Green Supply Chain Performance Measures: A Review and Bibliometric Analysis

Deepa Mishra[a], Angappa Gunasekaran[b], Thanos Papadopoulos[c] and Benjamin Hazen[d]

[a]Department of Industrial and Management Engineering, IIT Kanpur, Kanpur 208016, India

[b]Charlton College of Business, University of Massachusetts Dartmouth, North Dartmouth, MA, USA

[c]Kent Business School, University of Kent, Sail & Colour Loft, The Historic Dockyard, Chatham ME4 4TE United Kingdom

[d]University of Tennessee, Department of Marketing and Supply Chain Management, Knoxville, TN, USA

ABSTRACT

The concept of green supply chain management is evolving rapidly and gaining popularity in the research community. This research reviews the literature on green supply chain performance measures and for the purpose of providing thorough insight into the field. Using bibliometric and network analysis, the research critically evaluates 653 articles published over the past 22 years and identifies some of the top contributing authors, organizations and key research topics related to the field. In addition, the most influential works based on citations and PageRank have also been obtained and compared. At last, major research areas and potential future directions are identified by conducting network analysis.

Keywords: Green supply chain management; Performance measures; Bibliometric analysis; Network analysis

1. Introduction

Nowadays, organizations are increasingly facing competitive, regulatory, and community pressures, which makes it important to maintain a balance between economic and environmental performance (Shultz and Holbrook, 1999). In order to reduce these pressures and achieve environmental sustainability, firms need to incorporate strategies that will help in minimising the environmental impact of their products and services (Lewis and Gretsakis, 2001; Sarkis, 1995, 2001). It has been argued that firms can project an environmental image by reviewing and readjusting the principles upon which their business are based (Hick, 2000). In addition, Hansmann and Claudia (2001) noted that if an enterprise is able to successfully address the environmental issues, then it may generate more opportunities for competition and more methods

to increase value of core business programs. Various factors that propel competitive advantage via environmental performance were observed by the Confederation of British Industries (CBI) in 1994, and include market expectations, risk management, regulatory compliance and business efficiency (Zhu et al., 2005). In this context, green supply chain management (GSCM) emerges as a powerful tool which makes sure that all these factors are properly handled (Hutchison, 1998). Thus, GSCM helps a firm in gaining goodwill, profit and market share by minimising environmental risks and impacts, and at the same time, enhancing their ecological efficiency (Van Hoek and Erasmus, 2000).

With the considerable development in the area of GSCM, both researchers and practitioners of operations and supply chain management are interested in measuring green supply chain performance. The significance of measurements can be understood by Kaplan's (1990) claim that, "No measures, no improvement." According to Neely et al. (1995), a performance measure is "a set of metrics which helps in quantifying the efficiency and/or effectiveness of an action". Prior research reveals that various performance measures have been proposed for supply chains (Folan and Browne, 2005; Fynes et al., 2005; Gunasekaran and Kobu, 2007). However, these measures are inadequate in capturing the objectives, namely, economic efficiency and environmental protection, of green supply chains. This has led to the necessity of developing new and more inclusive green supply chain performance measures (GSC-PM).

In the past few years, scholars have reviewed the growing amount of literature on green and sustainable supply chain management (SSCM). Srivastava (2007) and Seuring and Müller (2008) provided a thorough review while Taticchi et al. (2013), Igarashi et al. (2013), Brandenburg et al. (2014) and Govindan et al. (2014), focused on some particular aspects of this field. For instance, Taticchi et al. (2013) critically reviewed the sustainable supply chain performance measurement literature and provided a roadmap for future research. Igarashi et al. (2013) reviewed the literature on green supplier selection and proposed a conceptual model. In addition, a comprehensive literature review was conducted by Govindan et al. (2014) on reverse logistics and closed loop supply chains. They reviewed 382 scientific articles through content analysis and identified future research opportunities. Although the aforementioned studies have been instrumental in reviewing and assimilating the existing literature, we propose that additional insight can be obtained by conducting a systematic review via rigorous quantitative bibliometric tools. With these tools, network analysis can be performed, which helps in identifying the established and emerging areas of research and in identifying the most influential scholars in the field. One such attempt has been made by Fahimnia et al. (2015) who reviewed GSCM literature using rigorous bibliometric tools.

