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REVISITING GREEN SUPPLIER SELECTION PUBLICATIONS FROM THE LAST DECADE (2010-2022): A STRUCTURED REVIEW AND BIBLIOMETRIC STUDY

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Abstract

Almost ten years have passed since some seminal structured literature reviews about multi-criteria decision-making for green supplier selection were published. We aimed to investigate the evolution of intellectual structures in this field through a structured literature review and bibliometric analysis using publications between 2010 and 2022. We noted that mathematical and analytical approaches are still dominating, and the complexity of the methods has increased. Bibliometrically, their theoretical foundation and techniques are the same despite the change of leading papers over time. Our contribution consist in extending earlier studies and discussing the evolution of the field.

Keywords: green supplier selection, multi-criteria decision-making, structured review, bibliometric analysis.

1 Introduction

The importance of selecting a proper supplier has already been demonstrated. A good supplier could help organizations to achieve superior monetary performance, efficient strategy implementation, higher quality, or better reputation (Dobos and Vörösmarty, 2019; Ellram, 1990; Famiyeh and Kwarteng, 2018; Kannan and Tan, 2002; Kaufmann, Mesching and Reimann, 2014). In order to contribute to the efficiency of supplier selection, academics have extensively investigated this organizational task in various aspects, such as: alignment

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of sourcing and business strategy (Chen, 2011), supplier selection criteria (Choi and Hartley, 1996; van der Rhee, Verma and Plaschka, 2009; Weber, Current and Benton, 1991), process and decision making (Kaufmann, Carter and Buhrmann, 2012; Riedl et al., 2013), optimization modeling (Ho, Xu and Dey, 2010; Xia and Wu, 2007) and sustainability in supplier selection (dos Santos, Godoy and Campos, 2019; Ehrgott et al., 2011; Kannan, 2018).

Until the end of the 1990s, the supplier selection process mainly employed conventional operational and strategical criteria such as quality, cost, delivery, and flexibility (Choi and Hartley, 1996; Ellram, 1990; Weber, Current and Benton, 1991). However, since the late 1990s, given the positive impact of sustainability on firm performance (Rao and Holt, 2005), sustainability concerns are getting more and more noticed in supply chain management and supplier selection.

Despite the importance of sustainability for the organization, relatively few papers studied green supplier selection until 2010. For instance, Igarashi, de Boer and Fet (2013) found only 60 papers focused on green supplier selection while reviewing the publications from 1991-2011; Genovese et al. (2013) collected 28 papers for their review of publications from 1997-2010; and Wetzstein et al. (2016) analyzed only 25 papers dealing with green supplier selection from 248 papers researching supplier selection.

More recently, Schramm, Cabral and Schramm (2020) analyzed 82 papers that investigated green supplier selection, published in the last three decades. They reported the multi-criteria decision-making (MCDM) methods mainly used to support green supplier selection. Despite their study's extensiveness, it was impossible to determine how the intellectual structure evolved from early research on green supplier selection to more recent studies. At the same time, the intellectual structure could be observed in earlier articles, such as Igarashi, de Boer and Fet (2013) and Genovese et al. (2013). Considering that no studies updated these earlier review papers with the last decade's data (2010-2022), our study investigates how the intellectual structure evolved from 2010 to 2022 in green supplier selection and how green supplier selection has developed in green supply chain management.

Methodologically, to answer our research question objectively, we adopted a Structured Literature Review (SLR) as suggested by Thomé, Scavarda and Scavarda (2016), which differs from the traditional literature review by providing a clear and well-defined process. As part of our SLR, we employed a bibliometric analysis using a sample of articles published from 2010 to 2022. From the bibliometric analysis, we could describe our sample articles quantitatively and obtain a citation network, bibliographic coupling, and a co-citation network,

which could allow us to infer the intellectual structure of the field. To support our bibliometric analysis, we used VOSviewer (van Eck and Waltman, 2017; Yu et al., 2020) to analyze the sample of manuscripts built through *the ISI Web of Science* and *Scopus* indexer.

Through an updated database, our study extended the earlier structured literature reviews; we identified the principal authors in green supplier selection, the prominent publications, the proximity of the leading publications, and the evolution of the intellectual structure of the last decade.

To organize this document, the rest of our manuscript is structured into: (2) a Literature review, (3) a Methodology, (4) Results and discussions, and (5) Final considerations.

2 Literature review

2.1 Structured literature review publications on green supplier selection

Supplier selection is a subject that has been studied since the 1960s, the seminal work of Dickson (1966) proposed a list with 23 supplier selection criteria that companies commonly use. This list of 23 criteria was updated later considering factors such as operational strategy (Weber, Current and Benton, 1991), industry (Choi and Hartley, 1996), nature of the product to be purchased (van der Rhee, Verma and Plaschka, 2009) or purchasing process (Scott, Burke and Szmerekovsky, 2018). Apart from supplier selection criteria, according to Wetzstein et al. (2016), research in supplier selection could be classified into six significant streams, where green supplier selection is one of them.

Although green supplier selection is one of the mainstreams in supplier selection, studies about selecting suppliers incorporating environmental and social/ethical criteria and the related process are relatively recent. Noci (1997) observed that the necessity of organizations to improve their environmental performances led to the necessity of considering these factors in supply chain management, thus impacting supplier selection. Following Noci (1997), the process of selecting a supplier considering these environmental and social/ethical criteria is called green supplier selection. It is not so different from the traditional supplier selection apart from the inclusion of sustainable factors in the process (Govindan et al., 2015; Noci, 1997; Qin, Liu and Pedrycz, 2017).

