*sustainability*

MDPI

*Review*

# The Collaborative Networks and Thematic Trends of Research on Purchasing and Supply Management for Environmental Sustainability: A Bibliometric Review

**Wenwen Zhu and Zhiqiang Wang ***

School of Business Administration, South China University of Technology, Guangzhou 510640, China; 201410105495@scut.edu.cn

* Correspondence: bmzqwang@scut.edu.cn; Tel.: +86-020-8711-2682

Received: 4 April 2018; Accepted: 8 May 2018; Published: 10 May 2018


**Abstract:** Improving environmental sustainability through purchasing and supply management (PSM) has gained increasing attention from both industry and academia. However, few attempts have been made to summarize the research development of this field. This study aims to identify the major author collaborative networks and thematic trends of this field by conducting a bibliometric review based on 371 peer-reviewed articles published between 1998 and 2017 using CiteSpace. The results show that this field is an emergent and fast-growing field which has been recognized by multiple disciplines. In terms of authors, the top ten influential authors represented by Sarkis, J., Zhu, Q.H., Vachon, S., and Klassen, R.D. were identified. Further, the four largest collaborative networks with varying research topics such as green supplier selection/evaluation and sustainable sub-supplier management were found. As for the research themes, the six largest research themes were abstracted: green supplier assessment, sustainable supplier/supply chain management, green supplier management, green supplier selection, environmental purchasing, and green supply chain management (GSCM). Further, the research thread over time was summarized as four stages: infancy stage, grow-up stage, surging stage, and deep-going stage. Finally, future research directions were given. To the best of the authors' knowledge, this is the first systematic review of this field using bibliometric analysis, comprehensively acknowledging the current research status of this field and that of the future.

**Keywords:** purchasing and supply management; environmental sustainability; bibliometric analysis; collaborative network; research themes identification; research themes evolution; CiteSpace

## 1. Introduction

A high level of environmental performance achieved by one firm can be jeopardized by its suppliers' poor environmental management [1]. This situation is aggravated as purchased materials and components account for a growing share of a company's entire expenditures [2,3]. For example, a well-known German auto-parts manufacturer, Schaeffler, indicated that the continuous production of more than 200 types of cars from 49 assembly plants would be affected due to the fact that its only needle supplier was required to shut down for violating China's environmental regulations. In such a case, the management of purchasing and supply becomes crucial for a firm to mitigate risks and achieve environmental sustainability across the whole supply chain.

Both industry and academia have made a great effort to explore how to improve environmental performance through purchasing and supply management. For industry, companies have increasingly adopted various methods to improve suppliers' environmental performance. For example, Adidas works closely with an NGO to monitor their suppliers' environmental performance in China

and has committed itself to delivering full transparency of their supplier' hazardous chemical use, emissions, and wastewater discharge [4]. For academia, researchers have discussed various approaches ranging from supplier codes of conduct [5], green supplier selection [6–8], supplier monitoring, and supplier collaboration [9], to sustainable/environmental supplier development [10,11] and so on. Further, the drivers/enablers and barriers to implement purchasing and supply management practices such as sustainable supplier development [12] and sub-supplier management [13–15] to improve environmental sustainability have been explored.

However, although many studies have been conducted, limited attention has been paid to outlining the development trends of research in this field. A literature review was considered as the primary method of synthesizing previous research [16], but the existing literature reviews (LRs) on this topic have a few limitations. First, most LRs focus on a broader supply chain management (SCM) area which may fail to capture the evolution of a specific part, such as PSM [17]. Second, among the limited LRs on PSM, only a small proportion only focused on environmental sustainability and tended to cover all three dimensions of sustainability, making the research state for environmental sustainability vague. Third, most existing LRs adopt qualitative methods which usually deal with a limited number of articles and are at risk of being unreliable due to subjective judgement and misinterpretation of researchers. Therefore, further efforts are needed to explore the development trends of this field.

Unlike existing reviews, this study conducted a bibliometric review and obtained a snapshot of this emerging and fast-growing field between 1998 and 2017 (by 20 October). Specifically, three research questions will be answered. First, who are the most influential researchers in this field and are there a few major collaborative networks? Second, what are the main research themes in this field? Third, how have those research themes evolved over time? Our findings could assist researchers around the world in better understanding the current state of research in this field, inspiring further research in the future. The remainder of the paper is organized as follows. Section 2 introduces the existing LRs on this topic, followed by Section 3, which presents the research methodology. Section 4 illustrates the results, using descriptive analysis, author analysis, and research themes analysis which includes research themes identification and research themes evolution analysis. Finally, Section 5 concludes and discusses the main findings, contributions, and future research directions, as well as limitations.

## 2. Previous Literature Reviews (LRs) in This Field

Based on the research domain, existing LRs on purchasing and supply management for environmental sustainability can be divided into two groups: SCM-focused and PSM-focused. The distinction between SCM and PSM can be seen through their definitions. SCM has been defined as "a process-oriented approach to managing product, information, and funds flows across the overall supply network, from the initial suppliers to the final end consumers" [18], whereas PSM refers to a "strategic approach to planning for and acquiring the organisation's current and future needs through effectively managing the supply base" [19]. It is clear that SCM is a wider concept which covers the activities of PSM. The current LRs in this field show a trend of a broader and combined range. Out of the 12 LRs listed in Table A1 (see Appendix A), there are eight articles focusing on SCM. However, LRs that assume a broad scope may fail to capture the evolution of a specific part of the field [17]. The intent of SCM-focused reviews in early years was mainly to describe the state of the art in this field, such as the topics and theories, and to identify the trends and gaps for future studies [20–24]. Further, more specific topics such as green supply chain integration [25], performance indicators of green SCM [26], and supply chain collaboration for sustainability [27] were reviewed in recent years. All these efforts allow researchers to have a comprehensive understanding of the research state of sustainable/green SCM. However, the knowledge for PSM is very limited. Tate, et al. [28] initially indicated that the development of environmental purchasing practice and research is in its early stages through a literature review and CSR report analysis. Then, the definitions and measures [29] and governance mechanisms [30] of sustainable PSM were summarized. Appolloni, et al. [31] further summarized the themes of green procurement through reviewing publications between 1996 and 2013,

but indicated that the practices of green procurement received less attention compared to drivers and barriers. However, no critical and comprehensive reviews on PSM have been found in the past three years, despite publications on this topic experiencing a sharp increase. Based on the above analysis, it is highly necessary to conduct a comprehensive literature review to capture the research development and evolution of this field.

Besides, as Table A1 (see Appendix A) shows, many LRs cover all aspects of sustainability, which includes environmental, economic, and social aspects. Among the four LRs on PSM, only two narrowed the scope to environmental sustainability. However, whether environmental sustainability should be integrated with social aspects should be explored further [31]. From the methodology perspective, most current LRs adopted qualitative methods such as systematic LR, consulting industrial experts, and CSR report analysis. However, a common problem of such qualitative reviews is that most of their findings rely on subjective judgement, which can be unreliable due to human misinterpretation and coding fatigue [32]. What is more, it is usually difficult for researchers to handle large amounts of articles. For instance, the number of articles that most existing LRs have analyzed is about one hundred or so. Furthermore, a qualitative method can identify the practices, drivers, and outcomes of PSM practices for environmental sustainability, but usually cannot provide the evolution of each topic over time and the complex collaborative networks between researchers. It is noteworthy that the bibliometric analysis method was adopted recently [24,27], providing a novel perspective to review articles in this field. However, both papers focus on the whole SCM area, rather than PSM specifically.

## 3. Research Methodology

### *3.1. Bibliometric Analysis Method*

The purpose of a literature review is to map, consolidate, and evaluate the intellectual territory of a domain area, and then identify the knowledge gaps to be filled in further research [33]. A sound application of methodological choices and rigor is required to conduct a literature review [34]. Some researchers have adopted the content analysis method [21,25] to analyze the research development of the SCM area. However, a common problem of such studies is that most of their outputs rely on subjective judgement, which may lead to unreliable results due to misinterpretation. What is more, it is very difficult and time consuming for researchers to distinguish most related papers from the vast available resources. In this paper, the bibliometric analysis method was adopted due to three reasons. First, compared to the more frequently used content analysis method, bibliometric analysis can handle large amounts of articles easier, faster, and more precisely, by taking advantage of computer algorithms. Second, bibliometric analysis allows us to capture more comprehensive information. Not only the general metadata such as authors, year of publication, and journals are available, but also the largest collaborative networks can be identified through co-authorship analysis. Additionally, the research themes and their evolution over time can also be analyzed by combining the keywords, title, and abstracts of publications, as well as the accompanying references which constitute the knowledge bases of this field. The information allows us to analyze the study of this field more comprehensively. Third, the interactive visualization interface of bibliometric tools such as CiteSpace make it easier for readers to understand the development of a research domain. Finally, the bibliometric analysis is well rooted in grounded and well-established theories such as impact theory and structure hole theory [35–37].

In this study, three bibliometric analyses were conducted. The first of these was co-authorship analysis. It can not only help us find the most influential contributors in this field, but also the major collaborative networks, as well as their research topics development. Second, we completed hybrid analysis of reference co-citation and term co-occurrence. This approach allows us to cluster studies in this field into a few categories in terms of research themes. Third, we analyzed the thematic trends over time based on the above cluster analysis. Among various bibliometric analysis tools, CiteSpace [35,38] was adopted due to its convenience to pre-process data (e.g., remove duplication and combine two

words in different formats), its excellent visualizing function to map references and authors, and its widespread applications by previous studies [39,40].

### 3.2. Data Collection

Bibliometric analyses are often based on three information sources: Web of Science, Scopus, and Google Scholar [41]. In this study, the database of Web of Science (WOS) was chosen as the source of material due to its compatibility with the bibliometric tool which was adopted in this study, CiteSpace. Though WOS may cover limited numbers of journals compared to Scopus, for example, it is very selective and covers peer-reviewed journals with high impact factors. Furthermore, previous studies have found a notable match between the results from WOS and Scopus [42].

The keywords used for data collection are listed in Table 1. Each search made use of the mixture of these two types of words: supply-related words such as supplier and supply chain, and green-related words such as green and environment. After integrating the related keywords used in the previous literature review on green/environmental/sustainable purchasing and supply or supply chain management [28–31], four keywords on supply were identified, namely supplier, supply, procurement, and purchasing. Four groups of keywords representing green/environmental issues were selected, namely green, environment/environmental, sustainable/sustainability & green, and sustainable/sustainability & environment/environmental. Papers on sustainability which cover social, economic, and environmental aspects may not highlight environmental/green words in the title. However, the environmental/green words are more likely to appear in broader terms (which covers title, abstracts, author keywords, and keywords plus) if the article discusses an environmental issue as a separate part. To narrow down our scope to green/environmental, but also include the papers on sustainable/sustainability that highlight green issues, we set a specific search strategy. If sustainable/sustainability appeared in the title of a paper, but the green/environmental word also appeared in broader terms, then the paper was selected as a target sample.

**Table 1.** Keywords for collecting data.

| | Title | Title | Topic |
|---|---|---|---|
| 1 | supplier | Green | |
| 2 | | environment * | |
| 3 | | sustainab * | green |
| 4 | | sustainab * | environment * |
| 5 | supply | green | |
| 6 | | environment * | |
| 7 | | sustainab * | green |
| 8 | | sustainab * | environment * |
| 9 | procurement | green | |
| 10 | | environment * | |
| 11 | | sustainab * | green |
| 12 | | sustainab * | environment * |
| 13 | purchasing | green | |
| 14 | | environment * | |
| 15 | | sustainab * | green |
| 16 | | sustainab * | environment * |

Note: "*" was used at the end of some keywords to expand the range of some possible studies (e.g., "sustainab *" can be sustainable or sustainability).

The data was obtained on 20 October, 2017 from Web of Science's core collection. The time span was set as "all years" to make sure that all the articles related to this topic could be searched for, irrespective of whether they were published long before the present study or recently (near data collection time), like the method adopted by previous similar studies [40,43,44]. The timeliness of this literature review can be guaranteed by considering as many latest publications as possible. Only articles in English were left. Furthermore, conference papers, editorial materials, letters, notes,

book chapters, and book reviews were excluded, since we wanted to investigate rigorous academic research from validated sources. This approach is common in similar studies [17]. Initially, 1855 papers (after remove duplications) were obtained. Although we tried to find the most related papers by using the above searching strategies, there were still some unrelated papers as different authors have their own styles for highlighting their articles. To exclude irrelevant articles, we conducted a content analysis of titles, abstracts of the whole 1855 papers, and sometimes even the full content of some to judge whether each paper concentrates on "Purchasing and supply management for environmental sustainability". Numerous papers were excluded for four reasons. First, it was not related to environmental sustainability. For example, "under uncertain environment" and "competitive environment" do not mean environmentally friendly. Secondly, our research unit is business/firm, rather than consumers. The articles discussing consumer purchase intentions were excluded. Thirdly, we do not intend to discuss public/government purchasing/procurement, thus only articles talking about private purchasing were left. Finally, we only focus on strategic and organizational issues in this study, so some papers relating to specific technical tools such as life-cycle analysis, inventory, and reverse-logistics were excluded. Finally, only 371 papers were left for further analysis.

