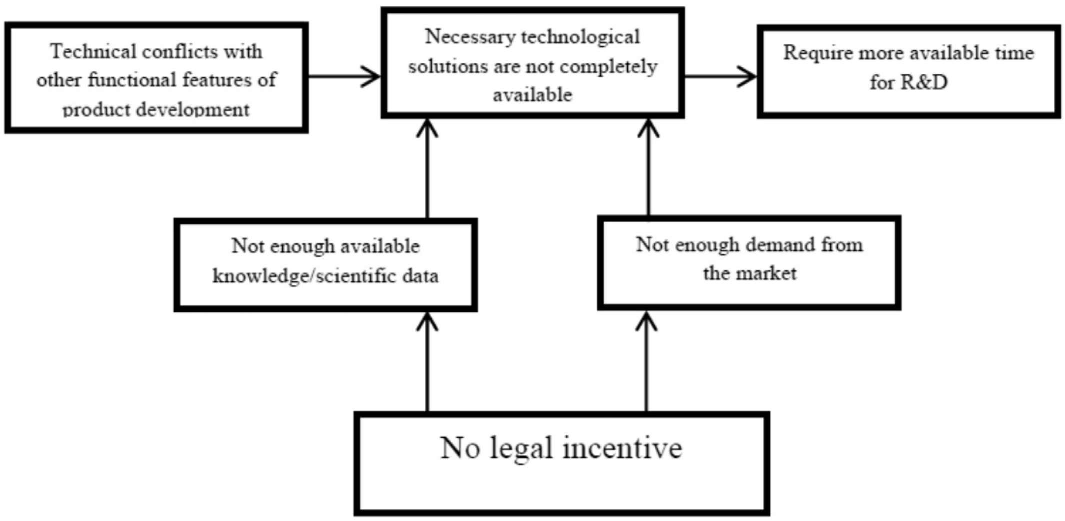

Fig. 1. ISM model for biodiversity-based eco-design barriers.

Table 5
Rank vectors for given and received by each criterion.

S. No	Barriers	Rank Vector
1	No legal incentive	**3**
2	Not enough demand from the market	**2**
3	Technical conflicts with other functional features of product development projects	**1**
4	Necessary technological solutions are not completely available	**1**
5	Require more available time for R&D	**1**
6	Not enough available knowledge/scientific data	**2**

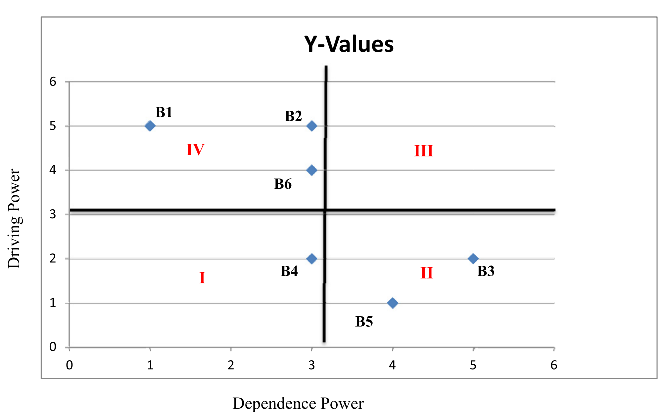

Fig. 2. Driving and dependence power diagram (MICMAC analysis).

- The driver power-dependence diagram indicates that independent barriers such as "no legal incentive," "not enough demand from the market," and "not enough available knowledge/scientific data" appear at the bottom of ISM hierarchy and demonstrate strong driving power and weak dependence. Thus, managers should place a high priority in tackling these barriers which have the capability of influencing other barriers, considered 'key barriers'. For instance, according to interviewees "Brazilian biodiversity law is confused," so the company might have difficulties in understanding, agreeing, or complying with those regulations. The company also revealed that they rely "upon demands from customers in order to intensify research and development on new natural raw material." Hence, customers might be an important enabler of the pursuit of biodiversity-based eco-design. Interviewees also highlighted that traditional knowledge from local communities is relevant to handle natural species properly in its environment.
- Only one factor, "necessary technological solutions are not completely available," is an autonomous barrier and is, therefore, relatively disconnected from the system. This barrier has less influence on the overall system and in many ways can be handled independently during management intervention. Nevertheless, these findings suggest that all of the studied barriers should be considered in a synergic way when adopting