As for the literature on green supplier selection, some structured literature reviews served as guidelines for the research on this topic. Igarashi, Boer and Fet (2013) mapped the literature on green supplier selection. It classified how the articles are distributed in research methodology, theories, stages of the purchas-

ing process, and what environmental criteria the articles treated. According to their study, most of the studies in green supplier selection are concentrated on the criteria formulation and final decision process, since these are the significant points that differ from the traditional selection. They also proposed a conceptual model of green supplier selection based on supply context, process, tools, and strategy alignment. However, they did not aim to demonstrate the intellectual structure underneath the green supplier selection criteria, nor how this structure had evolved for the period they investigated (1991-2011).

Genovese et al. (2013) conducted another relevant structured literature review in this area. These authors analyzed 28 papers, and they noted that 24 used a mathematical approach to investigate this subject and suggested that the availability of a waste management system is the most frequently occurring environmental criterion, followed by green design capability and environmental staff training and involvement. In addition to primary green supplier selection criteria, Genovese et al. (2013) noticed that, over time, studies tend to move from theoretical framework approaches involving only green criteria (Noci, 1997) to synthetic models where green are combined with the traditional criteria (Lee et al., 2009).

More recently, Zimmer, Fröhling and Schultmann (2016) conducted a structured literature review using a sample of 143 papers published from 1997 to 2014. They also observed that most of the publications in this field focused on the study of evaluation and final selection of suppliers. In contrast to earlier studies, Zimmer, Fröhling and Schultmann (2016) focused only on publications that bring models supporting green supplier selection, and they found that 62.2% used a combined model, such as linear programming and AHP or AHP and VIKOR, to support green supplier selection. Zimmer and colleagues also proposed a detailed mapping of green criteria employed by their sample papers, and they classified the selection criteria into three main categories: economic, environmental, and social. However, social criteria are less employed than the first two categories.

Similarly to Zimmer, Fröhling and Schultmann (2016), Schramm, Cabral and Schramm (2020) mapped structurally 82 papers dealing with mathematical approaches to support green supplier selection published between 1990 and 2019. Like previous studies, Schramm, Cabral and Schramm (2020) also observed that most of their analyzed papers integrate more than two methods. According to Schramm, Cabral and Schramm (2020), combining more methods can bring more robust results. However, the methods employed should avoid the high cognitive demand of the decision-makers. Unlike previous studies, Schramm, Cabral and Schramm (2020) did not investigate the green criteria used in their papers.

3 Methodology

Structured literature review has been widely employed to understand and organize the publications in a research field. For instance, Üsdisken and Pasadeos (1995) employed this approach to investigate differences in organization studies between US and European researchers; Burgess, Singh and Koroglu (2006) mapped the supply chain management publications between 1985 and 2003; Pilkington and Meredith (2009) studied the evolution of intellectual structure in operations management from 1980 to 2006. Song et al. (2019) investigated how classroom communication research evolved in the education field between 1999 and 2018.

There are two approaches to conducting a structured literature review. The first one is a more qualitative approach, such as those employed by Burgess, Singh and Koroglu (2006), Zimmer, Fröhling and Schultmann (2016), and Schramm, Cabral and Schramm (2020). In this approach, the researchers analyze a sample of papers, classify them according to several criteria and infer the theoretical paradigms existing in the sample, the dominant research methodology and approaches, the main research streams, definitions of research terminologies, and possible research gaps. Another approach is based on bibliometric investigation, such as those applied by Üsdisken and Pasadeos (1995), Pilkington and Meredith (2009), and Song et al. (2019).

In contrast to the qualitative approach, using bibliometric analysis, it is possible to analyze a larger sample. It uses the bibliographic data of a sample of publications to build the intellectual structure of the field (Zupic and Čater, 2015). Among the five significant metrics in the bibliometric analysis: keywords, citation, co-citation, bibliographic, and coauthor analyses, our study will employ the first four metrics to analyze our sample of publications. From these four bibliographic metrics, we could identify: a) the main topics treated by the sample articles (keyword analysis), b) the relatedness of the sample articles (bibliographic coupling and citation analysis), c) the relatedness of the references of the sample papers (co-citation analysis).

Keyword analysis counts the number of times that each keyword supplied by authors appears in the sample article and the number of times they appear together. From the frequency of the keywords co-occurrence, it is possible to identify the main topics treated by the sample papers.

Citation analysis counts the number of times each sample publication was cited and the number of times a sample paper cited other papers from the sample. This analysis assumes that the higher the citation of a paper in the sample, the more influential it is in the field. As opposed to citation analysis, the

co-citation analysis deals with the bibliographic references of our sample paper. This analysis is defined by the frequency at which two bibliographic references of the sample papers are cited together. This analysis assumes that papers are cited together when they have: a) similar theoretical foundation regardless of their positioning and/or b) complementary ideas. From the co-citation analysis, it could be possible to identify theoretical streams, concepts, models, or research methodologies (Pilkington and Meredith, 2009; Small, 1973).

The fourth metric that we adopted in our study is bibliographic coupling. This indicator counts the common references shared by two papers of the analyzed sample. From this indicator, it is expected that the more common references two publications share, the more similar they are (Zupic and Čater, 2015).

However, bibliometrics analysis is based on formal communication among scientific productions; therefore, the proximity of the publications and authors does not consider informal communications such as technical reports, exchanges among authors in conferences, events, or personal aspects.

3.1 Sampling and data treatment

For two reasons, we used the indexers ISI Web of Science (WoS) and Scopus to create the sample of articles for our study. First, it is one of the most reliable scientific publication databases (Yang et al., 2013), and second, this platform could provide the information to elaborate the bibliometric study we needed.