The reliability and objectivity of article selection or the deletion process was assured by involving two researchers in this step, as suggested by [33]. The two researchers independently marked all 1855 articles as kept or deleted. Since the two researchers have been cooperating for years, the intra-rater reliability was quite high. Finally, 1785 articles were marked in the same way, with a reliability of nearly 96.2%. Then, the two researchers discussed the articles for which they had opposite opinions and finally obtained consistent results.

## 4. Results and Discussion

### *4.1. Descriptive Analysis*

#### 4.1.1. Publication Distribution across Time

Figure 1 shows the annual publications from 1998 to 2017 (by 20 October). It is clear that there are limited publications in the first decade (1998–2007). Subsequently, the number of articles began to increase steadily but slowly during the period of 2008–2011. The publications saw a surge in 2012, followed by a remarkable increase in the most recent five years. The publications in this period accounted for nearly 84% of total articles. More surprisingly, the publications in the most recent two years, namely 2016–2017 (by 20 October), accounted for nearly half of all the 371 papers. This means that more and more scholars recognized the importance of this research field and also indicates a continuous growth trend of publications. In summary, the research on PSM for environmental sustainability is an emerging and increasingly popular research topic.

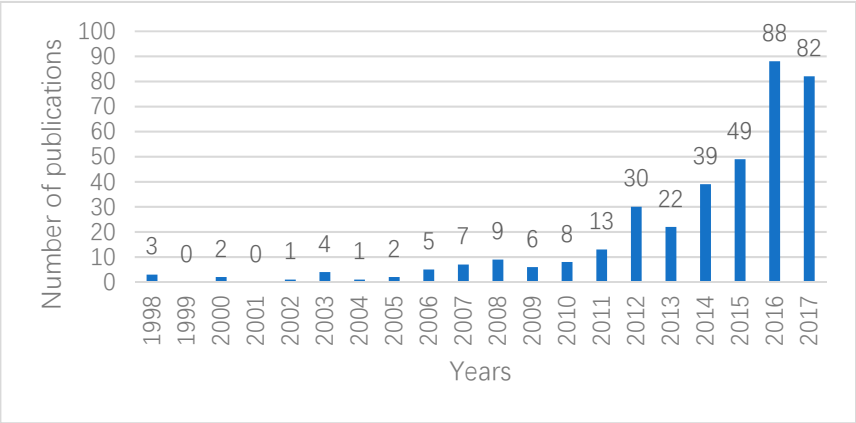



**Figure 1.** Publication distribution over time (the number of publications in 2017 is by 20 October).

#### 4.1.2. Publication Distribution across Journals

Table 2 shows the publication distribution across the top 20 journals that published the most on PSM for environmental sustainability. It should be noted that the top 20 journals published 259 out of 371 articles, accounting for nearly 70% of all the searched articles. This topic has attracted the most attention of scholars from the environmental science area and operations research/management science area. Specifically, the Journal of Cleaner Production, with 70 articles, comes first. Together with other journals in the environmental science area such as Sustainability, Business Strategy and the Environment, and Resources Conservation and Recycling, journals in this area published 113 articles, accounting for more than 30% of all searched articles. It is also noteworthy that journals in operations research/management science also contributed significantly. For example, the International Journal of Production Economics, with 27 articles, comes second. Together with other prominent journals in this area such as the International Journal of Production Research and Journal of Purchasing and Supply Management, journals in this area all together published 121 articles, contributing nearly 33% of all 371 articles. In addition, the research topic has also been accepted by journals in the industrial/engineering area (e.g., Computers & Industrial Engineering), marketing area (e.g., Industrial Marketing Management), and ethics/business area (e.g., Journal of Business Ethics). In summary, this research topic is multi-disciplinary and attractive to scholars in many research areas.

**Table 2.** Publication distribution across top 20 journals.

| Journal (s) | Publications |
|---|---|
| Journal of cleaner production (JCP) | 70 |
| International journal of production economics (IJPE) | 27 |
| Sustainability | 24 |
| International journal of production research (IJPR) | 22 |
| Journal of purchasing and supply management (JPSM) | 15 |
| Supply chain management-an international journal (SCM-IJ) | 15 |
| International journal of operations & production management (IJOPM) | 10 |
| Business strategy and the environment (BSE) | 9 |
| Journal of supply chain management (JSCM) | 9 |
| Transportation research part e-logistics and transportation review (TRE) | 8 |
| Computers & industrial engineering (CIE) | 8 |
| Production planning & control (PPC) | 7 |
| Resources conservation and recycling (RCR) | 5 |
| Corporate social responsibility and environmental management (CSREM) | 5 |
| Journal of business ethics (JBE) | 5 |
| Production and operations management (POM) | 4 |
| European journal of operational research (EJOR) | 4 |
| Expert systems with applications (ESA) | 4 |
| Industrial management & data systems (IMDS) | 4 |
| Industrial marketing management (IMM) | 4 |

#### 4.1.3. Research Topics Distribution across Top 10 Journals

Table 3 shows the distribution of research topics across the top ten journals in terms of the number of publications. It is an arbitrary classification of research topics which only provides a visual observation about the distribution of topics. SM represents the general concept of environmental or sustainable supplier management, which may include supplier relationship management, greening supplier approaches, and the combination of supplier selection, evaluation, and development, etc. The SS, SSE, and SD essentially belong to SM, but since some articles only focused on one specific aspect, whilst others did not subdivide topics, they were counted separately. It is clear that GSCM and SSCM received the most attention of nearly all journals. These two topics usually cover a broader range of practices which include not only upstream, but also downstream, supply chains. Most articles explored the drivers, barriers, and performance outcomes of GSCM or SSCM. SS, SE, and SD, as smaller

branches, have been discussed more by articles in JCP, IJPE, and Sustainability. The topics of IJPR were distributed relatively evenly.

**Table 3.** Research topic distribution across top 10 journals.

| Journals | SM | GP/SP | GSCM | SSCM | SS | SE | SD | Others |
|---|---|---|---|---|---|---|---|---|
| JCP | 7 | 7 | 21 | 18 | 11 | 5 | 2 | 2 |
| IJPE | 2 | 2 | 10 | 3 | 6 | 2 | 1 | 2 |
| Sustainability | 0 | 1 | 5 | 6 | 9 | 2 | 1 | 2 |
| IJPR | 2 | 2 | 8 | 3 | 3 | 4 | 3 | 0 |
| JPSM | 1 | 3 | 4 | 5 | 1 | 0 | 1 | 0 |
| SCM-IJ | 0 | 1 | 9 | 1 | 1 | 1 | 0 | 2 |
| IJOPM | 1 | 0 | 6 | 2 | 1 | 0 | 0 | 0 |
| BSE | 2 | 0 | 5 | 0 | 0 | 1 | 1 | 0 |
| JSCM | 2 | 1 | 3 | 2 | 0 | 0 | 0 | 1 |
| TRE | 1 | 1 | 6 | 0 | 0 | 0 | 0 | 0 |

Note: The number represents how many times a certain topic has been discussed by articles published in one journal. SM: supplier management (environmental, sustainable); GP/SP: green/sustainable purchasing/procurement; GSCM: green supply chain management; SSCM: sustainable supply chain management; SS: green or sustainable supplier selection; SE: green or sustainable supplier evaluation; SD: green/sustainable supplier development.

#### 4.1.4. Research Methodologies Distribution

Table 4 shows the methodology distribution across the 371 selected articles. It is clear that survey and math are the most frequently adopted methods, accounting for more than 70% of the total, followed by case study and theoretical and conceptual papers. The articles using a survey method usually design a questionnaire based on the proposed research framework and then collect data to confirm or validate research hypotheses. The math method includes both optimal programmings and specific evaluating methods. In addition, 57 articles adopted case studies, which is suitable for exploring newly emergent topics such as PSM for environemntal sustainability. The theoretical and conceptual method usually aims to develop a conceptual framework and propositions for future empirical tests. Besides, 25 articles adopted mixed methods such as "survey + expert interview", "literature review + report analysis", and "case + survey".

**Table 4.** Research methodology distribution.

| Research Methodology | Number | Percent of Total |
|---|---|---|
| Survey | 139 | 37.47% |
| Case study | 57 | 15.36% |
| Theoretical and conceptual paper | 22 | 5.93% |
| Math | 128 | 34.51% |
| Others | 25 | 6.73% |

Note: Math includes model and evaluation.

### *4.2. Author Analysis*

Through the analysis of author information obtained from the database we collected, the leading researchers could be scientifically revealed and identified. Furthermore, the major collaborative networks and the evolution of their research focuses can be identified through co-authorship analysis. Since the name of a single author may have different forms of abbreviations, the data was pre-processed to improve the quality of analysis. For example, Zhu, Q.H. and Zhu, Q. represent the same author, but the articles she has published may be counted separately. Therefore, the two names were combined before they were analyzed further.

#### 4.2.1. Influential Authors

To a certain extent, the devoted efforts of a researcher can be reflected by the researcher's number of publications. Similarly, the extent to which a researcher's publications have been cited by other studies can also represent the influence of a researcher. Further, the ratio of citations/publications shows the average influence or popularity of each article a researcher has published. As Table 5 shows, the top ten authors in terms of the number of publications, the citation frequencies, and citations/publications are listed. In terms of the number of publications, Sarkis, J., who published 25 papers on this topic, comes first, followed by Zhu, Q.H. and Lai, K.H. In addition, Jabbour, A.B.L.D., Govindan, K., Jabbour, C.J.C., and Blome, C. also contributed more than 10 papers. From the perspective of citation frequencies, Sarkis, J., who has been cited 2762 times, is still the most influential researcher, followed by Zhu, Q.H. with 2130 citations. It is noteworthy that although Vachon, S. and Klassen, R.D. published six papers on this topic, they have been cited by numerous studies. It shows that their articles have enduring and significant influences on follow-up research. This can be reflected by the indicator of citations/publications. As can be seen in the third row, Vachon, S. and Klassen, R.D. come first and second, with a ratio of 224.67 and 223.33, respectively. A similar phenomenon also happens to researchers such as Diabat, A. and Buyukozkan, G. On the country, although Jabbour, A.B.L.D. and Jabbour, C.J.C. published more than 10 papers on this topic, they have not been cited that much yet (the ratio is not high enough to be included here). One possible reason for this is that they focus on a specific new topic which has not attracted too much attention. Another possible reason is that their articles were published in recent years and thus have not been cited by too many other articles. Other researchers such as Lai, K.H., Govindan, K., Foerstl, K., and Blome, C. show a balanced level of influence in terms of number of publications, citation frequencies, and ratio citations/publications. To better understand the research focus of different researchers, as well as the collaborations among them, co-authorship analysis was conducted in the next part of the study.

**Table 5.** Top ten contributing authors in terms of publications and citations.

| Authors | Publications | Authors | Citations | Authors | Citations/Publications |
|---|---|---|---|---|---|
| Sarkis, J. | 25 | Sarkis, J. | 2762 | Vachon, S. | 224.67 |
| Zhu, Q.H. | 20 | Zhu, Q.H. | 2130 | Klassen, R.D. | 223.33 |
| Lai, K.H. | 14 | Vachon, S. | 1348 | Sarkis, J. | 110.48 |
| Jabbour, A.B.L.D. | 11 | Klassen, R.D. | 1340 | Zhu, Q.H. | 106.50 |
| Govindan, K. | 11 | Lai, K.H. | 1151 | Diabat, A. | 104.25 |
| Jabbour, C.J.C. | 10 | Govindan, K. | 552 | Lai, K.H. | 82.21 |
| Blome, C. | 10 | Diabat, A. | 417 | Buyukozkan, G. | 78.60 |
| Foerstl, K. | 8 | Buyukozkan, G. | 393 | Govindan, K. | 50.18 |
| Vachon, S. | 6 | Foerstl, K. | 374 | Foerstl, K. | 46.75 |
| Klassen, R.D. | 6 | Blome, C. | 373 | Blome, C. | 37.30 |

#### 4.2.2. Collaboration Network Analysis

The collaboration network was generated as shown in Figure 2. Two important metrics can provide information about the overall structural properties of the networks. The Modularity Q represents the extent to which the components of a system can be reasonably divided into independent blocks or clusters [45]. The silhouette metric evaluates the homogeneity of these clusters [46]. It is recommended that the value of Modularity Q and Mean Silhouette should be greater than 0.5 to ensure the credibility and feasibility of a network [40]. The value of Modularity Q and Mean Silhouette of this co-authorship network are 0.9517 and 0.7882, respectively, which are both above the recommended value, showing the high rationality of this network.