bio-based eco-design. The Sustainability Manager said "working in the field of biodiversity is not easy [...] there are many challenges [...] and the challenges are not isolated, they establish relationships and mutual influences [...] this context makes things more and more complex."
- Barriers such as "technical conflicts with other functional features of product development projects," and "require more available time for R&D" possess weak driving powers but strong dependency on other barriers (dependent barriers). Removal of these barriers ultimately depends on the removal of other barriers.

This research also shows that one group of barriers having high driving power and low dependency requires maximum attention because of their strategic importance. These barriers are "no legal incentive," "not enough demand from the market," and "not enough available knowledge/scientific data." Handling these barriers before the others would likely result in more efficient eco-design implementation. Finally, the group of barriers with high dependence and low driving power – which are influenced by the first group of barriers – includes "technical conflicts with other functional features of product development projects" and "requires more available time for R&D." This group should not be prioritised until initially reducing the barriers of the first group.

Based on the analyses of Figs. 1 and 2, it is clear that the elimination of the "no legal incentive" barrier would make the implementation of biodiversity-based eco-design much easier. This barrier is set at the bottom level of the ISM model and it drives other barriers. This means that weakening this barrier is paramount for further developing biodiversity eco-design. This barrier has been pointed out as a difficult one to remove because it is external to the firm's management and ultimately depends on government actions (Dangelico, 2015). The main implication of this research is to highlight that the Brazilian government plays a key role in promoting eco-design, especially in building up the necessary legal incentives for stimulating biodiversity-based eco-design and biodiversity conversations. Our research corroborates Pedrollo and Kinupp (2015)'s findings which suggested that the Brazilian legislation on biodiversity R&D requires numerous terms of agreements and the easing of bureaucratic obstacles. Governmental bodies in charge of promoting biodiversity do not deal rapidly with bureaucratic issues.

This work aimed to understand the barriers for biodiversity eco-design in a leading Brazilian company that specializes in natural products. The study's several contributions to both theory and practice can be highlighted. Firstly, the majority of works that discusses barriers to green initiatives have neglected eco-design as a focus of their study (Murillo-Luna et al., 2011; Chan, 2008; Shi et al., 2008; Hillary, 2004; Post and Altma, 1994). When the literature discusses barriers, it typically focuses on wider aspects of corporate environmental management. Additionally, most of the literature is conceptual (Brones and Carvalho, 2015; Hillary, 2004; Post and Altma, 1994), and the ISM methodology has not been applied extensively. Thus, this work contributes by adding a discussion on eco-design and for bringing evidence from the natural products sector. Second, the work extends the contribution of Pedrollo and Kinupp (2015) by suggesting that legislation aspects formulate the main challenges when dealing with biodiversity eco-design in Brazil. A third contribution is that this work adds evidence from an emerging economy context, which has been considered a gap in the state-of-the-art literature on sustainable production and consumption (Tseng et al., 2016).

Eco-design has been largely promoted as a way of reducing the environmental impacts of products, but experts acknowledge that there are inherent barriers for eco-design adoption (Pedrollo and Kinupp, 2015). Thus, a bio-based eco-design becomes even more complex in an emerging country such as Brazil, which has one of the richest biodiversity resources in the world, and, at same time, face challenges to deal with some basic environmental issues (Pedrollo and Kinupp, 2015). In Brazil, we can understand the complexity of bio-based eco-design as "promoting the carnival party" and this expression is frequently used to refer to the complex processes of everyday life.