Our sample is limited to English articles published from January 2010 to June 2022. The keywords that we used to search the publications were: "supplier selection" + "green"; "supplier selection" + "sustainability". Since these two indexers bring articles not only from social studies, we limited our search to the areas related to business management and sustainability, such as *environmental science*, *green sustainable science technology*, *operations research management science*, *environmental engineering*, *industrial engineering*, *manufacturing engineering*, *environmental studies*, *management*, *electrical*, *electronic engineering*, *multidisciplinary engineering*, *multidisciplinary science*, *business*, *chemical engineering*, *civil engineering*, *public environmental*, *occupational health*, *transportation*, *mechanical engineering*, *material science textile*, *regional urban planning*, *ethics*, and *public administration*. From our search, we first screened the abstracts of all articles and removed all those unrelated to our subject. Then we removed overlapping papers, obtaining a sample of 942 articles.

Before data treatment, we used the OpenRefine application to standardize the keywords supplied by the authors, for instance, "analytic hierarchy process" to "AHP". However, we did not reinterpret the keywords; for instance, if the article used "sustainable supplier selection", we kept it as it was; even another article

used "green supplier selection". We also standardized and corrected the bibliographic references of our sample articles since there were discrepancies across the references of the sample articles when referring to papers or books, for instance, different descriptions of the same author (Barney, B. Jay or Barney, J) or different editions of the same book or incorrect year of a cited reference. To run the bibliometric analysis, we employed the VOSviewer application (van Eck and Waltman, 2017; Yu et al., 2020).

4 Results and discussion

4.1 Description of the sample

From our sample of 942 articles, we noted that the top 10 journals published about green supplier selection are responsible for more than 30% of total production from 2010 to 2022 (Table 1), which means that the articles on this subject are widely spread in a significant number of journals (318 journals) and not restricted to those dedicated to sustainability. Among the top 10 journals, the *Journal of Cleaner Production* has the largest number of publications on this topic, which is somehow expected. One interesting observation is the fifth place of the *International Journal of Production Economics*, the top publisher among multidisciplinary journals. Our finding is in line with the bibliometric study of Fahimnia, Sarkis and Davarzani (2015), and the *Journal of Cleaner Production* remained the leading source of articles related to the green supply chain subjects.

Table 1: Journals that publish the largest number of papers on green supplier selection

Rank	Journal	# publications	Cumulated %
1	Journal of Cleaner Production	85	9.0%
2	Sustainability	66	16.0%
3	Computers & Industrial Engineering	25	18.7%
4	Journal of Intelligent & Fuzzy Systems	24	21.2%
5	International Journal of Production Economics	23	23.7%
6	International Journal of Production Research	19	25.7%
7	Mathematical Problems in Engineering	19	27.7%
8	Mathematics	18	29.6%
9	Symmetry	18	31.5%
10	Applied Soft Computing	16	33.2%

Regarding the number of publications per year, from Figure 1 it can be seen that the number of publications dealing with green supplier selection has increased consistently since 2010, indicating that this area has still many research opportunities, either as regards the methodology or the supplier selection process.

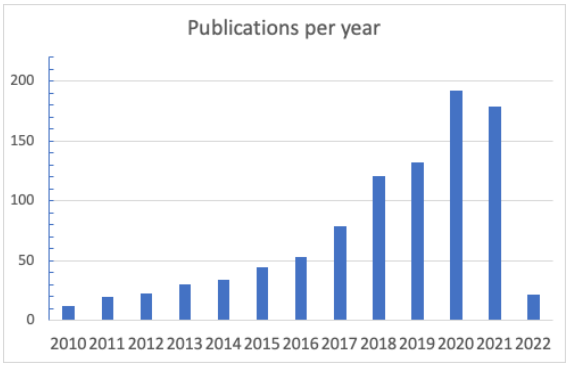


Figure 1: Number of publications per year

Regarding authorship, when considering only the first author, from Table 2 we can see that the ten most publishing authors are responsible for approximately 7% of total publications; therefore, we infer that contributions to the field are distributed, with a significant number of researchers (737 authors for 942 articles). We would like to remind that, for the counting of authorship, we considered only the first authors; while numerous prominent authors appear in several articles as second or third ones, such as Sarkis, Joseph (Dou and Sarkis, 2010), Kannan, Devika (Awasthi, Govindan and Gold, 2018) or Wei, Guiwu (Tang, Wei and Gao, 2019).

Table 2: Number of citations per author

Rank	Authors	# publications
1	Krishankumar, Raghunathan	8
2	Wei, Guiwu	8
3	Fallahpour, Alireza	7
4	Govindan, Kannan	7
5	Tavana, Madjid	7
6	Yazdani, Morteza	7
7	Kannan, Devika	6
8	Wang, Jie	6
9	Amindoust, Atefeh	5
10	Ghadimi, Pezhman	5

Regarding the principal authors whom Fahimnia, Sarkis and Davarzani (2015) noted in their green supply chain management study between 1996 and 2013, we noted that none of those top 10 authors appeared in our top 10 list. However, the top 10 authors identified by Fahimnia, Sarkis and Davarzani (2015) frequently appeared in the cited references and as second or third authors of our sample articles. We inferred that the different set of leading authors we obtained is due to the difference in period and the central theme of our sample

articles as opposed to theirs. While Fahimnia, Sarkis and Davarzani (2015) analyzed the articles centered on green supply chain management between 1992 and 2012, we focused on green supplier selection between 2010 and 2022.