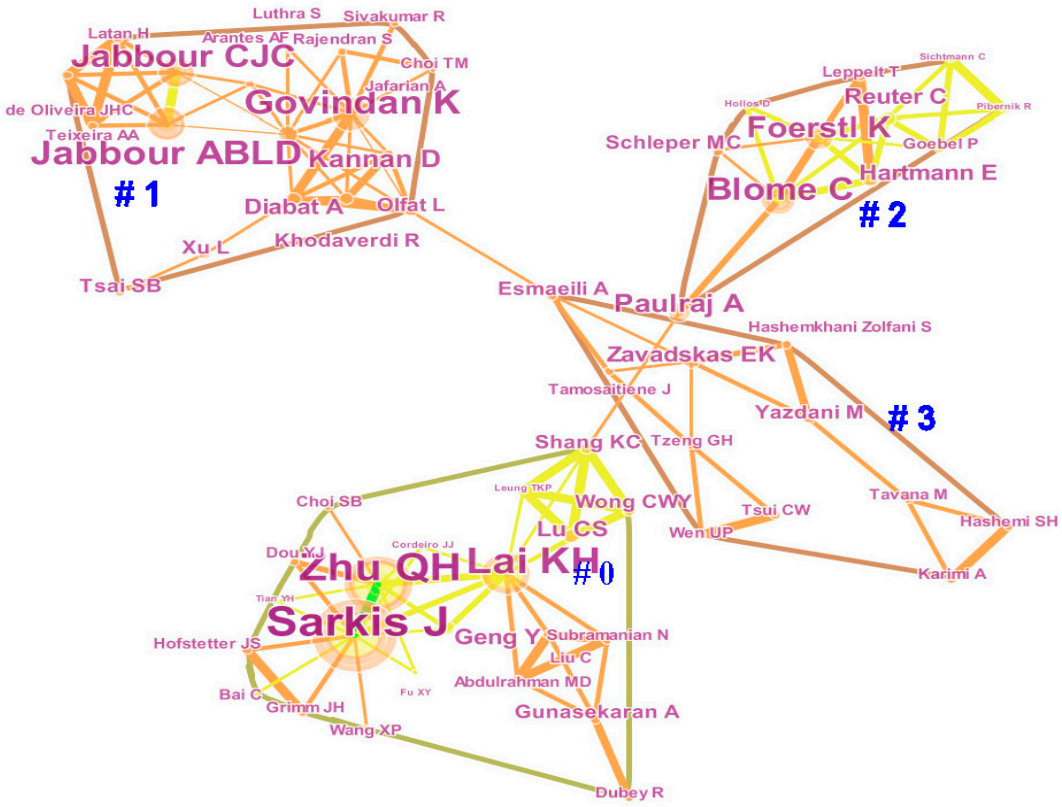



**Figure 2.** Co-authorship clusters.

There are 277 nodes and 354 links in the co-authorship network. Each node represents an author, as shown by the node label, the font size of which reflects the number of publications of this author. The links between each pair of nodes represent partnerships established by the co-authorship of researchers. The thickness of the link reflects levels of the cooperative relationships between two authors and the colors of the link (green, yellow, and orange) represent the first time (from 1998 to 2017) two researchers collaborated with each other. It can be clearly seen that the four largest clusters have been identified (small clusters were filtered). Table A2 (see Appendix A) shows the summary of the four largest co-authorship clusters in terms of cluster size, quality, and representative authors, as well as the main research fronts. The research fronts of each collaborative network were identified by combing quantitative and qualitative approaches. First, the Cite space software provided cluster labels through extracting the top terms from the title or keywords or abstract of articles that cited the publications of this collaborative network most using algorithms such as the Log likelihood ratio (LLR). The labels can capture the research topics of each collaborative network to some extent. Second, the contents of articles published by each collaborative network were analyzed in more detail to confirm and complement the research fronts of each cluster.

The largest cluster (#0) has 22 members and a silhouette value of 0.954. Based on the number of papers they published, Sarkis, J., Zhu, Q.H., and Lai, K.H. contributed the most. The labels were extracted from the abstract of articles published by this collaborative network. It is labelled as "composite sustainable manufacturing practice" by the LLR algorithm and "gscm practices" by the TFIDF algorithm. Then, the contents of publications of this cluster were further analyzed and summarized. There are three main research fronts: Chinese manufacturing industry-based green supply chain management (GSCM), sustainable supply chain management, and sustainable supplier management. First, Sarkis, J., Zhu, Q.H., Lai, K.H., and other researchers have collaborated with each other to publish numerous papers on GSCM in the context of the Chinese manufacturing industry. Specifically, Zhu and Sarkis [47] initially explored the effects of GSCM practices on firm performance.

Then, they further discussed the drivers and outcome performance of different types of GSCM practices such as green purchasing and internal environmental management practices [48–54]. They also found that the level of GSCM practices may vary across different industries and firm sizes [55,56]. The second research topic expanded the scope to sustainability which covers environmental, economic, and social aspects. For example, Lu, C.S. and co-authors explored the effect of SCM on sustainability performance [57,58]. Gunasekaran and co-authors further tested how the external customer pressure, supplier's sustainability, buyer-supplier trust, and internal innovativeness influence sustainability performance. The third topic is sub-supplier management for sustainability. Specifically, Grimm, J.H., Hofstetter, J.S., and co-authors identified the critical factors for sustainable sub-supplier management such as trust, buyer power, involvement of a direct supplier, and geographical cultural distance [14], and further proposed the adoption of different types of sub-supplier management practices such as supplier assessment and collaboration with suppliers that are influenced by different factors [15].

The second largest cluster (#1) has 18 members and a silhouette value of 0.986. Jabbour, A.B.L.D., and Govindan, K. contributed the most, followed by Jabbour, C.J.C., Kannan, D., and Diabat, A. It was labelled as the "best green supplier" by the LLR algorithm and "order" by the TFIDF algorithm. Three research fronts were summarized through further content analysis. The first topic is GSCM. Jabbour, A.B.L.D., Jabbour, C.J.C., and Govindan, K. mainly explored this topic, but from different perspectives compared to the researchers in cluster 0. First, the research samples are usually large Brazilian firms and the case study is the most adopted method. Second, the role of other factors such as human aspects [59,60], environmental management maturity [61,62], quality management [61], and eco-innovation [63] for the adoption of GSCM are discussed. The second topic is green supplier selection. Kannan, D., Govindan, K., and Jabbour, C.J.C. proposed that companies were still using traditional criteria to select suppliers without considering environmental performance and then discussed different methods to select suppliers considering environmental issues, such as the Fuzzy Axiomatic Design approach [64], fuzzy TOPSIS approach [65], and the integration of the fuzzy multi criteria decision making method and multi-objective programming approach [66]. Besides, the methods used to allocate orders to green suppliers [67,68] were also discussed. The third topic is sustainable supplier evaluation. For instance, Govindan, et al. [69] proposed a fuzzy multi criteria approach for measuring the sustainability performance of a supplier.

The third largest cluster (#2) has 11 members and a silhouette value of 0.983. Blome, C. comes first with 10 publications, followed by Foerstl, K., Paulraj, A., Hartmann, E., and Reuter, C. It was labelled as "chemical industry" by the LLR algorithm and "green procurement" by the TFIDF algorithm. They mainly focused on sustainable supplier management and green supplier management. For sustainable supplier management, some researchers initially indicated that mature and sustainable supplier management capabilities are a source of competitive advantage through multiple case studies [70,71]. Further, these researchers explored a specific aspect of this issue, such as sustainable supplier collaboration [72,73], sustainable supplier selection [74,75], and sustainable supplier relationship management [76], and showed that different kinds of sustainable supplier management practices may be driven by different factors, such as stakeholder-related pressures, process-related pressures, and product-related pressures [77]. Besides, Blome, C. and co-authors also discussed the antecedents and outcome performance of green supplier management practices, such as green supplier development and green procurement. They found that different practices were not isolated. For instance, Blome, et al. [78] showed that green procurement positively influences green supplier development, demonstrating that the former is the basis of the latter.

The fourth largest cluster (#3) has 11 members and a silhouette value of 0.973. Zavadskas, E.K. contributed the most with four papers, followed by Esmaeili, A., Yazdani, M., Hashemi, S.H., and Tsui, C.W. It was labelled as "supplier evaluation" by the LLR algorithm and "criteria" by the TFIDF algorithm. Through analyzing the articles that they have published, it can be clearly seen that they focus on the method of green/sustainable supplier selection and evaluation. A few methods were proposed and tested, such as the integration of MCDM and QFD [6,79], the integration of ANP

and QFD [80], the fuzzy Choquet Integral operator [81], a new hybrid COPRAS-G MADM Mode [82], and the WASPAS method [83]. Compared with studies in cluster #1, the researchers in this cluster combined more advanced methods to select or evaluate environmental/sustainable suppliers.

Figure 3 shows the timeline of co-authorship clusters, which clearly shows the researcher allocation across time. By analyzing the publications of researchers in different time periods, the research thread of each collaborative network can be summarized.

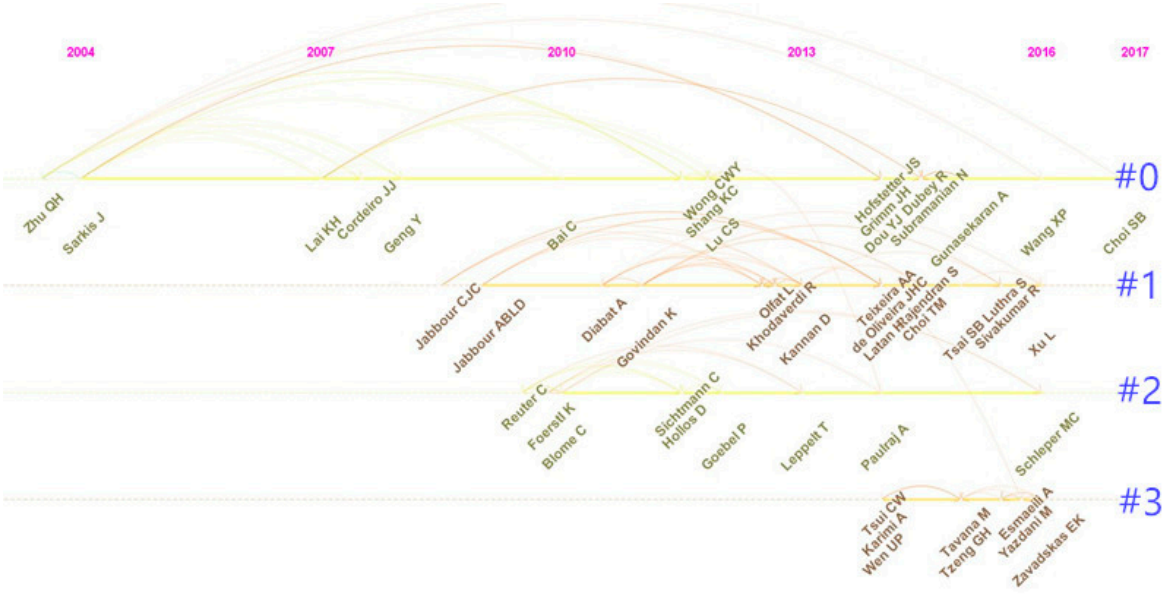



**Figure 3.** Timeline view of co-authorship clusters.

The largest cluster (#0) covers the widest time span, ranging from 2004 to 2017. Since the first article published by Zhu, Q.H. and Sarkis, J. [47], the study on GSCM in the Chinese context began to increase. From 2007, more researchers such as Lai, K.H. and Cordeiro, J.J. were involved in this collaboration. The research topics become greater and more specific, such as the initiatives and outcomes of GSCM implementation [84] and the firm-level correlates of emergent GSCM practices [85]. In 2013, more researchers such as Wong, C.W.Y., Shang, K.C., and Lu, C.S., were also involved in this network. They emphasized the important role of suppliers' environmental management maturity for the effectiveness of internal green operations [86] and provided more empirical evidence of the performance outcome of GSCM practices by expanding the scope to other contexts, such as Taiwan. From 2014, more researchers were involved and their research topics become more abundant, from sub-supplier management for sustainability [14,15] to green supplier development [87,88]. Some researchers expanded the scope to sustainability by discussing the effect of integrated practices such as lean, green, and social management systems on sustainability performance. Further, in the most recent two years, researchers broadened GSCM studies by focusing on a single industry [89] or a specific country, such as Korea [90]. In summary, the researchers in this cluster initially focused on GSCM and then expanded the scope to sustainable supply chain management (SSCM), with the research topic shifting from the drivers, barriers, and outcome performance of whole SCM to more specific supplier-related issues.

The second largest (#1) collaborative network covers the period of 2009-2016. Initially, researchers such as Jabbour, A.B.L.D. and Jabbour, C.J.C. mainly focused on GSCM and green supplier management. In 2011, researches such as Diabat, A. and Govindan, K. summarized the drivers of GSCM practices by reviewing GSCM literature and on consultations with experts in the industry [91]. Then, researchers such as Kannan, D. further discussed the method to select green suppliers and examine how to allocate orders in a green supply chain in 2013 [66]. Following this, more factors

were considered for GSCM such as human aspects, quality management, environmental management maturity of suppliers [61], and green training [92]. The researchers involved in the most recent two years focused more on the method of green supplier evaluation and selection [67,93]. In summary, this collaborative network mainly focuses on the GSCM practices of large companies in Brazil and then innovatively introduced the influence of other factors, such as human aspects and quality management. In the most recent two years, researchers began to explore the method to select or evaluate green suppliers.