To the best of our knowledge, no such study has been done on the performance measures of green supply chain, thus providing the impetus for this research.

Hence, the purpose of this paper is to review the literature on GSC-PM by exploiting rigorous bibliometric tools, and to aid the creation and accumulation of knowledge in this area by summarizing what we know about the subject. Specifically, the objectives of this paper are as follows: (i) review the literature on GSC-PM, that was published between 1995 and 2016; (ii) provide a thorough insight into the field by identifying top contributing authors, countries, journals and key research topics related to the field; (iii) obtain and compare the most influential works based on citations and PageRank; and (iv) identify established and emerging research clusters which would encourage scientists and researchers to explore and expand this body of research. By addressing these objectives, we aim to provide readers with a comprehensive understanding of the GSC-PM domain. We believe that this review will be significant for researchers, who want to recognise topic areas where research is lacking or have been researched, as well as for practitioners, who want to know the state of research and stay up to date on GSC-PM.

The outline for this article is as follows: in the next section, we review the literature on GSC-PM, which is followed by the presentation of the research method. Then, we present a detailed analysis using rigorous bibliometric tools. The paper ends with a short discussion of conclusions, limitations and future research directions.

2. Literature review

Green supply chains are defined as the extension of traditional supply chains with an aim to reduce environmental impacts of a product throughout its life cycle (Beamon, 1999b). By focussing on green design, resource saving, harmful material reduction, and product recycling or reuse, industries try to improve the environmental performance of their supply chains (Holt and Ghobadian, 2009; Lau, 2011; Testa and Iraldo, 2010). In literature, the term "green supply chain" has often been used interchangeably with closed loop supply chain (van Hoek, 1999; Beamon, 1999b; Steven, 2004; Inderfurth, 2004; Spengler et al., 2004; Zhu and Sarkis, 2006), sustainable supply chain (Linton et al., 2007; Beamon, 2005), integrated supply chain (Preuss, 2001; Mezher and Ajam, 2006; Vachon and Klassen, 2006; Zhu and Sarkis, 2006) and reverse logistics (Carter and Ellram, 1998; Fleischmann et al., 1997). However, it was found that no matter what terminology is chosen, the core tenet is a general focus on the environment. For instance, Ahi and Seary (2013) explained that SSCM is an extension of GSCM because it is a concept of supply chain management that is extended to include the economic, ecological (environmental), and societal aspects of business practices and theory. Carter and Ellram (1998) defined reverse logistics as a

process through which companies can become more environmentally efficient by recycling, reusing, and reducing the amount of materials used. Hence, we define a GSCM as "*the sum of green purchasing, green manufacturing and material management, green distribution and marketing, and reverse logistics*" (Hervani et al., 2005; Linton et al., 2007; Zhu and Sarkis, 2006). Scholars (Hervani et al., 2005; Rao, 2002) noted that GSCM has emerged as an approach to enhance competiveness and follow the environmental requirements of various regulatory bodies. It is "as an important new archetype for enterprises to achieve profit and market share objectives by lowering their environmental risks and impacts while raising their ecological efficiency" (Zhu et al., 2005, p. 450).

Prior research reveals that it is important to focus on the development of performance measures and metrics (Beamon, 1999; Gunasekaran et al., 2001; 2004; Lai et al., 2002). Harrington (1991, p. 164) suggested that '*If you cannot measure it, you cannot control it. If you cannot control it, you cannot manage it. If you cannot manage it, you cannot improve it'*. According to Wong and Wong (2008), the attempt of organizations to attain sustainable development at each level can be monitored by defining performance measures. In fact, performance measurement is beneficial in balancing the processes of GSCM and in finding out the areas where improvement is needed (Bond, 1999). Olugu and Wong (2009) conducted a detailed study on performance measurement and revealed that by measuring the performance of green supply chain, a firm can decide whether to continue with its current strategy or further improve it. Hence, performance measurement of green supply chains (GSC-PM) not only facilitates external reporting, internal control (managing the business better), and internal analysis (understanding the business better and continuous improvement), but also plays an important role in the planning, design, implementation and monitoring of systems (Hervani et al., 2005; Bjorklund et al., 2012). Emphasizing on the benefits of performance measurement, Zhu et al. (2008) stated that various forms of scales can be used to measure GSCM with an aim for continuous improvements, implementation of GSCM, and benchmarking.