To analyze our sample qualitatively, we selected the 100 most cited papers. From these articles, in terms of research methodology, we noted that only a few used empirical methods (survey or case study), while 87% used analytical methods (one or more methods combined). This result reflects the finding of previous studies (Genovese et al., 2013; Igarashi, de Boer and Fet, 2013).

Table 3: Publications and research methods

# publications	Methods
3	Case study
6	Survey (OLS or Structural equation modeling or Factor analysis)
4	Literature review
87	Analytical methods (AHP, ANP, TOPIS, DEA, DEMATEL, VIKOR, Fuzzy AHP, Fuzzy ANP, etc.)

The number of studies based on analytical methods is not surprising since most papers are related to engineering. In these papers, green supplier selection focused on the operational approach; for instance, green supplier selection and order allocation problem (Hamdan and Cheaitou, 2017), green supplier selection using objective operational factors such as quality rejection, cost, late delivery, and greenhouse gas emission (Shaw et al., 2012) or green supply chain management practices through sustainable supplier selection (Kannan, de Sousa Jabbour and Jabbour, 2014).

In addition, given the wide range of analytical methods and the possibility of their combinations, it is possible to explore the green supplier selection process with a multitude of approaches, for instance, a single approach such as the application of ANP for offshoring strategy based on green supplier selection (Dou and Sarkis, 2010); multiple objective mixed-integer linear programming for green supply chain management using operational and strategical factors (Mota et al., 2018) or a combination of multiple approaches, such as AHP and fuzzy linear multi-objective linear programming (Shaw et al., 2012); fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS (Büyüközkan and Çifçi, 2012); DEA, ANP and artificial neural network (Kuo, Wang and Tien, 2010); ANP and AHP (Sarkis, Meade and Presley, 2012) or ANP and QFD for green supplier selection (Tavana, Yazdani and Di Caprio, 2017). In addition, we also observed that researchers combined multiple methodologies to overcome the limitations of specific methods and find consistent results (Schramm, Cabral and Schramm, 2020).

Regarding the green supplier selection criteria, our analyzed sample papers suggested that in the green supplier selection process, the traditional selection factors, such as cost, quality, delivery, and flexibility should still be included (Arabsheybani, Paydar and Safaei, 2018; Dou and Sarkis, 2010; Hamdan and Cheaitou, 2017; Shaw et al., 2012; Tang and Wei, 2018a; Trapp and Sarkis, 2016; Wang, Wei and Wei, 2018; Wang et al., 2019). The adoption of traditional selection criteria could be explained by the transaction cost economy, where the company's primary aim is profit maximization (Hashemi, Karimi and Tavana, 2015). In addition to cost, quality and delivery, other traditional criteria can be considered, such as technical capability, manufacturing capability, financial status (Kuo and Lin, 2012), supplier reputation/ geographic location (Memari et al., 2019), shareholder, public and customer orientations (Reuter, Goebel and Foerstl, 2012). According to prior studies (Noci, 1997; Stević et al., 2020), green supplier selection, from the process perspective, can be seen as supplier selection that formally introduces the sustainability factors into the selection process.

According to our sample of papers, there are mainly two significant sustainability groups of factors: environmental and social/ethical criteria, which are similar to those observed by Zimmer, Fröhling and Schultmann (2016). The environmental criteria form an extensive list that involve factors such as greenhouse gas emission/ CO2 emission/ Carbon footprint (Govindan and Sivakumar, 2016; Huang et al., 2016; Kumar, Jain and Kumar, 2014; Shaw et al., 2012); energy usage/ resource consumptions/ waste minimization/ waste disposal (Agrawal, Singh and Murtaza, 2016; Kumar, Rahman and Chan, 2017; Shaw et al., 2012); environmental risk (Song, Ming and Liu, 2017); eco-design/ green image/ green principle/ green product/ green innovation (Che, 2010; Hashemi, Karimi and Tavana, 2015; Shen et al., 2013; Song, Ming and Liu, 2017; Tavana, Yazdani and Di Caprio, 2017; Zhang and Xu, 2015); green practices/ green certification/ ISO 14001/ EMAS (Fallahpour et al., 2017; Freeman and Chen, 2015; Hatami-Marbini et al., 2017; Kannan, 2018; Kannan, de Sousa Jabbour and Jabbour, 2014; Tseng and Chiu, 2013); reverse logistics/ reduce/ recycling/ reuse (Senthil, Srirangacharyulu and Ramesh, 2014; Tavana, Yazdani and Di Caprio, 2017; Yazdani et al., 2017); and environmental management system (Arabsheybani, Paydar and Safaei, 2018; Luthra et al., 2017; Senthil, Srirangacharyulu and Ramesh, 2014; Su et al., 2016; Tavana, Yazdani and Di Caprio, 2017; Yazdani et al., 2017). These factors are not necessarily used together but will depend on the organization's strategies and objectives (Demirtas and Üstün, 2008; Kumar, Rahman and Chan, 2017; Shaw et al., 2012).

The social/ethical criteria in green supplier selection are not as extensive as the environmental ones. Therefore they are less frequently used than conventional and environmental criteria (Stević et al., 2020; Zimmer, Fröhling and

Schultmann, 2016). For instance, Amindoust et al. (2012) used the rights of employees, rights of stakeholders, work safety, and labor health as environmental criteria to select green suppliers; Goren (2018) included occupational health and safety among environmental criteria; Bai et al. (2019) used those employed by Amindoust et al. (2012) plus community influence, contractual stakeholder's influence, occupational health education, training, and safety management system. As opposed to the previous authors, Hatami-Marbini et al. (2017) employed social criteria factors such as discrimination exposure risks, child labor practice risks, and corruption exposure. Besides those social criteria, some authors used ethical factors such as ethical behavior of suppliers' top management, incentives, implementation of a code of conduct, and obedience to authority (Goebel et al., 2012); formalization of ethical culture (Reuter, Goebel and Foerstl, 2012) or respect of human rights, underage labor, long working hours, feminist labor issue and organizational, legal responsibilities (Kumar et al., 2014). Remembering that these social or ethical factors could be used solely as the driver of green selection supplier criteria (Goebel et al., 2012; Reuter, Goebel and Foerstl, 2012) or combined them with other environmental criteria (Amindoust et al., 2012).