The third largest (#2) collaborative network mainly published articles between 2010 and 2016. Researchers such as Reuter, C., Foerstl, K., and Blome, C. initially collaborated to emphasize the importance of sustainable supplier management for risk management in the Chemical industry [70]. Then, researchers such as Sichtmann, C. and Goebel, P. explored the drivers of sustainable supplier selection in 2012 [75]. Meanwhile, more specific topics such as collaboration with suppliers and supplier relationship management for sustainability were further explored [72,76]. The latest study in this collaborative network is about the contextual barriers to implementing supplier development for sustainability [12]. In summary, the researchers in this network mainly focus on sustainable supplier management, from the importance of supplier management to specific practices, as well as drivers and barriers of sustainable supplier management.

The last one (#3) is a relatively new and young network which only covers the most recent three years, from 2015 to 2017. The research focus includes how to improve the performance of green suppliers [94] and the specific method employed to select green suppliers [6,80,82].

Based on the above analysis, the most influential authors and the four largest collaborative networks, as well as their research fronts and research thread, were identified and summarized, providing a general picture about the research statement of this field. However, it is noteworthy that a certain topic may be discussed by a few collaborative networks, with different methods and perspectives or under different contexts. Therefore, only analyzing the largest collaboratives networks independently is not enough to detect the research development of this field from a holistic perspective. To comprehensively understand the knowledge base and research trends of this field, research themes analysis was conducted in the following part of the study.

### *4.3. Research Themes Analysis*

Reference co-citation analysis is a frequently used statistical method to analyze underlying intellectual structures. If two pieces of literature are cited by n pieces of literature ($n$ = 1, 2, . . . ) at the same time, then these two pieces are said to have a relationship of co-citation and the intensity of being co-cited is n. It is generally believed that the literature co-cited is similar in terms of themes to a greater or lesser extent. Therefore, the number of times of being co-cited acts as a measurement of the literature's similarity in themes. Based on this principle, reference co-citation analysis can analyze the emergence of research topics. However, one drawback of reference co-citation is that the recently published articles usually cannot be fully embodied in the network due to limited citations. The term co-occurrence can complement it by integrating the noun phrases which were extracted from Title, Abstract, Author Keywords (DE), and Keywords Plus (ID). If two terms appear in the same literature, then the two terms have a relationship of co-occurrence. No matter how many times an article has been cited, the terms with a high frequency of occurrence can be identified. Thus, a new research front which has not been cited too much can also be illustrated. Therefore, in this paper, a hybrid network analysis of reference co-citation and terms co-occurrence was conducted, as shown in Figure 4. Each circular node represents an article with varied citation frequencies, which are reflected by the font size of the node label. The thickness of different links between two nodes represents the frequencies of two node articles being cited together and the color indicates the year they were first co-cited (green, yellow, and orange correspond to earlier and recent years from 1998 to 2017). The square node represents the terms that appeared the most in analyzed articles, capturing the research content of literatures in each cluster.

The importance of an article can be measured by two indicators. Citation frequency represents the recognized degree of an article in a certain research field, and it can reflect the academic contribution of the article [95,96]. Another important indicator is betweenness centrality, which is defined as the ratio of the shortest path between two nodes to the sum of all such shortest paths [36]. The concept stems from the importance of an individual in the social networks [97]. Nodes with a high betweenness centrality are usually located on paths linking different clusters and can be identified by a thick red–purple ring [40]. It can be used to identify potential pivotal nodes in a quantifiable way [35]. A highly cited reference may not have a high betweenness centrality, but when a high citation frequency and a high betweenness centrality appear simultaneously, it means that the article has exerted a fundamental and pivotal influence on the development of this field. Before running the data, the threshold to select nodes to form the network were set as default values. For example, only the 50 most cited or occurring items from each slice were selected.

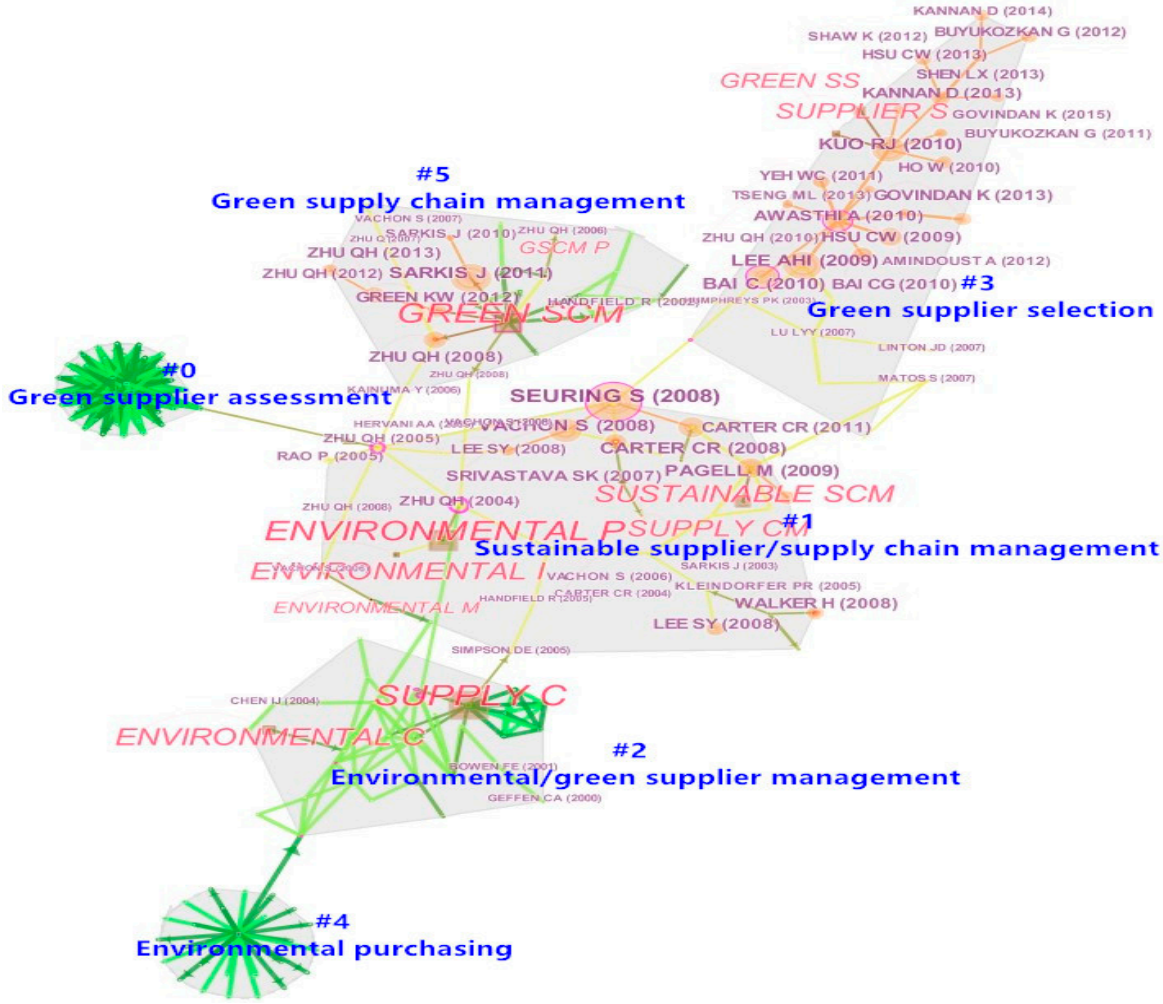



**Figure 4.** Reference co-citation & Term co-occurrence clusters.

4.3.1. Research Themes Identification

It is clear that the six largest clusters were identified. The value of modularity Q this network is 0.8135, and the silhouette values of the six largest clusters are all above 0.9, being highly above the recommended 0.5. Similar to co-authorship cluster analysis, quantitative and qualitative approaches were combined.

First, the Cite space software provides cluster labels through extracting the top terms from the keywords and abstracts of the articles that cited most articles of this cluster using the algorithm

of the Log likelihood ratio (LLR). Second, the frequency of terms extracted from the title, abstract, author keywords (DE) and keywords plus (ID) of articles in each cluster represents the research topics to some extent. Third, a further content analysis of the most important articles in terms of citation frequency and betweenness centrality was conducted to further confirm or complement the findings of the above two quantitative approaches. The combination of quantitative and qualitative approaches can improve the quality and effectiveness of analysis by taking advantage of scientific bibliometric methods which are embedded in grounded and well-established theories.

The six largest clusters were summarized in Table A3 (see Appendix A). Cluster 0 has 38 members (17 terms and 21 articles) and a silhouette value of 0.954. It is labelled as "applying environmental criteria" with keyword terms and "analytical hierarchy process" with abstract terms. The most frequently appearing terms are environmental D (7) and supplier A (1). Based on the above analysis, it can be inferred that "green supplier assessment" is the main research front of cluster 1. However, although this cluster is the largest in terms of size, each article member was cited no more than once. This means that there are no pivotal references and thus further content analysis is meaningless. All the cited articles in this cluster were published before 1999, meaning that research in this area had just started.

Cluster 1 has 38 members (seven terms and 28 articles) and a silhouette value of 0.895. It is labelled as "sustainable global supplier management" with keyword terms and "sustainability aspects" with abstract terms. The most frequently appearing terms are environmental P (101), Sustainable SCM (47), Environmental I (46), and Supply CM (40). Based on the above quantitative analysis, the research fronts of this cluster could be "sustainable supplier management". Further, the most important articles in terms of citation frequency and betweenness centrality are shown in Table A3 (see Appendix A). Among those articles, Zhu and Sarkis [47] and Seuring and Müller [21] exerted a fundamental influence since high citation frequency and betweenness centrality appear simultaneously. The former one provided one of the initial empirical pieces of evidence on the relationship between GSCM and firm performance and the latter one proposed a conceptual framework for SSCM and put forward two distinct strategies: (1) supplier management for risks and performance, and (2) supply chain management for sustainable products. Further, the theoretical foundations of SSCM were enhanced through systematic literature reviews and rich case studies [20,98,99]. All these efforts pave a solid road for further studies on a specific topic such as sustainable supplier management and collaboration with suppliers as well as customers. For example, Lee and Klassen [9] mapped factors which improve environmental capabilities of small and medium-sized suppliers over time through case studies. Further, Vachon and Klassen [100] showed how collaboration with suppliers and customers are linked to firm performance. The content analysis further confirms that "sustainable supplier/supply chain management" is the major research front of this cluster.

Cluster 2 has 31 members (four terms and 27 articles) and a silhouette value of 0.969. It is labelled as "plant-level environmental investment" with keyword terms and "environmental management" with abstract terms by LLR. The terms with the highest frequencies are Supply C (110) and Environmental C (53). Combining the cluster labels and top terms, the main topic of this cluster is likely to be related to "environmental management in supply chain". Next, the representative cited articles were further analyzed. Carter and Carter [101] provided initial evidence on the interorganizational determinants of environmental purchasing. Then, researchers devoted further efforts to determining the importance of suppliers for environmental sustainability from different perspectives, such as buying firms' different supplier development strategies [102], the role of partnership between original equipment manufacturers (OEMS) and their suppliers [103], and the importance of green supply management in making supply green [104]. Further, Rao [105] and Klassen and Vachon [106] expanded the scope to the whole supply chain, but still focused on environmental issues. In summary, most papers in this cluster focus on environmental issues related to suppliers. Thus, combining the above quantitative findings, it is reasonable to name the research front of this cluster as "Environmental/green supplier management".

Cluster 3 has 38 members (two terms and 29 articles) and a silhouette value of 0.928. It is labelled as "supplier selection" with keyword terms and "best green supplier" with abstract terms. The terms with the highest frequency are Supplier S (31) and Green SS (28). Based on the above results, it can be understood that the articles in this cluster are focusing on "green supplier selection". Furthermore, the cited articles in this paper show a very focused research topic, namely green supplier selection. Firstly, the two pivotal papers with both a high citation frequency and betweenness centrality explored how to integrate sustainability into suppliers and how to evaluate the environmental performance of suppliers [107,108]. Further, nearly all other papers discussed green supplier selection issues using different methods such as MADA methods [109] and the analytic network process [110] across different industries such as high-tech industry [111]. Therefore, the conclusion can be draw that the papers in this cluster focus on "Green supplier selection".

Cluster 4 has 38 members (12 terms and 14 articles) and a silhouette value of 0.999. It is labelled as "purchasing" with keyword terms and "environmental purchasing" with abstract terms. There are no outstanding terms, but only terms such as Upstream, S.C. and Social, R., which only appear once. The research front can thus be "Environmental purchasing". However, there are very limited important articles and frequently appearing terms, and all the papers were published before 2000. This means the studies in this field are still in their infancy at this stage.