There are no more representative aspects of Brazilian culture than its abundant and unique biodiversity and its festive culture. Carnival, the largest and most popular party in the world, makes Brazilians stop to see a myriad of parades and to hear popular samba music. The parades are pulled by "singers of samba," a prestigious position/job in Brazilian culture. Carnival is related to organising complex events that require a full engagement of a variety of stakeholders. However, metaphorically, would the integration of biodiversity into eco-design be as successful as the coordination of the samba singers during the carnival? Based on our findings, we suggest that the Brazilian government and institutions have failed in promoting legal incentives for bio-based eco-design due to the fact legal incentives were identified as the main obstacles. Thus, adopting bio-based eco-design in the studied company is metaphorically comparable to carnival without the "singers of the samba." Without the government's incentives, biodiversity eco-design will face a number of significant barriers. This major result is aligned with previous research which has argued that governments should play a vital role in promoting eco-innovation (Veugelers, 2012; Kesidou and Demirel, 2012).

5. Conclusion

By and large, "lack of legal incentive" for the adoption of eco-design has been the most influential barrier to the adoption of eco-design. The article states that biodiversity-based R&D and eco-design development organizations after dealing with the "lack of legal incentive," should tackle "not enough demand from the market", and "not enough available knowledge/scientific data". In this sense, the results show that the lack of technical and scientific knowledge of products and processes has hindered the availability of technological solutions for the development of environmentally sustainable products. The conclusion is that the major barrier "lack of legal incentive" creates a domino effect in which the major barrier (lack of legal incentive) jeopardizes the development of skills, projects, and research and development in the field of green product based on biodiversity. Thus, it is important to be created an industrial policy in which eco-design will be "simple to use."

This article makes a case in the field of biodiversity eco-design and sustainability innovation by means of presenting and discussing that although previous studies have indicated that lack of legal incentive is a relevant barrier to the adoption of eco-design, no other research has shown the hierarchical relationships of influences among the main barriers to the adoption of eco-design. Therefore, the application of the ISM was important to provide these relationships in a company context that develops products based on biodiversity. The results presented by this article may be useful for public policy makers and companies interested in promoting product innovation strategies related to environmental sustainability. In addition, this study also indicates which priorities should be observed for the effective adoption of eco-design, which may contribute to greater dissemination and better performance in its application.

This work has its own limitations. Its results are geographically restricted to Brazil. Even though there are limited studies in biodiversity sector related to green product development and eco-design, the evidence portrayed in this study only represents the experience of one company. Finally, we acknowledge that other barriers, which were not considered in this research, can exert influence on developing biodiversity-based eco-design.

Our research analyzed an emerging economy; however, it is strongly recommended that future comparative studies be pursued between mature and less mature economies.

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References

Abdulrahman, M.D., Gunasekaran, A., Subramanian, N., 2014. Critical barriers in implementing reverse logistics in the Chinese manufacturing sectors. Int. J. Prod. Econ. 147, 460–471.

Ansari, M.F., Kharb, R.K., Luthra, S., Shimmi, S.L., Chatterji, S., 2013. Analysis of barriers to implement solar power installations in India using interpretive structural modeling technique. Renew. Sustain. Energy Rev. 27, 163–174.

Azevedo, S., Carvalho, H., Cruz-Machado, V., 2013. Using interpretive structural modelling to identify and rank performance measures: an application in the automotive supply chain. Baltic J. Manag. 8, 208–230.

Boiral, O., Heras-Saizarbitoria, I., February 2017. Managing biodiversity through stakeholder involvement: why, who, and for what initiatives? J. Bus. Ethics 140 (3), 403–421.

Bouzon, M.K., Govindan, K., Rodriguez, C.M.T., 2015. Reducing the extraction of minerals: reverse logistics in the machinery manufacturing industry sector in Brazil using ISM approach. Resour. Pol. 46, 27–36.

Bovea, M.D., Pérez-Beliz, V., 2012. A taxonomy of ecodesign tools for integrating environmental requirements into the product design process. J. Clean. Prod. 20, 61–71.

Brones, F., Carvalho, M.M., 2015. From 50 to 1: integrating literature toward a systemic ecodesign model. J. Clean. Prod. 96, 44–57.