A wide range of metrics to measure performance of green supply chains have been proposed in literature (Ahi and Searcy, 2015). For instance, Hervani et al. (2005) noted that the overall objective of a green supply chain is to reduce the negative environmental impacts (air, water, and land pollution) and waste of resources (energy, materials, products) starting from the extraction of raw materials up to the final usage and delivery of products. They proposed the use of ISO 14031 as a basis for the performance measurement of green supply chains. In addition, Bjorklund and colleagues performed a literature review on logistics management and performance measurement with a link to environmental logistics theory, and highlighted the need of investigating the impact of environmental measurement activities on external agents (Bjorklund et al., 2012). They noted

that various process-oriented measures should be incorporated at different managerial levels in the supply chain. In an attempt to capture the attention that buyers pay to the incoming quality of products provided by suppliers, "quality" was introduced as a measure of GSCM by Graham et al. (1994) and was later used in the studies of Buyukozkan and Cifci (2011), Gold et al. (2010), Kuo et al. (2010) and Zhu et al. (2010). In addition, "information processing cost" and "air emissions" are the other two metrics that focus on GSCM (Stewart, 1995; Hart and Ahuja, 1996; Klassen and McLaughlin, 1996). Kuo et al. (2010) considered "green competencies", "current environment efficiency", "supplier's green image", and "net life cycle cost" as the metrics for assessing supplier performance.

Furthermore, tools such as, analytical hierarchy process (AHP), activity-based costing, design for environment analysis (DEA), life cycle analysis and balanced scorecard (BSC) have been introduced for GSC-PM. Among these, few tools can be directly used for assessing the performance, while others need to be adapted. For instance, Faruk et al. (2002) introduced a management tool known as ecological supply chain analysis (ECOSCAN) to examine the effect of environmental management across the supply chain. This tool is based on the life cycle analysis model which focuses on the connection between life cycle analysis and GSCM methods. In addition, AHP initially developed by Saaty (1980), was viewed as a decision support model by Handfield et al. (2002), Pineda-Henson et al. (2002) and Sarkis (1998, 2003). This model can assist the managers in comprehending the trade-offs between environmental dimensions. Handfield et al. (2002) integrated AHP with a comprehensive information system which supports Environmentally Conscious Purchasing. AHP has also been used to assess the impact of environment by following life cycle assessment approach which mainly deals with the manufacturing operations (Pineda-Henson et al., 2002), and to choose the environment friendly practices and technology (Sarkis, 1998, 2003) inside the firms and some considering supply chain issues. Another important tool for performance measurement was introduced by Kaplan and Norton (1992), termed as 'balanced scorecard'. Through this tool, a firm can develop vision, strategy and put them into actions. Balanced scorecard provides feedback on internal processes as well as on external results so that strategic performance and results can be continuously improved. In an attempt to include environmental performance measures, extensions have been made to BSC (Epstein and Wisner, 2001; Zingales et al., 2002). Examples of environmental performance measures based on the categories of BSC are shown in Table 1.

Table 1

Environmentally based performance measures by the balanced scorecard categories.

Financial	Internal Process
Percentage of proactive vs reactive expenditures	Percentage of production and office materials recycled
$ Capital investments	# Certified suppliers
$ Operating expenditures	# Accidents and spills
Disposal costs	Internal audit scores
Recycling revenues	Energy consumption
Revenues from "green" products	Percentage of facilities certified
$ Fines and penalties	Percentage of product remanufactured
Cost avoidance from environmental actions	Energy use
	Greenhouse gas emissions
	Hazardous material output
Customer	**Learning and growth**
# Green products	Percentage of Employees trained
Product safety	# Community complaints
# Recalls	Percentage of renewable resource use
Customer returns	# Violations reported by employees
Unfavourable press coverage	# Employees with incentives related to environmental goals
Percentage of products reclaimed after use	# Functions with environmental responsibilities
Functional product eco-efficiency	Emergency response programs

*Source: Hervani et al. (2005)

Additionally, a robust tool known as data envelopment analysis has been developed to measure performance. The mathematical programming models of DEA are designed in a way that it can be used as a tool for multiple criteria decision evaluation (Hervani et al., 2005). In their work on environmental performance measurement, Sarkis and Talluri (2004) summed up the applications and recommendations of DEA. Nagel (2004) used ratios to determine the environmental performance of the suppliers and Harris (2004) discussed the business value of strategic sourcing and environmental issues.