Cluster 5 has 25 members (three terms and 22 articles) and a silhouette value of 0.936. It is labelled as "green supply chain management practice" with keyword terms and "gscm practice" with abstract terms. The most frequently appearing terms are Green SCM (90) and GSCM P (13). It can be inferred that the main topic of this cluster may be "green supply chain management". The further content analysis of the most important cited articles shows that nearly all these papers were published by Zhu, Q.H., Sarkis, J., and their co-authors. Their focus is on GSCM, especially sampled at Chinese manufacturing enterprises. Among those studies, Sarkis, Zhu and Lai [22] was cited the most because of its fundamental contribution to the theoretic review of GSCM. Besides, Zhu, Q.H. and co-authors explored GSCM practices in terms of the measurement model [112] and the shareholder pressures of the adoption of GSCM [113] as well as the antecedents and performance outcomes of internal and external GSCM practices [48,49,85]. Therefore, the focus of this cluster can be named "Green supply chain management".

In summary, although six largest clusters were identified, all the articles in cluster 0 and cluster 4 were published before 2000 and do not have a very significant impact in terms of citation frequency and betweenness centrality. This means that research in this area was in its infancy at around 2000. The other four clusters (#1, #2, #3, #5) illustrate the four main research themes of this field, namely sustainable supplier/supply chain management, green supplier management, green supplier selection, and GSCM. To better understand how these research themes evolved and developed over time from a holistic perspective, the evolution of research themes was further analyzed.

#### 4.3.2. Research Themes Evolution Analysis

CiteSpace can demonstrate the above generated reference co-citation & term co-occurrence network by highlighting new-added links of different periods of time. Since the time slice was set as 5, the whole period from 1998 to 2017 (by 20 October) was divided into four periods, namely 1998–2002, 2003–2007, 2008–2012, and 2013–2017 (by 20 October), as shown in Figure A1 (see Appendix B). To make it easier to recognize the newly emergent links during each period, the authors circled the newly emerged studies in a specific period using a black dotted line.

It can be seen that articles published during the period of 1998–2002 mainly appear in cluster 0, cluster 4, and a small part of cluster 2. As analyzed above, the study in this field was still in its infancy during this period. The importance of PSM for environmental sustainability, however, was initially proposed and examined. Specifically, Carter and Carter [101] firstly explored the interorganizational determinants of environmental purchasing. Then, other researchers emphasized the important role of supplier/supply management (e.g., strong partnership with suppliers) for environmental

sustainability [103,104]. Furthermore, Handfield, et al. [114] explored how to apply environmental criteria to assess suppliers.

Between 2003 and 2007, more articles were published, which mainly appeared in cluster 2 and part of cluster 5. During this period, most papers expanded the research scope from environmental purchasing and supply management to the whole supply chain, namely GSCM. Specifically, Klassen and Vachon [106] tested how collaboration and evaluation in the supply chain (including suppliers as well as customers) influence plant-level environmental investment. Zhu and Sarkis [56] compared the drivers and practices of different industries among Chinese manufacturing enterprises. Further, Vachon [115] and Vachon and Klassen [116] explored the relationship between GSCM practices and the selection of environmental technologies.

During the period of 2008–2012, the number of articles surged and the research content was more abundant. The topics range from GSCM and SSCM to more supplier-specific topics. Specifically, the studies on GSCM, as mentioned in the period of 2003–2007, continue and become more in-depth. The drivers and barriers of GSCM practices [117], the optimization of GSCM [118], its implications for "closing the loop" and firm performance [119,120], and environmental supply chain collaboration [100] were all explored in further detail. Besides, Sarkis, Zhu and Lai [22] reviewed and summarized recent studies on GSCM under nine broad organizational theories, not only addressing the research status of this field, but also identifying future research opportunities. Further, some researchers expanded the scope to the whole sustainability by considering environmental, economic, and social aspects. For example, Seuring and Müller [121] identified the core issues in SSCM. Carter and Rogers [20] presented a framework of SSCM and developed research propositions to consider the supporting facts to implement SSCM practices based on a few well-established theories. Carter and Easton [23] further contributed to this field by systematically reviewing the articles on SSCM from the past 20 years. Another more specific branch is on suppliers. Lee [3] and Lee and Klassen [9] initially identified the drivers and enablers to encourage the participation of small and medium-sized suppliers in GSCM practices and to improve their environmental management capabilities. Foerstl, Reuter, Hartmann and Blome [70] further discussed supplier management in broader sustainable supply chain management. Next, most studies explored the method of green/sustainable supplier selection [107,109,111,122–124], supplier evaluation [108,123], and supplier development [125].

From 2013 to 2017 (by 20 October), most publications appear in Cluster 3, which was named "Green supplier selection". The research topics in this period range from GSCM to green supplier selection and evaluation. Zhu, Sarkis and Lai [48] and Tseng and Chiu [126] tested GSCM from novel perspectives. The former explored the antecedents of internal and external GSCM practices based on institutional theory and the latter evaluated green supply chain performance using linguistic preferences. This means that since the researchers began their efforts on GSCM in the period of 2003–2007, the research on this topic has never stopped but gone further. Other publications in this period, however, continued to explore the subject of green supplier selection and/or evaluation [64,66,69,127,128]. To summarise the studies on green supplier evaluation and selection approaches, Govindan, et al. [129] conducted a systematic literature review and identified the multi criteria decision making approaches.

In summary, during the past 20 years, research on PSM for environmental sustainability experienced four stages, namely an infancy stage, grow-up stage, surging stage, and deep-going stage. The first five years, namely 1998–2002, represent the infancy stage. During this stage, although limited articles were published, the important role of supply/supplier management for environmental sustainability and specific practices such as environmental purchasing and green supplier assessment were proposed and examined. Between 2003 and 2007, the studies in this field began to grow gradually. Specifically, the research scope was expanded to the whole supply chain, focusing on environmental issues. During 2008 and 2012, studies in this field experienced a surge in both the number of publications and research topics, which cover various GSCM practices across broader industries and countries, the core issues, and supporting factors of SSCM, as well as

supplier-specific topics such as suppliers' participation in GSCM practices, supplier development, and the methods of supplier selection and evaluation. During the most recent five years, 2013–2017 (by 20 October), the studies in this field became more focused and deeper. For instance, a series of integrated and advanced methods to select or evaluate green suppliers were discussed. Besides, a few studies also tested GSCM from novel perspectives or based on novel methods. In sum, after a long period of steady and continuous growth, research in this field is gradually becoming more and more mature and thorough.

## 5. Conclusions and Discussion

This study presented a systematic literature review on PSM for environmental sustainability base on 317 peer-reviewed publications collected from the core collection of WOS through rigorous bibliometric analysis. The increasing number of publications over the years, especially the most recent five years, shows that this field has attracted fast growing attention of academia. The articles in this field were mostly accepted by journals in the environmental science area and operations research/management area, followed by other areas such as industrial/engineering, marketing, and ethics/business, showing that it is a multi-disciplinary topic. Although it is evolving into a popular research field, a thorough bibliometric analysis to scientifically reveal and visualize the contributing researchers and research themes evolution has not been conducted. This initial effort has contributed to this field by identifying the most influential authors, as well as their collaboration networks, and providing a roadmap of research themes evolution, not only acknowledging current research development in this field, but also enlightening future research directions.

### *5.1. Main Contributions*

In terms of author analysis, the most influential authors and major collaborative networks were identified. Based on the number of publications and citation frequencies, Sarkis, J., Zhu, Q.H., and Lai, K.H. are the most influential contributors. Other researchers such as Jabbour, A.B.L.D., Govindan, K., Blome, C., Vachon, S., and Klassen, D. also contributed to varying degrees in either number of publications or citation frequencies, or both. Further, the four largest collaborative networks were identified, and among them, researchers represented by Sarkis, J., Zhu, Q.H., and Lai, K.H. formed the largest one, which covers the longest period, from 2004 to 2017 (by 20 October). The researchers in this cluster initially focused on GSCM and then expanded the scope to SSCM, with the research topic shifting from general SCM to more specific supplier-related issues. The researchers represented by Jabbour, A.B.L.D. and Govindan, K. constituted the second largest network. Their publications mainly emerged between 2009 and 2016 and their research themes ranged from GSCM, to green supplier selection and sustainable supplier evaluation. The third largest network consisted of researchers represented by Blome, C., Foerstl, K., and Paulraj, A. Their studies mainly emerged between 2010 and 2016 and focused on sustainable supplier management such as sustainable supplier selection and contextual barriers to implementing sustainable supplier development. The last one represented by Zavadskas, E.K., Esmaeili, A., and Yazdani, M. focused on the specific method employed to evaluate and select suppliers for environmental sustainability from 2015 to 2017 (by 20 October).

Regarding the research themes, this study contributes by identifying main research themes and further summarizing their evolutions over time. Although six clusters were initially reveled, only four main research themes were summarized after analyzing the content of articles in each cluster: sustainable supplier/supply chain management, environmental/green supplier management, green supplier selection, and GSCM. Although the perspective or focus of each theme is different, the contents are interrelated. For instance, green supplier selection is a specific aspect of green supplier management, which further constitutes an important part of GSCM. To better understand the research themes evolution from a holistic perspective, four periods were summarized. During the infancy stage, 1998–2002, preliminary efforts were made to propose the importance of PSM for environmental sustainability. Then, the research scope was expanded to the whole supply chain,

focusing on environmental issues, namely GSCM, between 2003 and 2007. The number of articles and topics experienced a surge between 2008 and 2012. GSCM was discussed from many different perspectives and based on different countries and industries. Furthermore, SSCM and supplier specific topics also began to attract increasing attention. During the most recent five years, 2013–2017 (by 20 October), the research became deeper and more focused. For instance, a large amount of studies discussed various methods to select and evaluate suppliers considering their environmental performance. Overall, research in this field is becoming more abundant and in-depth.

### *5.2. Future Research Directions*

Based on the acknowledgement of current research development in this field, several future research directions were proposed for further investigation. First, as discussed above, numerous and advanced methods have been proposed to explore how to select or evaluate suppliers considering environmental criterion, whilst fewer studies have explored the methods of a hands-on approach such as supplier development. Future studies could put more effort into exploring methods to stimulate a supplier's environmental innovativeness or to help suppliers improve environmental management capabilities. Second, while most of the articles we reviewed focus on the first-tier supplier management, significant environmental problems are often generated by lower-tier suppliers since they are always responsible for the production process and the first-tier suppliers are often responsible for the assembly link. Therefore, how to improve the sub-tier supplier's environmental performance is important. Although a few studies have explored this issue, the knowledge is still very limited. More studies are needed in the future to explore the barriers and solutions to extend environmental sustainability to sub-tier suppliers. Third, most studies analyzed in this study focused on the buyers' perspective to find out specific PSM practices such as green purchasing and green supplier selection, as well as the drivers, barriers, and performance outcomes, but fewer studies tested how suppliers respond to the buyer's different practices. Future studies could put more effort into exploring the supplier's responses to the buyer's different practices, which can help uncover this issue more comprehensively. Fourth, as discussed above, many studies consider sustainability as an integrated concept which includes environmental, economic, and social aspects. Further research should explore whether green issues should be investigated separately or integrated with economic and social aspects, as suggested by Appolloni, Sun, Jia and Li [31]. Finally, in terms of research methodologies, it is suggested that researchers try less adopted methods such as case studies, which are very useful to record more observations when one research topic has not been explored that much, as well as theoretical and conceptual methods.

### *5.3. Limitations*

Despite its contributions, this study also has some limitations. First, the database we selected, Web of Science, may cover a limited number of articles. Multi-source searching and a cross-comparison among different databases would be more convincing. Second, although we believe the right keywords have been selected to achieve our goal, they may be improved in the future to search articles more accurately. Third, although we identified the main research themes and their evolution, deeper information on each research theme, such as methodologies, theoretical background, and the main findings, is still unclear. Future studies may continue to obtain deeper insights into different research themes.

**Author Contributions:** W.Z. and Z.W. designed this research together. W.Z. collected data from Web of Science, and then two authors worked together to select/delete data to get the final articles and conducted further analysis. W.Z. finished the first draft and Z.W. made revisions. Two authors have read and approved the final manuscript.

**Acknowledgments:** This study was funded by the National Natural Science Foundation of China (grant numbers: 71473087, 71520107001, 71420107024), the Fundamental Research Funds for the Central Universities, SCUT (XZD03), and China Scholarship Council (201706150073).