Brones, F., Carvalho, M.M., Zancul, E.S., 2014. Ecodesign in project management: a missing link for the integration of sustainability in product development? J. Clean. Prod. 80, 106–118.

Byggeth, S., Hochschorner, E., 2006. Handling trade-offs in ecodesign tools for sustainable product development and procurement. J. Clean. Prod. 14, 1420–1430.

Chan, E.S., 2008. Barriers to EMS in the hotel industry. Int. J. Hospit. Manag. 27, 187–196.

Chan, E.S., 2011. Implementing environmental management systems in small-and medium-sized hotels: Obstacles. J. Hospit. Tourism Res. 35, 3–23.

Chasteen, J.C., 1996. The prehistory of Samba: carnival dancing in Rio de Janeiro, 1840–1917. J. Lat. Am. Stud. 28, 29–47.

Dalhammar, C., 2016. Industry attitudes towards ecodesign standards for improved resource efficiency. J. Clean. Prod. 123, 155–166.

Dangelico, R.M., 2015. Green product innovation: where we are and where we are going. Bus. Strat. Environ. 25, 560–573.

Debata, B.R., Sree, K., Patnaik, B., Mahapatra, S.S., 2013. Evaluating medical tourism enablers with interpretive structural modeling. Benchmark Int. J. 20, 716–743.

Dekoninck, E.A., Domingo, L., O'Hare, J.A., Pigosso, D.C.A., Reyes, T., Troussier, N., 2016. Defining the challenges for ecodesign implementation in companies: development and consolidation of a framework. J. Clean. Prod. 135, 410–425.

Diabat, A., Govindan, K., 2011. An analysis of the drivers affecting the implementation of green supply chain management. Resour. Conservat. Recycl. 55 (6), 659–667.

Dubey, R., Ali, S.S., 2014. Identification of flexible manufacturing system dimensions and their interrelationship using total interpretive structural modelling and fuzzy MICMAC analysis. Global J. Flex. Syst. Manag. 15, 131–143.

Duperrin, J.C., Godet, M., 1973. The Method for Hierarchical System Elements. Rapp. Econ. De CEA. R-45-51. Paris (In French).

Earthwatch Institute (Europe), 2002. International union for conservation of nature and natural resources, world business Council for sustainable development. In: Business and Biodiversity: the Handbook for Corporate Actions (Atar, Switzerland).

Englund, O., Berndes, G., 2015. How do sustainability standards consider biodiversity? Wiley Interdiscip. Rev. Energy Environ. 4, 26–50.

Farris, D.R., Sage, A.P., 1975. On the use of interpretive structural modeling for worth assessment. Comput. Electr. Eng. 2, 149–174.

Finksel, J., 2012. Design for Environment: a Guide to Sustainable Product Development, second ed. McGraw-Hill, New York.

Fujimoto, J., Kondoh, S., Poland, D., 2009. Ecodesign of multilateral recycling systems in Asia. Int. J. Environ. Technol. Manag. 11, 276–289.

Govindan, K., Palaniappan, Q. Zhu, Kannan, D., 2012. Analysis of third party reverse logistics provider using interpretive structural modeling. Int. J. Prod. Econ. 140, 204–211.

Govindan, K., Kannan, D., Mathiyazhagan, K., Jabbour, A.B.L.S., Jabbour, C.J.C., 2013. Analysing green supply chain management practices in Brazil's electrical/electronics industry using interpretive structural modelling. Int. J. Environ. Stud. 70, 477–493.

Govindan, K., Azevedo, S.G., Carvalho, H., Cruz-Machado, V., 2015. Lean, green and resilient practices influence on supply chain performance: interpretive structural modeling approach. Int. J. Environ. Sci. Technol. 12, 15–34.

Gupta, U., Ramesh, A., 2015. Analyzing the barriers of health care supply chain in India: the contribution and interaction of factors. Proc. Soc. Behav. Sci. 189, 217–228.

Haleem, A., Sushil, M.A.Q., Kumar, S., 2012. Analysis of critical success factors of world-class manufacturing practices: an application of interpretative structural modelling and interpretative ranking process. Prod. Plann. Contr. 23, 722–734.