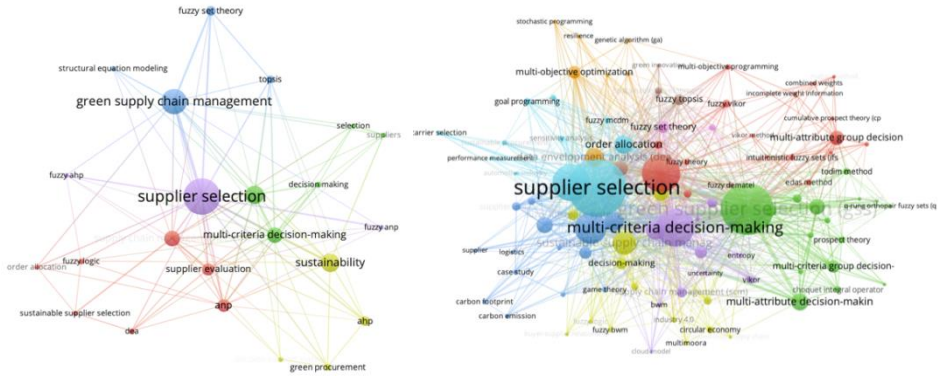
Concerning the evolution of research on green supplier selection, we did not observe the pattern suggested by Genovese et al. (2013), where publications that focus on the theoretical framework are narrower in their scope of supplier selection criteria, which means that they focus on environmental ones, while synthetic models combine traditional and environmental criteria. For instance, dos Santos, Godoy and Campos (2019) and Zhang and Xu (2015) used only green criteria in their modeling to evaluate green supplier performance. We observed that combining green supplier selection criteria with conventional ones depends on the researcher's approach: narrower vs wider and strategical vs operational.

4.2 Bibliometric analysis

For the bibliometric analysis, we separated our sample into two periods to evaluate possible changes in intellectual structure (2010-2015; 2016-2022). We started by analyzing the keywords, citation network, bibliographic coupling, and co-citation networks. It is worthwhile to remember that the citation network analyzes how influential each article of our sample papers is and how these influential articles are related. The bibliographic coupling analyzes the relatedness of the sample articles based on how many references they share. The co-citation network analyzes the relatedness of the cited references based on how often they are cited together.

4.2.1 Keyword analysis

From the keyword analysis, we could observe a proliferation of keywords from the first period to the second. This phenomenon is expected since publications increase consistently from 2010 to 2022. In both periods, the keyword is consistent with our search. We noted that the central theme is supplier selection. Still, in the first period, it is related to green supply chain management, while in the second, the term green supplier selection (GSS) appeared significantly related to supplier selection. In addition, we noticed that the supplier selection process is treated as a multicriteria decision-making problem in both periods, but with many more alternative methods associated.



2010-2015 2016-2022

Figure 2: Keyword analysis

4.2.2 Citation analysis

The five most cited papers during the period 2010-2015 are: Govindan, Jafarian and Nourbakhsh (2015), Govindan, Khodaverdi and Jafarian (2013), Buyukozkan and Çifçi (2012), Bai and Sarkis (2010), and Kannan et al. (2013), each one with more than 500 citations (see appendix). However, from Figure 3, we can see that among these top-cited articles, Kuo, Wang and Tien (2010) played a central role since our top-cited papers cited it. Our top-cited papers cited Kuo, Wang and Tien (2010), because this article justifies the importance of sustainable supplier selection in green supplier management. This paper is also essential due to the integration of several methods for supplier selection (Artificial Neural Network, DEA, MADA, and ANP). In addition, Kuo, Wang and Tien (2010) bring an extensive list of supplier selection criteria that include traditional, environmental, and, especially, social ones, as social criteria are not considered often in the studies at that moment (Amindoust et al., 2012).

In the same fashion as Fahimnia, Sarkis and Davarzani (2015), who compiled an extensive literature review about green supply chain management through a bibliometric study and pointed out a possible green supply chain management typology, research methodologies, and critical research areas, Govindan et al. (2015) is also highly influential in this area of research, because it is an extensive literature review paper. However, Govindan, Jafarian and Nourbakhsh (2015) discussed the Multi-criteria decision-making in green supplier selection based on the methodology (individual vs. integrated), and they mapped the selection criteria.