**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

**Table A1.** Previous literature reviews (LRs) on PSM for environmental sustainability.

| Source(s) (Chronological Order) | Domain (SCM/PSM) | Scope (S/E) | No. | Methodology | Main Contributions |
|---|---|---|---|---|---|
| Carter and Rogers [20] | SCM | S | N.A | Conceptual theory building | Introduce the concept of sustainability to the field of SCM. |
| Seuring and Müller [21] | SCM | S | 191 | Systematic LR | Identifies two strategies of SSCM: supplier management for risk management and sustainable products. |
| Carter and Easton [23] | SCM | S | 80 | Systematic LR | Identifies the trends and gaps of SSCM. |
| Sarkis, Zhu and Lai [22] | SCM | E | N.A | LR | Organizational theoretic review of GSCM. |
| Tate, et al. [28] | PSM | E | 152 + 68 | LR + CSR report analysis | Indicates the development of environmental purchasing practice and research is in its early stages. |
| Miemczyk, Johnsen and Macquet [29] | PSM | S | 113 | Systematic LR | Definitions and measures of sustainable PSM at the dyad, chain and network levels. |
| Gimenez and Tachizawa [30] | PSM | S | 41 | Systematic LR | Identifies the enablers and firm performance of two governance mechanisms: supplier assessment and collaboration. |
| Appolloni, Sun, Jia and Li [31] | PSM | E | 86 | LR | Identifies the drivers, barriers and performance outcomes of the adoption of green procurement. |
| Wong, Wong and Boon-Itt [25] | SCM | E | 142 | Systematic LR | Categorizes four types of green supply chain integration practices. |
| Fahimnia, Sarkis and Davarzani [24] | SCM | E | 884 | Bibliometric analysis | Identified key research topics, interrelations and collaboration patterns of GSCM. |
| Sharma, Chandna and Bhardwaj [26] | SCM | E | 23 | LR + consulting industrial experts | Suggests performance indicators of GSCM in agroindustry |
| Chen, Zhao, Tang, Price, Zhang and Zhu [27] | SCM | S | 174 | Bibliometric analysis + content analysis | Summarize research state of supply chain collaboration for sustainability. |

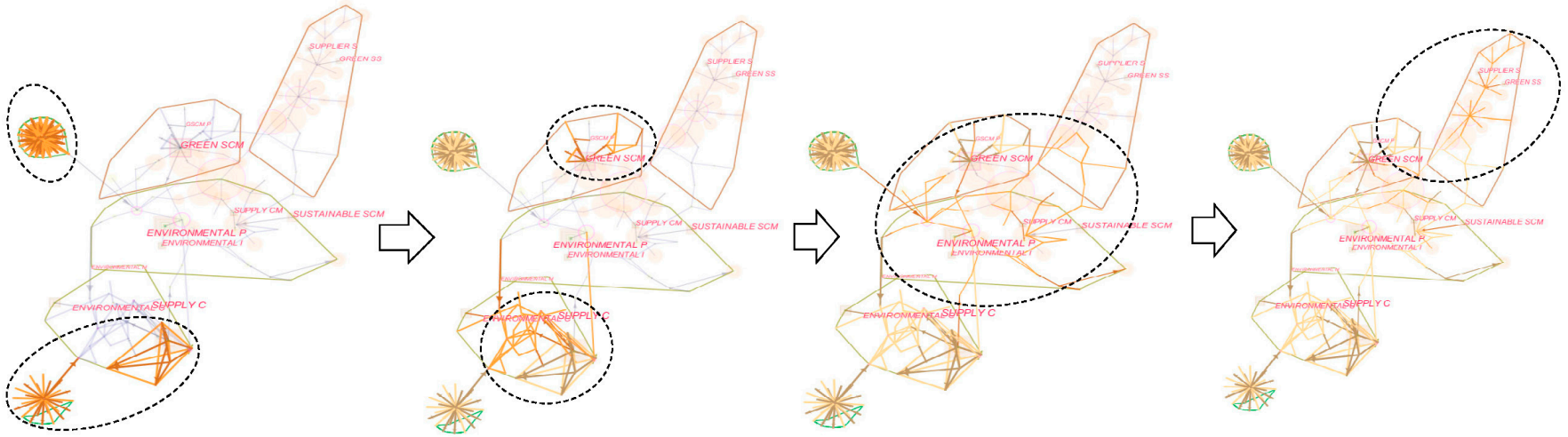
**Table A2.** Summary of four largest co-authorship clusters.

| Cluster ID | Size | Sihouette | Top Authors | Publications | Cluster Label (LLR/TFIDF) | Research Fronts (Content Analysis) |
|---|---|---|---|---|---|---|
| 0 | 22 | 0.954 | Sarkis, J.<br>Zhu, Q.H.<br>Lai, K.H.<br>Lu, C.S.<br>Geng, Y. | 25<br>20<br>14<br>4<br>4 | Composite sustainable manufacturing practice/gscm practices | GSCM (Chinese manufacturing industry);<br>Sustainable supply chain management;<br>Sustainable sub-supplier management. |
| 1 | 18 | 0.986 | Jabbour, A.B.L.D.<br>Govindan, K.<br>Jabbour, C.J.C.<br>Kannan, D.<br>Diabat, A. | 11<br>11<br>10<br>5<br>4 | Best green supplier/Order | GSCM (large Brazilian firms);<br>Green supplier selection;<br>Sustainable supplier evaluation. |
| 2 | 11 | 0.983 | Blome, C.<br>Foerstl, K.<br>Paulraj, A.<br>Hartmann, E.<br>Reuter, C. | 10<br>8<br>6<br>4<br>4 | Chemical industry/Green procurement | Sustainable supplier management;<br>Green supplier management. |
| 3 | 11 | 0.973 | Zavadskas, E.K.<br>Esmaeili, A.<br>Yazdani, M.<br>Hashemi, S.H.<br>Tsui, C.W. | 4<br>3<br>3<br>2<br>2 | Supplier evaluation/Criteria | Green supplier selection/evaluation;<br>Sustainable supplier selection. |

**Table A3.** Summary of six largest reference co-citation & term co-occurrence clusters.

| ID | Size | Silhouette | Cluster Labels (Keyword/Abstract) | Top Terms (Frequency) | Representative Cited Articles (Citation Frequency, betweenness Centrality) | Research Front (Combined) |
|---|---|---|---|---|---|---|
| 0 | 38 | 0.997 | Applying environmental criteria /Analytical hierarchy process | Environmental D (7)<br>Supplier A (1) | None | Green supplier assessment |
| 1 | 35 | 0.895 | Sustainable global supplier management/Sustainability aspects | Environmental P (101)<br>Sustainable SCM (47)<br>Environmental I (46)<br>Supply cm (40) | Seuring, S. 2008 JCP [95, 0.16]<br>Zhu, Q.H. 2004 JOM [31, 0.29]<br>Carter, C.R. 2008 IJPDLM [52, 0.04]<br>Pagell, M. 2009 JSCM [51, 0.04]<br>Srivastavask 2007 IJMR [39, 0.02]<br>Zhu, Q.H. 2005 IJOPM [21,0.32]<br>Vachon, S. 2008 JCP [9, 0.14]<br>Lee, S.Y. 2008 POM [36,0.00]<br>Lee, S.Y. 2008 SCM [30, 0.00] | Sustainable supplier/supply chain management |
| 2 | 31 | 0.969 | Plant-level environmental investment /Environmental management | Supply C 110<br>Environmental C 53 | Carter, C.R. 1998 DS [4, 0.15]<br>Krause, D.R. 2000 DS [5, 0.15]<br>Geffen, C.A. 2000 IJOPM [11, 0.00]<br>Bowen, F.E. 2001 POM [9, 0.01]<br>Rao, P. 2002 IJOPM [6, 0.01]<br>King, A. 2002 MS [3, 0.22]<br>Klassen, R.D. 2003 POM [5, 0.08]<br>Chen, I.J. 2004 JOM [9, 0.01] | Environmental/green supplier management |
| 3 | 31 | 0.928 | Supplier selection/Best green supplier | Supplier S 31<br>Green, S.S. 28 | Bai, C. 2010 IJPE [54, 0.10]<br>Awasthi, A. 2010 IJPE [48, 0.12]<br>Lee, A.H.I. 2009 ESA [71, 0.03]<br>Kuo, R.J. 2010 JCP [57, 0.07]<br>Hsu, C.W. 2009 JCP [40, 0.00]<br>Bai, C.G. 2010 JCP [38, 0.00]<br>Kannan, D. 2013 JCP [36, 0.03]<br>Govindan, K. 2013 JCP [34, 0.00] | Green supplier selection |
| 4 | 26 | 0.999 | Purchasing/Environmental purchasing | Upstream, S.C. 1<br>Social R 1 | Walton, S.V. 1998 JSCM [4, 0.00] | Environmental purchasing |
| 5 | 25 | 0.936 | Green supply chain management practice/Gscm practice | Green SCM 90<br>GSCM P 13 | Sarkis, J. 2011 IJPE [70,0.01]<br>Zhu, Q.H. 2008 IJPE [42,0.04]<br>Green, K.W. 2012 SCM [36,0.01]<br>Zhu, Q.H. 2013 JPSM [35,0.01]<br>Zhu, Q.H. 2012 IJPR [30,0.00]<br>Sarkis, J. 2010 JOM [23,0.00]<br>Handfield, R. 2002 EJOR [13,0.05]<br>Zhu, Q.H. 2008 Omega [8,0.09] | GSCM |

## Appendix B




**1998–2002: infancy stage**

Environmental purchasing;

Green supply/supplier management;

Green supplier assessment.

**2003–2007: grow-up stage**

Primary GSCM: collaboration, evaluation, practices, drivers.

**2008–2012: surging stage**

GSCM: drivers, barriers, optimization, implication, collaboration, theoretical basis etc.

SSCM: core issues, supporting factors etc.

Supplier-specific topics: supplier participation, supplier selection, evaluation, development.

**2013–2017: deep-going stage**

GSCM: novel perspectives (e.g. institutional theory, supply chain performance evaluation etc.);

Green supplier selection and evaluation (more integrated and advanced method);

**Figure A1.** Evolution of the study on purchasing and supply management for environmental sustainability.

## References


1. Faruk, A.C.; Lamming, R.C.; Cousins, P.D.; Bowen, F.E. Analyzing, mapping, and managing environmental impacts along supply Chains. *J. Ind. Ecol.* **2001**, *5*, 13–36. [CrossRef]
2. Caniels, M.C.J.; Gehrsitz, M.H.; Semeijn, J. Participation of suppliers in greening supply Chains: An empirical analysis of german automotive suppliers. *J. Purch. Supply Manag.* **2013**, *19*, 134–143. [CrossRef]
3. Lee, S.Y. Drivers for the participation of small and medium-sized suppliers in green supply Chain initiatives. *Supply Chain Manag. Int. J.* **2008**, *13*, 185–198. [CrossRef]
4. Institute of Public and Environmental Affairs. *2015 Sustainability Progress Report—How We Create Responsibly*; Institute of Public and Environmental Affairs: Beijing, China, 2015.
5. Wu, J.; Ma, Z.Z. Export intensity and mne customers' environmental requirements: Effects on local Chinese suppliers' environment strategies. *J. Bus. Ethics* **2016**, *135*, 327–339. [CrossRef]
6. Yazdani, M.; Chatterjee, P.; Zavadskas, E.K.; Hashemkhani Zolfani, S. Integrated qfd-mcdm framework for green supplier selection. *J. Clean. Prod.* **2017**, *142*, 3728–3740. [CrossRef]
7. Guo, Z.X.; Liu, H.T.; Zhang, D.Q.; Yang, J. Green supplier evaluation and selection in apparel manufacturing using a fuzzy multi-criteria decision-making approach. *Sustainability* **2017**, *9*, 650.
8. Mendoza-Fong, J.R.; Garcia-Alcaraz, J.L.; Diaz-Reza, J.R.; Muro, J.; Fernandez, J.B. The role of green and traditional supplier attributes on business performance. *Sustainability* **2017**, *9*, 1520. [CrossRef]
9. Lee, S.Y.; Klassen, R.D. Drivers and enablers that foster environmental management capabilities in small- and medium-sized suppliers in supply Chains. *Prod. Oper. Manag.* **2008**, *17*, 573–586. [CrossRef]
10. Sancha, C.; Longoni, A.; Gimenez, C. Sustainable supplier development practices: Drivers and enablers in a global context. *J. Purch. Supply Manag.* **2015**, *21*, 95–102. [CrossRef]
11. Wang, C.N.; Huang, Y.F.; Le, T.N.; Ta, T.T. An innovative approach to enhancing the sustainable development of japanese automobile suppliers. *Sustainability* **2016**, *8*, 420. [CrossRef]
12. Busse, C.; Schleper, M.C.; Niu, M.L.; Wagner, S.M. Supplier development for sustainability: Contextual barriers in global supply Chains. *Int. J. Phys. Distrib. Logist. Manag.* **2016**, *46*, 442–468. [CrossRef]
13. Wilhelm, M.; Blome, C.; Wieck, E.; Xiao, C.Y. Implementing sustainability in multi-tier supply Chains: Strategies and contingencies in managing sub-suppliers. *Int. J. Prod. Econ.* **2016**, *182*, 196–212. [CrossRef]
14. Grimm, J.H.; Hofstetter, J.S.; Sarkis, J. Critical factors for sub-supplier management: A sustainable food supply Chains perspective. *Int. J. Prod. Econ.* **2014**, *152*, 159–173. [CrossRef]
15. Grimm, J.H.; Hofstetter, J.S.; Sarkis, J. Exploring sub-suppliers' compliance with corporate sustainability standards. *J. Clean. Prod.* **2016**, *112*, 1971–1984. [CrossRef]
16. Seuring, S.; Gold, S. Conducting content-analysis based literature reviews in supply Chain management. *Supply Chain Manag. Int. J.* **2012**, *17*, 544–555. [CrossRef]
17. Spina, G.; Caniato, F.; Luzzini, D.; Ronchi, S. Assessing the use of external grand theories in purchasing and supply management research. *J. Purch. Supply Manag.* **2016**, *22*, 18–30. [CrossRef]
18. Metz, P.J. Demystifying supply Chain management. *Supply Chain Manag. Rev.* **1998**, *1*, 46–55.
19. Monczka, R.M.; Handfield, R.B.; Giunipero, L.C.; Patterson, J.L. *Purchasing and Supply Chain Management*; Cengage Learning: Boston, MA, USA, 2015.
20. Carter, C.R.; Rogers, D.S. A framework of sustainable supply Chain management: Moving toward new theory. *Int. J. Phys. Distrib. Logist. Manag.* **2008**, *38*, 360–387. [CrossRef]
21. Seuring, S.; Müller, M. From a literature review to a conceptual framework for sustainable supply Chain management. *J. Clean. Prod.* **2008**, *16*, 1699–1710. [CrossRef]
22. Sarkis, J.; Zhu, Q.; Lai, K.H. An organizational theoretic review of green supply Chain management literature. *Int. J. Prod. Econ.* **2011**, *130*, 1–15. [CrossRef]
23. Carter, C.R.; Easton, P.L. Sustainable supply Chain management: Evolution and future directions. *Int. J. Phys. Distrib. Logist. Manag.* **2011**, *41*, 46–62. [CrossRef]
24. Fahimnia, B.; Sarkis, J.; Davarzani, H. Green supply Chain management: A review and bibliometric analysis. *Int. J. Prod. Econ.* **2015**, *162*, 101–114. [CrossRef]
25. Wong, C.Y.; Wong, C.W.; Boon-Itt, S. Integrating environmental management into supply Chains: A systematic literature review and theoretical framework. *Int. J. Phys. Distrib. Logist. Manag.* **2015**, *45*, 43–68. [CrossRef]