Hellström, T., 2007. Dimensions of environmentally sustainable innovation: the structure of eco-innovation concepts. Sustain. Dev. 15, 148–159.

Hillary, R., 2004. Environmental management systems and the smaller enterprise. J. Clean. Prod. 12, 561–569.

Hur, T., Lee, J., Ryu, J., Kwon, E., 2005. Simplified LCA and matrix methods in identifying the environmental aspects of a product system. J. Environ. Manag. 75, 229–237.

IUCN, 2014. Biodiversity for Business: a Guide to Using Knowledge Products Delivered through IUCN (Gland, Switzerland).

Jabbour, C.J.C., Jugend, D., Jabbour, A.B.L.S., Gunasekaran, A., Latan, H., 2015. Green product development and performance of Brazilian firms: measuring the role of human and technical aspects. J. Clean. Prod. 87, 442–451.

Jia, P., Diabat, A., Mathiyazhagan, K., 2015. Analyzing the SSCM practices in the mining and mineral industry by ISM approach. Resour. Pol. 46, 76–85.

Jindal, A., Sangwan, K.S., 2013. Development of an interpretive structural model of drivers for reverse logistics implementation in Indian industry. Int. J. Bus. Perform. Supply Chain Model. 5, 325–342.

Kannan, D., Diabat, A., Shankar, K.M., 2014. Analyzing the drivers of end-of-life tire management using interpretive structural modeling (ISM). Int. J. Adv. Manuf. Technol. 72, 1603–1614.

Karlsson, R., Luttropp, C., 2006. EcoDesign: what's happening? an overview of the subject area of EcoDesign and of the papers in this special issue. J. Clean. Prod. 14, 1291–1298.

Kehbila, A., Ertel, G.J., Brent, A.C., 2009. Strategic corporate environmental management within the South African automotive industry: motivations, benefits, hurdles. Corp. Soc. Responsib. Environ. Manag. 16, 310–323.

Kesidou, E., Demirel, P., 2012. On the drivers of eco-innovations: empirical evidence from the UK. Res. Pol. 41, 862–870.

Khan, I., Rahman, Z., 2015. Brand experience anatomy in retailing: an interpretive structural modeling approach. J. Retailing Consum. Serv. 24, 60–69.

Kumar, N., 2013. Implementing lean manufacturing system: ISM approach. J. Ind. Eng. Manag. 6, 996–1012.

Küçüksayraç, E., 2015. Design for sustainability in companies: strategies, drivers and needs of Turkey's best performing businesses. J. Clean. Prod. 106, 455–465.

Lendaris, G.G., 1980. Structural modeling a tutorial guide. IEEE Trans. Syst. Man Cybern. 10, 807–840.

Lopes, C.S.D., Azevedo, P.S., 2014. Environmental requirements for furniture industry: the case study of Brazilian Southeast industry. Environ. Dev. Sustain. 16, 1013–1029.

Luchs, M.G., Brower, J., Chitturi, R., 2012. Product choice and the importance of aesthetic design given the emotion-laden trade-off between sustainability and functional performance. J. Prod. Innovat. Manag. 29, 903–916.

Luiz, O.R., Jugend, D., Jabbour, J.C.C., Luiz, O., Souza, F.N., 2016. Ecodesign field of research throughout the world: mapping the territory by using an evolutionary lens. Scientometrics 109, 241–259.

Luthra, S., Kumar, V., Kumar, S., Haleem, A., 2011. Barriers to implement green supply chain management in automobile industry using interpretive structural modeling technique: an Indian perspective. J. Ind. Eng. Manag. 4, 231–257.

Luttropp, C., Lagerstedt, J., 2006. EcoDesign and the ten golden rules: generic advice for merging environmental aspects into product development. J. Clean. Prod. 14, 1396–1408.

Mahajan, R., Agrawal, R., Sharma, V., Nangia, V., 2014. Factors affecting quality of management education in India: an interpretive structural modelling approach. Int. J. Educ. Manag. 28, 379–399.