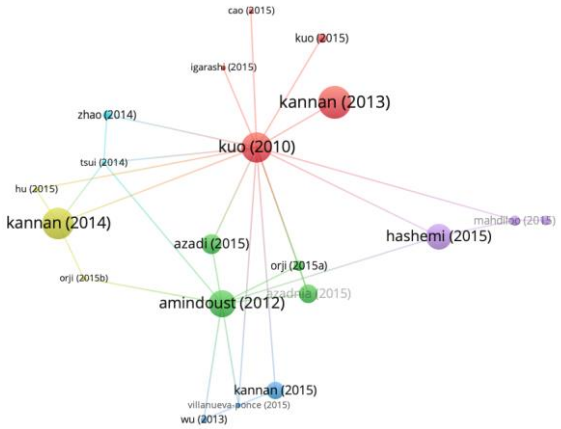


Figure 3: Citation network (2010-2015)

The top five cited papers in the period 2016-2021 are Luthra et al. (2017), Qin, Liu and Pedrycz (2017), Awasthi, Govindan and Gold (2018), Stević et al. (2020) and Banaeian et al. (2018). Since the second period is recent, these papers have at least 230 citations. From Figure 4, we observe that Luthra et al. (2017), Qin, Liu and Pedrycz (2017), and Stević et al. (2020) assumed the central roles in our citation network. Our sample often cites Luthra et al. (2017), because they applied − in a very instructive way − the integration of two commonly used methods in multi-criteria decision-making, AHP, and VIKOR, to the green supplier selection in the Indian automobile industry; in addition, they included social criteria in their supplier selection, which until then occurred very rarely. To eliminate the limitations of TOPSIS, Qin, Liu and Pedrycz (2017) extended the TODIM (Interactive and Multicriteria Decision-Making) into the fuzzy environment. Similarly, Stević et al. (2020) discussed how each of the previous papers contributed to the field by extending the commonly used methods; they also proposed a new method called Measurement of Alternatives and Ranking according to COmpromise Solution (MARCOS).

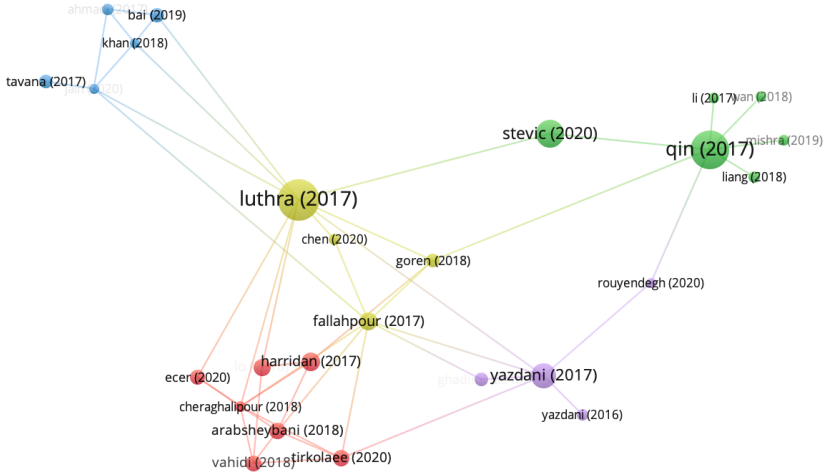


Figure 4: Citation network (2016-2021)

4.2.3 Bibliographic coupling

To complement the citation analysis, we also conducted a bibliographic coupling analysis, which assessed the relatedness of the papers based on the number of shared references. The rationale behind this analysis is that the more references two publications share, the more similar they are.

From the bibliographic coupling analysis, we can note that in our sample of papers from 2010-2015 (Figure 5), there are four clusters of papers. The first small group is composed of empirically-oriented papers, related mainly to sustainable supply chain and supply chain management (Harms, Hansen and Schaltegger, 2013; Paulraj, 2011). The second group focused on commonly used methods in MCDM (AHP, ANP, DEMATEL, etc.) and their extensions applied to the sustainable supplier selection (Bai and Sarkis, 2010; Dai and Blackhurst, 2012; Govindan et al., 2015; Govindan, Jafarian and Nourbakhsh, 2015; Hsu et al., 2013). The third group is related mainly to applying fuzzy concepts and their integration/extension to those commonly used MCDM methods (Büyüközkan, 2012; Büyüközkan and Çifçi, 2011; Govindan, Khodaverdi and Jafarian, 2013; Tseng and Chiu, 2013). The fourth group is related to the sustainable supplier selection (Ehrgott et al., 2011; Goebel et al., 2012) by applying diverse MCDM methods and their extensions, such as ANP, fuzzy AHP, or integration of artificial neural networks to the MADA (Freeman and Chen, 2015; Hashemi, Karimi and Tavana, 2015; Kuo, Wang and Tien, 2010; Wu, Hsieh and Chang, 2013).

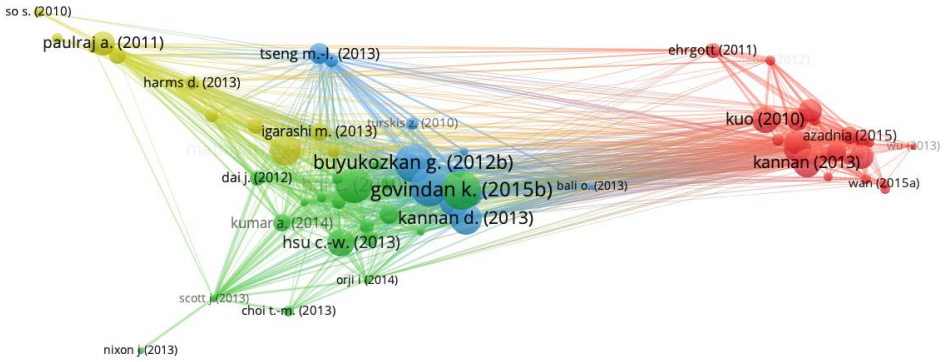


Figure 5: Analysis of bibliographic coupling (2010-2015)

Concerning the bibliographic coupling of the second period, Figure 6 also demonstrated that publications of 2016-2021 could be grouped into four major groups. The first group focuses mainly on the development of integration of common MCDM methods such as AHP and VIKOR, the extension of TODIM, or the proposition of MARCOS (Luthra et al., 2017; Qin, Liu and Pedrycz, 2017; Stević et al., 2020). The second cluster focuses on the Pythagorean fuzzy set and its extensions (Tang and Wei, 2018b; Wan, Jin and Dong, 2018; Wei et al., 2018). Similarly to the first period, there is a group of papers focusing on applying fuzzy concepts to MCDM methods for the green supplier selection (Awasthi and Kannan, 2016; Guo et al., 2017; Memari et al., 2019; Wu et al., 2019) and another group that employs diverse methods (analytical and empirical) to investigate green supplier selection (Huang et al., 2016; Jabbarzadeh, Fahimnia and Sabouhi, 2018; Kumar, 2019; Su et al., 2016).