3. Research methodology and data statistics

Literature review is one of the most important elements of any research work. It aims to map and assess the relevant literature in order to identify the possible research gaps which would be helpful in further strengthening the body of knowledge (Tranfield et al., 2003). In view of Saunders et al. (2009), a structured literature review is conducted herein by adopting an iterative cycle which starts by defining relevant keywords, followed by literature search, and ends with the analysis. For creating a literature review, a five step methodology was proposed by Rowley and Slack (2004) which includes scanning documents, making notes, structuring the literature review, writing the literature review, and building the bibliography. In a similar manner, we adopted a five step literature review process to identify the influential works, ascertain the recent areas of research and offer insights into current research interests and directions for future research in the field. Figure 1 shows the research methodology adopted in this paper.

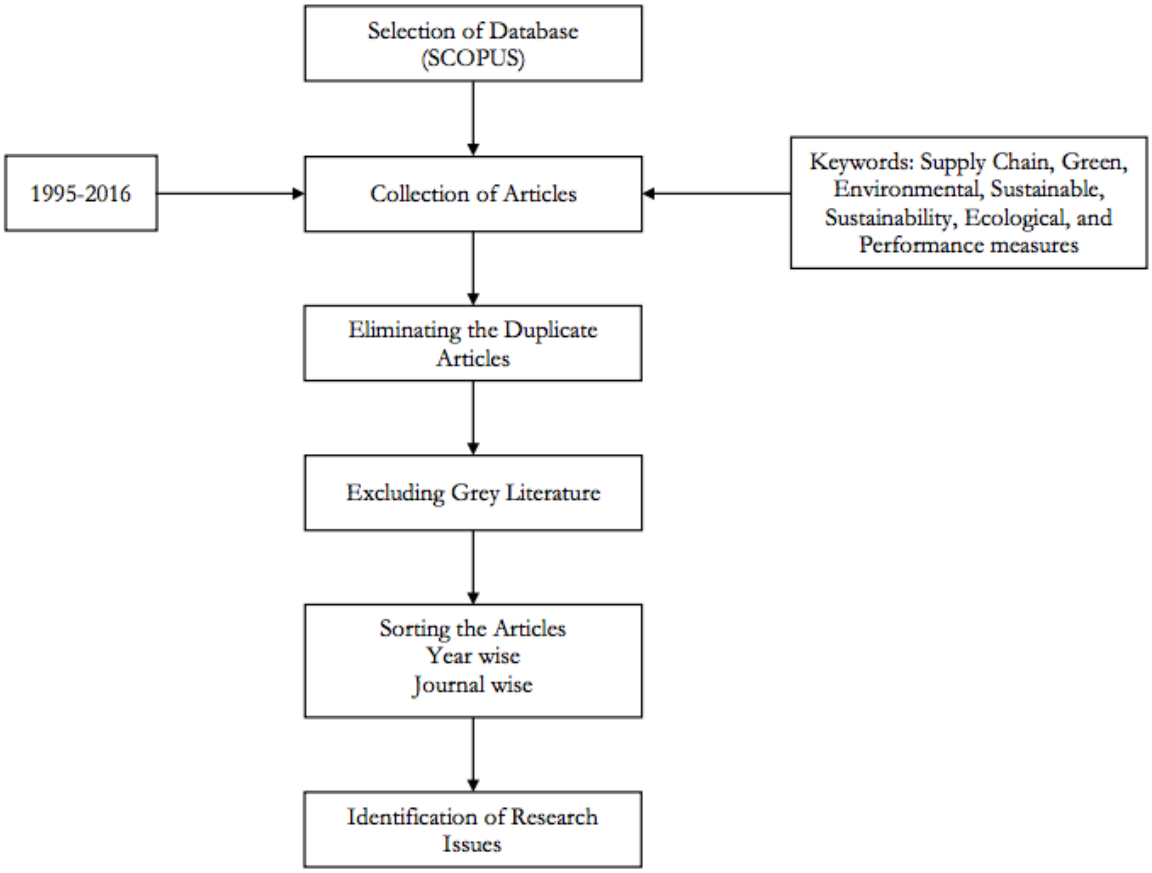

Figure 1: Research methodology

3.1 Defining keywords

In this study, the following query keywords were used: *Supply Chain*, *Green, Environmental, Sustainable, Sustainability, Ecological,* and *Performance measures*. Using these keywords, five different combinations were made which are (1) Green AND Supply Chain, (2) Environmental AND Sustainable AND Supply Chain, (3) Environmental AND Sustainability AND Supply Chain, (4) Ecological AND Supply Chain, (5) Performance measures AND Green AND Supply chain. While selecting keywords, we tried to ensure that the aspects of green supply chain as well as its performance measures were fully captured.

3.2 Initial results

We collected articles using the Scopus database. The reason for restricting ourselves to Scopus is that it is the largest abstract and citation database and includes over 20,000 peer-reviewed journals in the fields of science, technology, medicine, social sciences, and arts and humanities (Fahimnia et al., 2015). These peer-reviewed journals belong to various publishing houses including Elsevier,

Emerald, Informs, Taylor and Francis, Springer and Inderscience. According to Yong-Hak (2013), Scopus database is more comprehensive as compared to Web-of-Science (WoS) database, since WoS includes only ISI indexed journals which is limited to only 12,000 titles. In addition, Chicksand et al. (2012) suggested that Scopus is a good source of supply chain peer reviewed articles.