Massoud, M.A., Fayad, R., Kamleh, R., El-Fadel, M., 2010. Environmental management system (ISO 14001) certification in developing countries: challenges and implementation strategies 1. Environ. Sci. Technol. 44, 1884–1887.

Mathiyazhagan, K., Haq, A.N., 2013. Analysis of the influential pressures for green supply chain management adoption—an Indian perspective using interpretive structural modeling. Int. J. Adv. Manuf. Technol. 68, 817–833.

Mathiyazhagan, K., Govindan, K., NoorulHaq, A., Geng, Y., 2013. An ISM approach for the barrier analysis in implementing green supply chain management. J. Clean. Prod. 47, 283–297.

Mehta, N., Verma, P., Seth, P., 2014. Total quality management implementation in engineering education in India: an interpretive structural modelling approach. Total Qual. Manag. Bus. Excel. 25, 124–140.

Mitra Debnath, R., Shankar, R., 2012. Improving service quality in technical education: use of interpretive structural modeling. Qual. Assur. Educ. 20, 387–407.

Mittal, V.K., Sangwan, K.S., 2014. Development of a model of barriers to environmentally conscious manufacturing implementation. Int. J. Prod. Res. 52, 584–594.

Mongbay, 2016. Countries with the highest biological biodiversity. Access: February