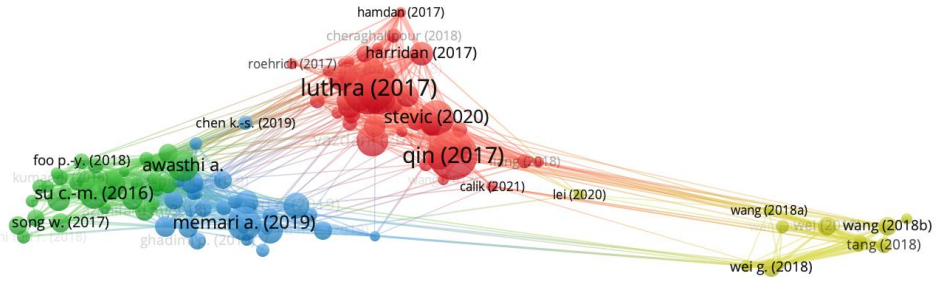


Figure 6: Analysis of bibliographic coupling (2016-2021)

4.2.4 Co-citation analysis

From the co-citation analysis, we could observe that for the period 2010-2015 (Figure 6), the intellectual structure that supported our sample papers was composed mainly of three groups of references. The first group is related to the concept of sustainable supply chain management, its definition, and how it relates to the organizational performance (Rao, 2002; Rao and Holt, 2005; Sarkis, 2003; Srivastava, 2007). The second theme of the intellectual structure is related to supplier selection, and includes: selection criteria (Dickson, 1966; Weber, Current and Benton, 1991), integration of environmental criteria in the supplier selection (Humphreys, Wong and Chan, 2003), and definition of green supplier selection (Noci, 1997). The third theme of the intellectual structure is associated with instruction-oriented references that apply commonly used MCDM methods in green supplier selection, such as the employment of ANP (Hsu and Hu, 2009), AHP (Handfield et al., 2002), concepts of fuzzy set theory (Zadeh, 1965; Zimmermann, 2011) and its application in green supplier selection, including fuzzy AHP (Lee et al., 2009), Fuzzy TOPSIS (Govindan, Khodaverdi and Jafarian, 2013), or integration of several fuzzy methods (Büyüközkan and Çifçi, 2012).

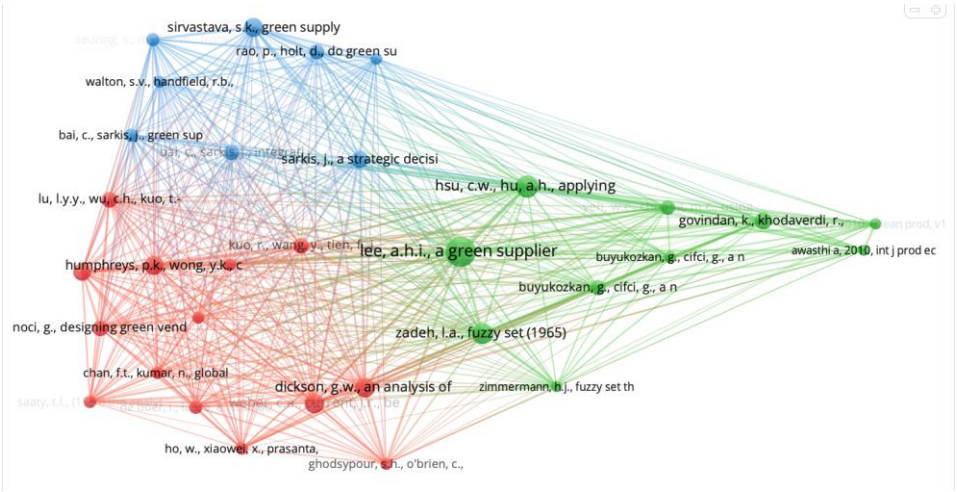


Figure 7: Co-citation network of the bibliographic references of publications in 2010-2015

From the analysis of the co-citation network of the sample papers from 2016-2022 (Figure 7), our first observation is an increase in the number of nodes in this network, which suggests an increase in the number of references co-cited. This augmentation is expected, since the number of publications in 2016-2022 increased. By comparing the intellectual structure of the co-citation of both periods,

we could note that the themes found in the first period occur also in the second one. In green supplier selection studies it is essential to define its relationship to green supply chain management; therefore, we noticed a cluster of papers dedicated to supporting this topic (Carter and Rogers, 2008; Sarkis, 2003; Seuring and Müller, 2008; Srivastava, 2007). Another repeated cluster is the one that explained the methodology fundamentals, such as AHP, ANP, and Fuzzy set theory (Atanassov, 1994; Saaty, 1980; Yager, 2013; Zadeh, 1965). The papers in this cluster are highly co-cited with references that employed MCDM methods to study green supplier selection.