The aforementioned keywords were searched in "title, abstract, keywords" of articles belonging to Scopus database. The initial search resulted in 2078 articles. Table 2 shows the number of articles obtained for each combination of keywords. The results were then saved in RIS format which contained the necessary information related to the paper such as title, authors' names and affiliations, abstract, keywords and references.

Table 2

Initial results.

Search keywords	Search results (no. of papers)
Green AND Supply chain	679
Environmental AND Sustainable AND Supply Chain	525
Environmental AND Sustainability AND Supply Chain	428
Ecological AND Supply Chain	259
Performance measures AND Green AND Supply chain	187
Total	2078

3.3 Refining the initial results

For the refinement of the search results, duplicates were removed as few papers were present in more than one combination of keywords. On eliminating such duplications, we were left with 1896 papers. Following the objectives of our study, we restricted those papers to scientific articles that appeared in peer reviewed journals, as these can be considered as "certified knowledge" (Rodriguez et al., 2004). This reduction resulted in 1343 relevant documents, published during the 22-year period of 1995-2016. The breakdown of refined search results for each of the five combination of keywords is shown in Table 3. For carrying out these refinements in the RIS file, Endnote bibliography software was used. Then, the final RIS data file was stored for future analysis.

Table 3

Refined search results.

Search keywords	Search results (no. of papers)
Green AND Supply chain	523
Environmental AND Sustainable AND Supply Chain	397
Environmental AND Sustainability AND Supply Chain	127
Ecological AND Supply Chain	158
Performance measures AND Green AND Supply chain	138
Total	1343

3.4 Initial data statistics

To further reduce the number of articles and ensure quality of articles analysed, we further narrowed down the retained articles to those that were in the top 20 journals (in terms of quantity of papers published that met our aforementioned criteria). It was found that these journals have published 653 articles in this field of research. For each of these journals, Table 4 shows the number of articles published during the time period 1995-2016. It also depicts the total number of articles published in each year.