2016. Available at: http://rainforests.mongabay.com/03highest_biodiversity.htm.
Muduli, K., Govindan, K., Barve, A., Kannan, D., Geng, Y., 2013. Role of behavioural factors in green supply chain management implementation in Indian mining industries. Resour. Conservat. Recycl. 76, 50–60.
Murillo-Luna, J.L., Garcés-Ayerbe, C., Rivera-Torres, P., 2011. Barriers to the adoption of proactive environmental strategies. J. Clean. Prod. 19, 1417–1425.
Paramanathan, S., Farrukh, C., Phaal, R., Probert, D., 2004. Implementing industrial sustainability: the research issues in technology management. R&D Manag. 34, 527–537.
Park, P., Tahara, K., 2008. Quantifying producer and consumer based eco-efficiencies for the identification of key ecodesign issues. J. Clean. Prod. 16, 95–104.
Pedrollo, C.T., Kinupp, V.F., 2015. Sustainability or colonialism? Legislative obstacles to research and development of natural products and patents on traditional knowledge in Brazil. Acta Bot. Bras. 29, 452–456.
Pigosso, D.C.A., Zanette, E.T., Guelere Filho, A., Ometto, A.R., Rozenfeld, R., 2010. Ecodesign methods focused on remanufacturing. J. Clean. Prod. 18, 21–31.
Pigosso, D.C.A., Rozenfeld, H., McAloone, T.C., 2013. Ecodesign maturity model: a management framework to support ecodesign implementation into manufacturing companies. J. Clean. Prod. 59, 160–173.
Plouffe, S., Lanoie, P., Berneman, C., Vernier, M., 2011. Economic benefits tied to ecodesign. J. Clean. Prod. 19, 573–579.
Poduval, P.S., Pramod, V.R., 2015. Interpretive structural modeling (ISM) and its application in analyzing factors inhibiting implementation of total productive maintenance (TPM). Int. J. Qual. Reliab. Manag. 32, 308–331.
Polomé, P., 2016. Private forest owners motivations for adopting biodiversity-related protection programs. J. Environ. Manag. 183, 212–219.
Polzin, F., von Flotow, P., Klerkx, L., 2016. Addressing barriers to eco-innovation: exploring the finance mobilisation functions of institutional innovation intermediaries. Technol. Forecast. Soc. Change 103, 34–46.
Post, J.E., Altma, B.W., 1994. Managing the environmental change process: barriers and opportunities. J. Organ. Change Manag. 7, 64–81.
Poulikidou, S., Björklund, A., Tyskeng, S., 2014. Empirical study on integration of environmental aspects into product development: processes, requirements and the use of tools in vehicle manufacturing companies in Sweden. J. Clean. Prod. 8, 34–45.
Sage, A.P., 1977. Interpretive Structural Modeling: Methodology for Large-scale Systems. McGraw-Hill, New York.
Sanyé-Mengual, E., Pérez-López, P., González-García, S., Lozano, R.G., Feijoo, G., Moreira, M.T., Gabarrell, X., Rieradevall, J., 2014. Eco-designing the use phase of products in sustainable manufacturing. J. Ind. Ecol. 18, 545–557.
Seebode, D., Jeanrenaud, S., Bessant, J., 2012. Managing innovation for sustainability. R&D Manag. 42, 195–206.
Sharma, B.P., Singh, M.D., Neha, 2012. Modeling the knowledge sharing barriers using an ISM approach. In: International Conference on Information and Knowledge Management, pp. 233–238.
Shepherd, D.A., Patzelt, H., 2011. The new field of sustainable entrepreneurship: studying entrepreneurial action linking “what is to be sustained” with “what is to be developed”. Enterpren. Theor. Pract. 35, 137–163.
Shi, H., Peng, S.Z., Liu, Y., Zhong, P., 2008. Barriers to the implementation of cleaner production in Chinese SMEs: government, industry and expert stakeholders' perspectives. J. Clean. Prod. 16, 842–852.
Studer, S., Welford, R., Hills, P., 2006. Engaging Hong Kong businesses in environmental change: drivers and barriers. Bus. Strat. Environ. 15, 416–431.
Sushil, 2012. Interpreting the interpretive structural model. Global J. Flex. Syst. Manag. 13, 87–106.
SustainabilityForAll, 2016. The top 10 countries in biodiversity. Access: February 2016. Available at: http://www.activesustainability.com/top-10-countries-in-biodiversity#1.
Thakkar, J., Kanda, A., Deshmukh, S.G., 2008. Interpretive structural modeling (ISM) of IT-enablers for Indian manufacturing SMEs. Inform. Manag. Comput. Secur. 16, 113–136.
Tseng, M., Tan, K.H., Geng, Y., Govindan, K., 2016. Sustainable consumption and production in emerging markets. Int. J. Prod. Econ. 181, 257–261.
van Hemel, C., Cramer, J., 2002. Barriers and stimuli for ecodesign in SMEs. J. Clean. Prod. 10, 439–453.
Venkatesh, V.G., Rathiand, S., Patwa, S., 2015. Analysis on supply chain risks in Indian apparel retail chains and proposal of risk prioritization model using Interpretive structural modeling. J. Retailing Consum. Serv. 26, 153–167.
Vercalsteren, A., 2001. Integrating the ecodesign concept in small and medium-size enterprises: experiences in the Flemish Region of Belgium. Environ. Manag. Health 12, 347–355.
Veugelers, R., 2012. Which policy instruments to induce clean innovating? Res. Pol. 41, 1770–1778.
Walker, H., Di Sisto, L., McBain, D., 2008. Drivers and barriers to environmental supply chain management practices: lessons from the public and private sectors. J. Purch. Supply Manag. 14, 69–85.
Warfield, J.W., 1974. Developing interconnected matrices in structural modeling. IEEE Transcript on Systems. Men Cybern. 4, 51–81.
Warfield, J.W., 1990. A Science of Generic Design. Managing Complexity through Systems Design L. Intersys. Pub., Salinas. CA.
Wijethilake, C., 2017. Proactive sustainability strategy and corporate sustainability performance: the mediating effect of sustainability control systems. J. Environ. Manag. 196, 569–582.
Yang, F., Freedman, B., Cote, R., 2004. Principles and practice of ecological design. Environ. Rev. 12, 97–112.
Zhu, Q., Geng, Y., 2013. Drivers and barriers of extended supply chain practices for energy saving and emission reduction among Chinese manufacturers. J. Clean. Prod. 40, 6–12.
Zhu, Q., Geng, Y., Lai, K., 2010. Circular economy practices among Chinese manufacturers varying in environmental-oriented supply chain cooperation and the performance implications. J. Environ. Manag. 91, 1324–1331.