By contrast to the previous period, this time the cluster about supplier selection and the one about the application of MCDM methods in supplier selection are the same. This tendency suggests that MCDM and supplier selection are highly related, and it became the central reference for studies in this field. (Büyüközkan and Çifçi, 2012; Dickson, 1966; Govindan, Khodaverdi and Jafarian, 2013; Govindan, Jafarian and Nourbakhsh, 2015; Kuo, Wang and Tien, 2010; Lee et al., 2009; Weber, Current and Benton, 1991). In addition to this central cluster, the last cluster of intellectual structure that we identified is related mainly to the integration of multiple MCDM methods in the green supplier selection (Amindoust et al., 2012; Kuo, Wang and Tien, 2010; Luthra et al., 2017; Memari et al., 2019; Qin, Liu and Pedrycz, 2017).

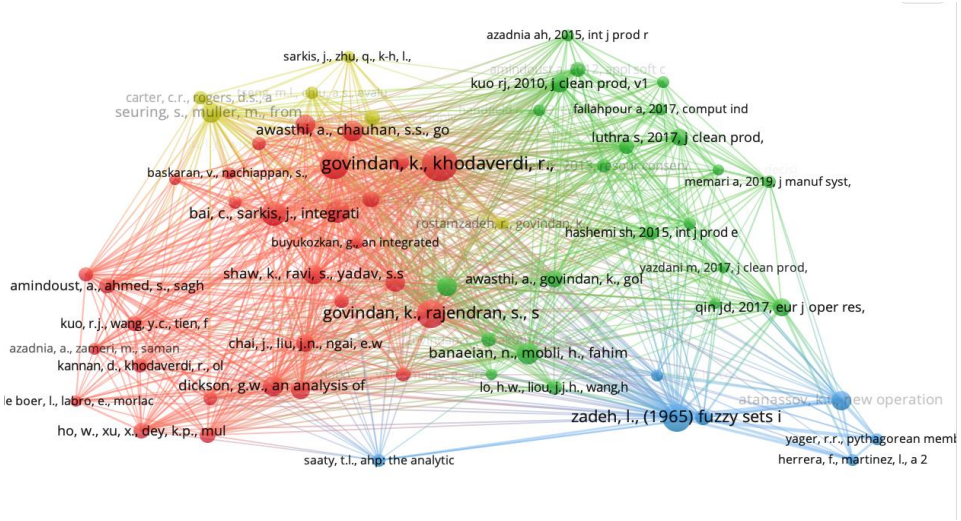


Figure 8: Co-citation network of the bibliographic references of publications in 2016-2021

5 Final considerations

Using a sample of 942 publications, our study analyzed structurally and bibliometrically the intellectual patterns of publications in green supplier selection. We compared our results to the existing structured literature review papers (Fahimnia, Sarkis and Davarzani, 2015; Genovese et al., 2013; Igarashi, de Boer and Fet, 2013; Schramm, Cabral and Schramm, 2020; Zimmer, Fröhling and Schultmann, 2016) and updated the results with papers published between 2010 and 2022. Practically, our paper serves as a picture of the current state of the field and can serve as a map for other researchers to start their investigations in green supplier selection.

Our results suggest that research in green supplier selection maintained the same pattern over the last decade (Genovese et al., 2013; Igarashi, de Boer and Fet, 2013), when the majority of papers used mathematical and analytical models, such as AHP, ANP, DEA, TOPIS, VIKOR, Linear programming, Fuzzy theory, Grey system theory, etc. (Zimmer, Fröhling and Schultmann, 2016). Our results also agreed with earlier studies, suggesting that combining those methods would increase the models' robustness and consistency or their application in the fuzzy environment (Qin, Liu and Pedrycz, 2017). Regarding the area and journal of publications, we found no discrepancies with the early studies, where the *Journal of Cleaner Production* is still the leading publisher in this field.

From the bibliographic coupling, we observed that our sample, in both periods, can be grouped into four main streams. Likewise, our co-citation analysis suggests that the intellectual structures in both periods demonstrated similar patterns. Both periods have a group of references that serve as methodological foundations (Saaty, 1980; Zadeh, 1965; Zimmermann, 2011), a group for green supply chain management concepts (Carter and Rogers, 2008; Sarkis, 2003; Seuring and Müller, 2008; Srivastava, 2007), a group for supplier selection criteria and integration of environmental factors in supplier selection (Dickson, 1966; Humphreys, Wong and Chan, 2003; Noci, 1997; Weber, Current and Benton, 1991) and a group of application of MCDM methods and its developments (Amindoust et al., 2012; Govindan, Khodaverdi and Jafarian, 2013; Hsu and Hu, 2009; Humphreys, Wong and Chan, 2003; Kuo, Wang and Tien, 2010; Lee et al., 2009; Luthra et al., 2017; Memari et al., 2019; Qin, Liu and Pedrycz, 2017; Stević et al., 2020).

5.1 Limitations and future studies

As with any structured literature review and bibliometric analysis, the first limitation is related to the choice of the sample of publications. We worked with ISI Web of Science and SCOPUS to make our study more comprehensive. The advantage of bibliometric analysis is its ability to analyze a significant number of papers. However, negative citations, where the citing article criticizes the cited publication, as well as some harmful citation practices, such as self-citation and self-team citation, can eventually alter the results of the metrics or the qualitative interpretation of the results. Nevertheless, bibliometric analysis is still a very reliable and objective method for analyzing the literature (Lim et al., 2009; Okubo, 1997; Zupic and Čater, 2015).

Our sample did not cover publications before 2010, hence we are not sure what the influence of those papers was in our bibliometric analysis. Therefore, we suggest that future studies create a sample of papers from 1999-2020, similarly to Schramm, Cabral and Schramm (2020), and investigate it through bibliometric metrics.

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