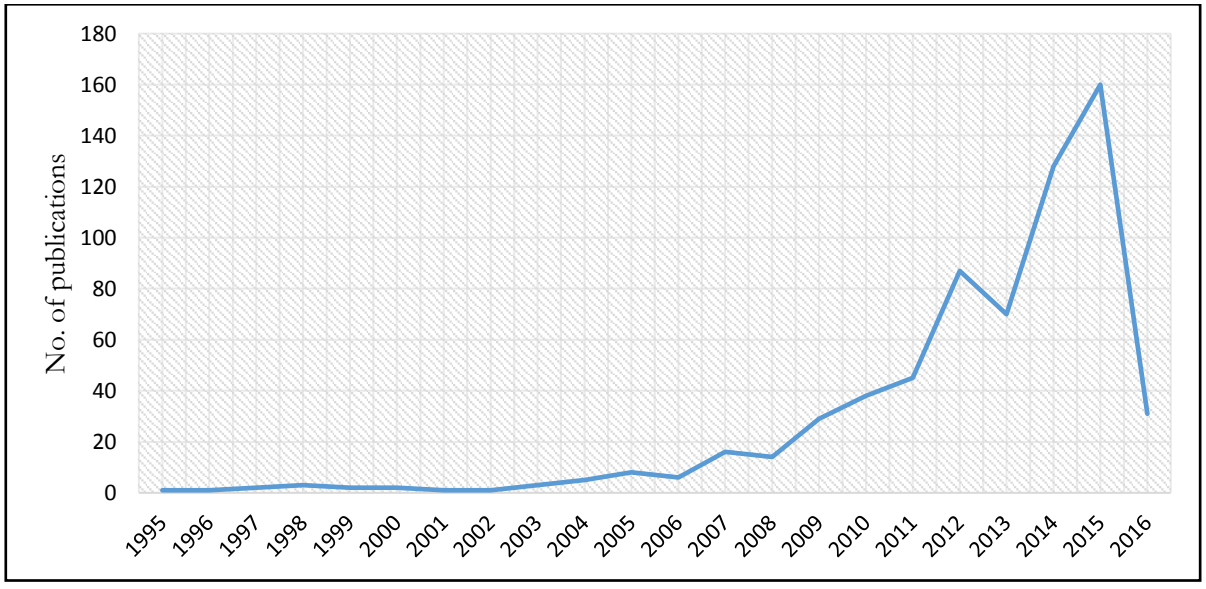

Figure 2. Publication frequency during 1995-2016.

Figure 2 demonstrates the changing pattern of publications in each year, starting from 1995 until the beginning of 2016. It can be clearly seen from the figure that the number of publications on GSC-PM increased slowly from 1995 to 2006. Interestingly, a dramatic rise in publications of this field can be observed after 2007. This indicates that the interest of scholars has increased rapidly in the past 10 years.

Table 4

Journal-wise publication breakdown table.

Source	Publication year																					
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
JCP															7	8	6	7	39	41	52	16	176
IJPE							1					2	1	5	1	1	4	19	3	20	25		82
SCM:IJ				2	1	1				1	1	1		2	3		1	15	4	9	10	1	52
IJPR													6		3	3	1	11	5	6	17		52
BSE		1	1		1					1	3	1	1	4	1	3	3	2	3	8	8		41
RCR																1	6	4	3	6	7	3	30
IJPDLM						1							1	2	1	6	3	3	1	1	5		24
EJOR	1			1						1					2	1		4	2	7	2	1	22
PPC													1					6	2	6	4	2	21
IJOPM								1	1		2	1	1			1		1	1	4	4	2	19
IJLSM														1		1	1	2		11	1		17
EE			1						1	1	1		2		2	2	2	3	1		1		17
MRR																1	7		1		5		14
BIJ									1		1	1				3	2	2		1	3		14
JMTM															1	1	1		1	4	6		14
JIE															4	1	2	2	1	1	3		14
JSCM															3	2		1	2	1	2	2	13
Sustainability															1	3	4	4					12
EI																	1	1	1	1	5	3	12
JOM										1			3				1			1		1	7
Total	1	1	2	3	2	2	1	1	3	5	8	6	16	14	29	38	45	87	70	128	160	31	653

3.5 Data analysis

The process of data analysis was performed in two steps, that is, bibliometric analysis and network analysis, which will be discussed in the forthcoming sections. Bibliometric analysis is a straightforward analytical technique of measuring and assessing a large number of scientific publications and citations (Ismail et al., 2009). Using bibliometric tools for conducting network analysis is a powerful approach to identify established and emerging relevant areas of research. It also proves beneficial in determining the clusters of research and researchers depicting the manner in which different schools of thought might have emerged on the basis of author and institutional characteristics. By doing so, one can get an idea of the recent topics covered by these researchers and hence, recognize the additional emerging research fields (Fahimnia et al., 2015).