26. Sharma, V.; Chandna, P.; Bhardwaj, A. Green supply Chain management related performance indicators in agro industry: A review. *J. Clean. Prod.* **2016**, *141*, 1194–1208. [CrossRef]
27. Chen, L.; Zhao, X.; Tang, O.; Price, L.; Zhang, S.; Zhu, W. Supply Chain collaboration for sustainability: A literature review and future research agenda. *Int. J. Prod. Econ.* **2017**, *194*, 73–87. [CrossRef]
28. Tate, W.L.; Ellram, L.M.; Dooley, K.J. Environmental purchasing and supplier management (epsm): Theory and practice. *J. Purch. Supply Manag.* **2012**, *18*, 173–188. [CrossRef]
29. Miemczyk, J.; Johnsen, T.E.; Macquet, M. Sustainable purchasing and supply management: A structured literature review of definitions and measures at the dyad, Chain and network levels. *Supply Chain Manag. Int. J.* **2012**, *17*, 478–496. [CrossRef]
30. Gimenez, C.; Tachizawa, E.M. Extending sustainability to suppliers: A systematic literature review. *Supply Chain Manag.* **2012**, *17*, 531–543. [CrossRef]
31. Appolloni, A.; Sun, H.; Jia, F.; Li, X. Green procurement in the private sector: A state of the art review between 1996 and 2013. *J. Clean. Prod.* **2014**, *85*, 122–133. [CrossRef]
32. Dooley, K.J. Using manifest content analysis in purchasing and supply management research. *J. Purch. Supply Manag.* **2016**, *22*, 244–246. [CrossRef]
33. Tranfield, D.; Denyer, D.; Smart, P. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *Br. J. Manag.* **2003**, *14*, 207–222. [CrossRef]
34. Briner, R.B.; Denyer, D. Systematic review and evidence synthesis as a practice and scholarship tool. In *book of Oxford Handbook of Evidence-Based Management: Companies, Classrooms and Research*; Oxford University Press: Oxford, UK, 2012; pp. 112–129.
35. Chen, C. Citespace ii: Detecting and visualizing emerging trends and transient patterns in scientific literature. *J. Assoc. Inf. Sci. Technol.* **2006**, *57*, 359–377. [CrossRef]
36. Freeman, L.C. Centrality in social networks conceptual clarification. *Soc. Netw.* **1978**, *1*, 215–239. [CrossRef]
37. Burt, R.S. Structural holes and good ideas. *Am. J. Sociol.* **2004**, *110*, 349–399. [CrossRef]
38. Chen, C. The Citespace Manual. Available online: https://www.researchgate.net/profile/Arsev_Aydinoglu/publication/274377526_Collaborative_interdisciplinary_astrobiology_research_a_bibliometric_study_of_the_NASA_Astrobiology_Institute/links/5670463b08ae0d8b0cc0e112.pdf (accessed on 8 May 2018).
39. Ruan, J.; Chan, F.T.; Zhu, F.; Wang, X.; Yang, J. A visualization review of cloud computing algorithms in the last decade. *Sustainability* **2016**, *8*, 1008. [CrossRef]
40. Song, J.; Zhang, H.; Dong, W. A review of emerging trends in global ppp research: Analysis and visualization. *Scientometrics* **2016**, *107*, 1111–1147. [CrossRef]
41. Del Río, P.; Peñasco, C.; Romero-Jordán, D. What drives eco-innovators? A critical review of the empirical literature based on econometric methods. *J. Clean. Prod.* **2016**, *112*, 2158–2170. [CrossRef]
42. Gavel, Y.; Iselid, L. Web of science and scopus: A journal title overlap study. *Online Inf. Rev.* **2008**, *32*, 8–21. [CrossRef]
43. Yu, D.; Xu, C. Mapping research on carbon emissions trading: A co-citation analysis. *Renew. Sustain. Energy Rev.* **2017**, *74*, 1314–1322. [CrossRef]
44. Rajeev, A.; Pati, R.K.; Padhi, S.S.; Govindan, K. Evolution of sustainability in supply Chain management: A literature review. *J. Clean. Prod.* **2017**, *162*, 299–314. [CrossRef]
45. Shibata, N.; Kajikawa, Y.; Takeda, Y.; Matsushima, K. Detecting emerging research fronts based on topological measures in citation networks of scientific publications. *Technovation* **2008**, *28*, 758–775. [CrossRef]
46. Rousseeuw, P.J. Silhouettes: A graphical aid to the interpretation and validation of cluster analysis. *J. Comput. Appl. Math.* **1987**, *20*, 53–65. [CrossRef]
47. Zhu, Q.H.; Sarkis, J. Relationships between operational practices and performance among early adopters of green supply Chain management practices in Chinese manufacturing enterprises. *J. Oper. Manag.* **2004**, *22*, 265–289. [CrossRef]
48. Zhu, Q.H.; Sarkis, J.; Lai, K.H. Institutional-based antecedents and performance outcomes of internal and external green supply Chain management practices. *J. Purch. Supply Manag.* **2013**, *19*, 106–117. [CrossRef]
49. Zhu, Q.H.; Sarkis, J.; Lai, K.H. Examining the effects of green supply Chain management practices and their mediations on performance improvements. *Int. J. Prod. Res.* **2012**, *50*, 1377–1394. [CrossRef]
50. Zhu, Q.H.; Sarkis, J.; Lai, K.H. An institutional theoretic investigation on the links between internationalization of Chinese manufacturers and their environmental supply Chain management. *Resour. Conserv. Recycl.* **2011**, *55*, 623–630. [CrossRef]

51. Zhu, Q.H.; Geng, Y.; Sarkis, J.; Lai, K.H. Evaluating green supply Chain management among Chinese manufacturers from the ecological modernization perspective. *Transp. Res. Part E-Logist. Transp. Rev.* **2011**, *47*, 808–821. [CrossRef]
52. Zhu, Q.H.; Geng, Y.; Lai, K.H. Environmental supply Chain cooperation and its effect on the circular economy practice-performance relationship among Chinese manufacturers. *J. Ind. Ecol.* **2011**, *15*, 405–419. [CrossRef]
53. Zhu, Q.; Sarkis, J. The moderating effects of institutional pressures on emergent green supply Chain practices and performance. *Int. J. Prod. Res.* **2007**, *45*, 4333–4355. [CrossRef]
54. Zhu, Q.H.; Sarkis, J.; Lai, K.H. Green supply Chain management: Pressures, practices and performance within the Chinese automobile industry. *J. Clean. Prod.* **2007**, *15*, 1041–1052. [CrossRef]
55. Zhu, Q.H.; Sarkis, J.; Lai, K.H.; Geng, Y. The role of organizational size in the adoption of green supply Chain management practices in China. *Corp. Soc. Responsib. Environ. Manag.* **2008**, *15*, 322–337. [CrossRef]
56. Zhu, Q.; Sarkis, J. An inter-sectoral comparison of green supply Chain management in China: Drivers and practices. *J. Clean. Prod.* **2006**, *14*, 472–486. [CrossRef]
57. Lu, C.S.; Lai, P.L.; Chiang, Y.P. Container terminal employees' perceptions of the effects of sustainable supply Chain management on sustainability performance. *Marit. Policy Manag.* **2016**, *43*, 597–613. [CrossRef]
58. Lu, C.S.; Shang, K.C.; Lin, C.C. Examining sustainability performance at ports: Port managers' perspectives on developing sustainable supply Chains. *Marit. Policy Manag.* **2016**, *43*, 909–927. [CrossRef]
59. Jabbour, C.J.C.; Jabbour, A. Green human resource management and green supply Chain management: Linking two emerging agendas. *J. Clean. Prod.* **2016**, *112*, 1824–1833. [CrossRef]
60. Jabbour, C.J.C.; Mauricio, A.L.; Jabbour, A. Critical success factors and green supply Chain management proactivity: Shedding light on the human aspects of this relationship based on cases from the Brazilian industry. *Prod. Plan. Control* **2017**, *28*, 671–683. [CrossRef]
61. Jabbour, A.; Jabbour, C.J.C.; Latan, H.; Teixeira, A.A.; de Oliveira, J.H.C. Quality management, environmental management maturity, green supply Chain practices and green performance of Brazilian companies with iso 14001 certification: Direct and indirect effects. *Transp. Res. Part E-Logist. Transp. Rev.* **2014**, *67*, 39–51. [CrossRef]
62. Jabbour, A.B.; Jabbour, C.; Govindan, K.; Kannan, D.; Arantes, A.F. Mixed methodology to analyze the relationship between maturity of environmental management and the adoption of green supply Chain management in brazil. *Resour. Conserv. Recycl.* **2014**, *92*, 255–267. [CrossRef]
63. Jabbour, C.J.C.; Neto, A.S.; Gobbo, J.A.; Ribeiro, M.D.; Jabbour, A. "Eco-innovations in more sustainable supply Chains for a low-carbon economy: A multiple case study of human critical success factors in Brazilian leading companies". *Int. J. Prod. Econ.* **2015**, *164*, 245–257. [CrossRef]
64. Kannan, D.; Govindan, K.; Rajendran, S. Fuzzy axiomatic design approach based green supplier selection: A case study from singapore. *J. Clean. Prod.* **2015**, *96*, 194–208. [CrossRef]
65. Kannan, D.; Jabbour, A.; Jabbour, C.J.C. Selecting green suppliers based on gscm practices: Using fuzzy topsis applied to a Brazilian electronics company. *Eur. J. Oper. Res.* **2014**, *233*, 432–447. [CrossRef]
66. Kannan, D.; Khodaverdi, R.; Olfat, L.; Jafarian, A.; Diabat, A. Integrated fuzzy multi criteria decision making method and multi-objective programming approach for supplier selection and order allocation in a green supply Chain. *J. Clean. Prod.* **2013**, *47*, 355–367. [CrossRef]
67. Govindan, K.; Kadzinski, M.; Sivakumar, R. Application of a novel promethee-based method for construction of a group compromise ranking to prioritization of green suppliers in food supply Chain. *Omega-Int. J. Manag. Sci.* **2017**, *71*, 129–145. [CrossRef]
68. Govindan, K.; Muduli, K.; Devika, K.; Barve, A. Investigation of the influential strength of factors on adoption of green supply Chain management practices: An indian mining scenario. *Resour. Conserv. Recycl.* **2016**, *107*, 185–194. [CrossRef]
69. Govindan, K.; Khodaverdi, R.; Jafarian, A. A fuzzy multi criteria approach for measuring sustainability performance of a supplier based on triple bottom line approach. *J. Clean. Prod.* **2013**, *47*, 345–354. [CrossRef]
70. Foerstl, K.; Reuter, C.; Hartmann, E.; Blome, C. Managing supplier sustainability risks in a dynamically changing environment-sustainable supplier management in the chemical industry. *J. Purch. Supply Manag.* **2010**, *16*, 118–130. [CrossRef]
71. Reuter, C.; Foerstl, K.; Hartmann, E.; Blome, C. Sustainable global supplier management: The role of dynamic capabilities in achieving competitive advantage. *J. Supply Chain Manag.* **2010**, *46*, 45–63. [CrossRef]

72. Hollos, D.; Blome, C.; Foerstl, K. Does sustainable supplier co-operation affect performance? Examining implications for the triple bottom line. *Int. J. Prod. Res.* **2012**, *50*, 2968–2986. [CrossRef]
73. Blome, C.; Paulraj, A.; Schuetz, K. Supply Chain collaboration and sustainability: A profile deviation analysis. *Int. J. Oper. Prod. Manag.* **2014**, *34*, 639–663. [CrossRef]
74. Reuter, C.; Goebel, P.; Foerstl, K. The impact of stakeholder orientation on sustainability and cost prevalence in supplier selection decisions. *J. Purch. Supply Manag.* **2012**, *18*, 270–281. [CrossRef]
75. Goebel, P.; Reuter, C.; Pibernik, R.; Sichtmann, C. The influence of ethical culture on supplier selection in the context of sustainable sourcing. *Int. J. Prod. Econ.* **2012**, *140*, 7–17. [CrossRef]
76. Leppelt, T.; Foerstl, K.; Reuter, C.; Hartmann, E. Sustainability management beyond organizational boundaries-sustainable supplier relationship management in the chemical industry. *J. Clean. Prod.* **2013**, *56*, 94–102. [CrossRef]
77. Foerstl, K.; Azadegan, A.; Leppelt, T.; Hartmann, E. Drivers of supplier sustainability: Moving beyond compliance to commitment. *J. Supply Chain Manag.* **2015**, *51*, 67–92. [CrossRef]
78. Blome, C.; Hollos, D.; Paulraj, A. Green procurement and green supplier development: Antecedents and effects on supplier performance. *Int. J. Prod. Res.* **2014**, *52*, 32–49. [CrossRef]
79. Yazdani, M.; Hashemkhani Zolfani, S.; Zavadskas, E.K. New integration of mcdm methods and qfd in the selection of green suppliers. *J. Bus. Econ. Manag.* **2016**, *17*, 1097–1113. [CrossRef]
80. Tavana, M.; Yazdani, M.; Di Caprio, D. An application of an integrated anp-qfd framework for sustainable supplier selection. *Int. J. Logist.-Res. Appl.* **2017**, *20*, 254–275. [CrossRef]
81. Shahryari Nia, A.; Olfat, L.; Esmaeili, A.; Rostamzadeh, R.; Antucheviciene, J. Using fuzzy choquet integral operator for supplier selection with environmental considerations. *J. Bus. Econ. Manag.* **2016**, *17*, 503–526. [CrossRef]
82. Liou, J.J.H.; Tamosaitiene, J.; Zavadskas, E.K.; Tzeng, G.H. New hybrid copras-g madm model for improving and selecting suppliers in green supply Chain management. *Int. J. Prod. Res.* **2016**, *54*, 114–134. [CrossRef]
83. Keshavarz Ghorabaee, M.; Zavadskas, E.K.; Amiri, M.; Esmaeili, A. Multi-criteria evaluation of green suppliers using an extended waspas method with interval type-2 fuzzy sets. *J. Clean. Prod.* **2016**, *137*, 213–229. [CrossRef]
84. Zhu, Q.H.; Sarkis, J.; Lai, K.H. Initiatives and outcomes of green supply Chain management implementation by Chinese manufacturers. *J. Environ. Manag.* **2007**, *85*, 179–189. [CrossRef] [PubMed]
85. Zhu, Q.H.; Sarkis, J.; Cordeiro, J.J.; Lai, K.H. Firm-level correlates of emergent green supply Chain management practices in the Chinese context. *Omega-Int. J. Manag. Sci.* **2008**, *36*, 577–591. [CrossRef]
86. Wong, C.W.Y.; Lai, K.H.; Shang, K.C.; Lu, C.S.; Leung, T.K.P. Green operations and the moderating role of environmental management capability of suppliers on manufacturing firm performance. *Int. J. Prod. Econ.* **2012**, *140*, 283–294. [CrossRef]
87. Dou, Y.J.; Zhu, Q.H.; Sarkis, J. Evaluating green supplier development programs with a grey-analytical network process-based methodology. *Eur. J. Oper. Res.* **2014**, *233*, 420–431. [CrossRef]
88. Dou, Y.J.; Zhu, Q.H.; Sarkis, J. Integrating strategic carbon management into formal evaluation of environmental supplier development programs. *Bus. Strategy Environ.* **2015**, *24*, 873–891. [CrossRef]
89. Kusi-Sarpong, S.; Sarkis, J.; Wang, X.P. Assessing green supply Chain practices in the Ghanaian mining industry: A framework and evaluation. *Int. J. Prod. Econ.* **2016**, *181*, 325–341. [CrossRef]
90. Choi, S.B.; Min, H.; Joo, H.Y.; Choi, H.B. Assessing the impact of green supply Chain practices on firm performance in the korean manufacturing industry. *Int. J. Logist. Res. Appl.* **2017**, *20*, 129–145. [CrossRef]
91. Diabat, A.; Govindan, K. An analysis of the drivers affecting the implementation of green supply Chain management. *Resour. Conserv. Recycl.* **2011**, *55*, 659–667. [CrossRef]
92. Teixeira, A.A.; Jabbour, C.J.C.; Jabbour, A.; Latan, H.; de Oliveira, J.H.C. Green training and green supply Chain management: Evidence from Brazilian firms. *J. Clean. Prod.* **2016**, *116*, 170–176. [CrossRef]
93. Tsai, S.B.; Wei, Y.M.; Chen, K.Y.; Xu, L.; Du, P.; Lee, H.C. Evaluating green suppliers from a green environmental perspective. *Environ. Plan. B-Plan. Des.* **2016**, *43*, 941–959. [CrossRef]
94. Tsui, C.W.; Tzeng, G.H.; Wen, U.P. A hybrid mcdm approach for improving the performance of green suppliers in the tft-lcd industry. *Int. J. Prod. Res.* **2015**, *53*, 6436–6454. [CrossRef]
95. Yoshikane, F. Multiple regression analysis of a patent's citation frequency and quantitative characteristics: The case of japanese patents. *Scientometrics* **2013**, *96*, 365–379. [CrossRef]

96. Ale Ebrahim, N.; Salehi, H.; Embi, M.A.; Habibi, F.; Gholizadeh, H.; Motahar, S.M.; Ordi, A. Effective strategies for increasing citation frequency. *Int. Educ. Stud.* **2013**, *6*, 93–99. [CrossRef]
97. Agryzkov, T.; Oliver, J.L.; Tortosa, L.; Vicent, J. A new betweenness centrality measure based on an algorithm for ranking the nodes of a network. *Appl. Math. Comput.* **2014**, *244*, 467–478. [CrossRef]
98. Srivastava, S.K. Green supply-Chain management: A state-of-the-art literature review. *Int. J. Manag. Rev.* **2007**, *9*, 53–80. [CrossRef]
99. Pagell, M.; Wu, Z. Building a more complete theory of sustainable supply Chain management using case studies of 10 exemplars. *J. Supply Chain Manag.* **2009**, *45*, 37–56. [CrossRef]
100. Vachon, S.; Klassen, R.D. Environmental management and manufacturing performance: The role of collaboration in the supply Chain. *Int. J. Prod. Econ.* **2008**, *111*, 299–315. [CrossRef]
101. Carter, C.R.; Carter, J.R. Interorganizational determinants of environmental purchasing: Initial evidence from the consumer products industries. *Decis. Sci.* **1998**, *29*, 659–684. [CrossRef]
102. Krause, D.R.; Scannell, T.V.; Calantone, R.J. A structural analysis of the effectiveness of buying firms' strategies to improve supplier performance. *Decis. Sci.* **2000**, *31*, 33–55. [CrossRef]
103. Geffen, C.A.; Rothenberg, S. Suppliers and environmental innovation: The automotive paint process. *Int. J. Oper. Prod. Manag.* **2000**, *20*, 166–186. [CrossRef]
104. Bowen, F.E.; Cousins, P.D.; Lamming, R.C.; Farukt, A.C. The role of supply management capabilities in green supply. *Prod. Oper. Manag.* **2001**, *10*, 174–189. [CrossRef]
105. Rao, P. Greening the supply Chain: A new initiative in south East Asia. *Int. J. Oper. Prod. Manag.* **2002**, *22*, 632–655. [CrossRef]
106. Klassen, R.D.; Vachon, S. Collaboration and evaluation in the supply Chain: The impact on plant-level environmental investment. *Prod. Oper. Manag.* **2003**, *12*, 336–352. [CrossRef]
107. Bai, C.; Sarkis, J. Integrating sustainability into supplier selection with grey system and rough set methodologies. *Int. J. Prod. Econ.* **2010**, *124*, 252–264. [CrossRef]
108. Awasthi, A.; Chauhan, S.S.; Goyal, S.K. A fuzzy multicriteria approach for evaluating environmental performance of suppliers. *Int. J. Prod. Econ.* **2010**, *126*, 370–378. [CrossRef]
109. Kuo, R.J.; Wang, Y.C.; Tien, F.C. Integration of artificial neural network and mada methods for green supplier selection. *J. Clean. Prod.* **2010**, *18*, 1161–1170. [CrossRef]
110. Hsu, C.-W.; Hu, A.H. Applying hazardous substance management to supplier selection using analytic network process. *J. Clean. Prod.* **2009**, *17*, 255–264. [CrossRef]
111. Lee, A.H.I.; Kang, H.Y.; Hsu, C.F.; Hung, H.C. A green supplier selection model for high-tech industry. *Expert Syst. Appl.* **2009**, *36*, 7917–7927. [CrossRef]
112. Zhu, Q.; Sarkis, J.; Lai, K.-H. Confirmation of a measurement model for green supply Chain management practices implementation. *Int. J. Prod. Econ.* **2008**, *111*, 261–273. [CrossRef]
113. Sarkis, J.; Gonzalez-Torre, P.; Adenso-Diaz, B. Stakeholder pressure and the adoption of environmental practices: The mediating effect of training. *J. Oper. Manag.* **2010**, *28*, 163–176. [CrossRef]
114. Handfield, R.; Walton, S.V.; Sroufe, R.; Melnyk, S.A. Applying environmental criteria to supplier assessment: A study in the application of the analytical hierarchy process. *Eur. J. Oper. Res.* **2002**, *141*, 70–87. [CrossRef]
115. Vachon, S. Green supply Chain practices and the selection of environmental technologies. *Int. J. Prod. Res.* **2007**, *45*, 4357–4379. [CrossRef]
116. Vachon, S.; Klassen, R.D. Supply Chain management and environmental technologies: The role of integration. *Int. J. Prod. Res.* **2007**, *45*, 401–423. [CrossRef]
117. Walker, H.; Di Sisto, L.; McBain, D. Drivers and barriers to environmental supply Chain management practices: Lessons from the public and private sectors. *J. Purch. Supply Manag.* **2008**, *14*, 69–85. [CrossRef]
118. Tsai, W.-H.; Hung, S.-J. A fuzzy goal programming approach for green supply Chain optimisation under activity-based costing and performance evaluation with a value-Chain structure. *Int. J. Prod. Res.* **2009**, *47*, 4991–5017. [CrossRef]
119. Zhu, Q.; Sarkis, J.; Lai, K.-h. Green supply Chain management implications for "closing the loop". *Transp. Res. Part E Logist. Transp. Rev.* **2008**, *44*, 1–18. [CrossRef]
120. Green, K.W.; Zelbst, P.J.; Meacham, J.; Bhadauria, V.S. Green supply Chain management practices: Impact on performance. *Supply Chain Manag. Int. J.* **2012**, *17*, 290–305. [CrossRef]
121. Seuring, S.; Müller, M. Core issues in sustainable supply Chain management—A Delphi study. *Bus. Strategy Environ.* **2008**, *17*, 455–466. [CrossRef]

122. Zhu, Q.; Dou, Y.; Sarkis, J. A portfolio-based analysis for green supplier management using the analytical network process. *Supply Chain Manag. Int. J.* **2010**, *15*, 306–319. [CrossRef]
123. Ho, W.; Xu, X.; Dey, P.K. Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. *Eur. J. Oper. Res.* **2010**, *202*, 16–24. [CrossRef]
124. Shaw, K.; Shankar, R.; Yadav, S.S.; Thakur, L.S. Supplier selection using fuzzy ahp and fuzzy multi-objective linear programming for developing low carbon supply Chain. *Expert Syst. Appl.* **2012**, *39*, 8182–8192. [CrossRef]
125. Bai, C.G.; Sarkis, J. Green supplier development: Analytical evaluation using rough set theory. *J. Clean. Prod.* **2010**, *18*, 1200–1210. [CrossRef]
126. Tseng, M.-L.; Chiu, A.S. Evaluating firm's green supply Chain management in linguistic preferences. *J. Clean. Prod.* **2013**, *40*, 22–31. [CrossRef]
127. Shen, L.; Olfat, L.; Govindan, K.; Khodaverdi, R.; Diabat, A. A fuzzy multi criteria approach for evaluating green supplier's performance in green supply Chain with linguistic preferences. *Resour. Conserv. Recycl.* **2013**, *74*, 170–179. [CrossRef]
128. Hsu, C.W.; Kuo, T.C.; Chen, S.H.; Hu, A.H. Using dematel to develop a carbon management model of supplier selection in green supply Chain management. *J. Clean. Prod.* **2013**, *56*, 164–172. [CrossRef]
129. Govindan, K.; Rajendran, S.; Sarkis, J.; Murugesan, P. Multi criteria decision making approaches for green supplier evaluation and selection: A literature review. *J. Clean. Prod.* **2015**, *98*, 66–83. [CrossRef]