For conducting bibliometric analysis, BibExcel software was used which provides data statistics containing author, affiliation and keyword statistics. The reason for choosing BibExcel is that it provides flexibility to deal with huge amount of data and is compatible with other applications such as, Excel, Pajek and Gephi (Persson et al., 2009). Through BibExcel, data is prepared for network analysis. This analysis is done using Gephi, which is preferred over Pajek (Batagelj and Mrvar, 2011) and VOS viewer (van Eck and Waltman, 2013) as it has the ability to handle large

data sets efficiently and can produce a range of innovative visualization, analysis and investigation options.

4. Bibliometric analysis

Earlier, different software packages were used for conducting bibliometric analysis, where each software had its own capabilities and limitations. Among them, the most popular ones are Publish or Perish, HistCite, and BibExcel. In this study, we chose BibExcel as it is highly flexible in changing and altering the imported data from different databases like Scopus and WoS. Another advantage of using BibExcel is its ability to offer an extensive data analysis which can be further used by network analysis tools; Gephi, VOS viewer and Pajek. For instance, HistCite can only work with data imported from WoS while, Publish or Perish works with Google Scholar and Microsoft Academic Search. It is worth mentioning here that except BibExcel, other tools do not generate data for future network analysis.

The data entered in BibExcel is in RIS format and contains all the necessary bibliographic information related to the papers. In our analysis, we mainly concentrate on the information of authors, title, journal, publication year, keywords, affiliations, and references. During these analyses, RIS file is converted into different formats and, as a result, various file types are produced. To get a thorough knowledge about the processes and applications of BibExcel, readers may refer Paloviita (2009) and Persson et al. (2009). The coming sub-sections present statistics on author, affiliation and keyword that is obtained from BibExcel analysis.

4.1 Author influence

In order to analyse the influence of authors using BibExcel, the author field was first taken out from the RIS data file and then the frequency of occurrence of these authors was noted. In Table 5, the top ten contributing authors along-with their number of publications is mentioned. It can be clearly observed that Sarkis with 34 publications dominates the list, and is followed by Govindan with 23 publications. It is worth mentioning here that Sarkis and Zhu have also co-authored a large number of papers. In addition, Govindan has published papers with a variety of researchers including Kannan, D., Diabat, A, Seuring S., and Geng Y.

Table 5

Top ten contributing authors.

Author	Number of published articles
Sarkis, J.	34
Govindan, K.	23
Zhu, Q.	13
Kannan, D.	9
Diabat, A.	8
Genovese, A.	7
Lenzen, M.	7
Seuring, S.	7
Gunasekaran, A.	6
Geng, Y.	6

4.2 Affiliation statistics

In a similar manner, we used BibExcel to extract the affiliation of authors from the RIS data file. Then, corresponding to each affiliation, the city in which the organization is situated was taken out for further analysis. Through the coordinates of these cities, the geographical locations of all the contributing organizations were obtained in gpsvisualizer.com (Figure 3).

Figure 3. Geographical locations of contributing countries.

The red circles show the origin of contribution for the organizations in the field of green supply chain. As can be seen, organizations in the Eastern United States and the Western Europe are the major contributors. In fact, the overall dispersion of red circles in the map depicts that researchers across the world are attracted towards the area of green supply chain. Table 6 shows the top performing organizations, their geographical location and the number of publications. On comparing Table 5 and Table 6, it can be noticed that the top contributing authors, that is, Sarkis, Govindan, Zhu and Kannan, belong to Clark University, University of Southern Denmark, Dalian University of Technology and Aalborg University, respectively. Hence, we may conclude that the work of one or two researchers is sufficient to make an organization a top performer (Fahimnia et al., 2015). Table 7 shows the top 20 countries contributing in the field of GSC-PM.

Table 6

Top 10 contributing organizations.

Organization	Location	No. of Papers
University of Southern Denmark	Denmark	25
Clark University	United States	21
Dalian University of Technology	China	15
National Taipei University	Taiwan	11
Hong Kong Polytechnic University	Hong Kong	10
Aalborg University	Denmark	9
Masdar Institute of Science and Technology	United Arab Emirates	8
Ryerson University	Canada	5
Chinese Academy of Sciences,	China	5
Cardiff University	United Kingdom	4

Table 7

Top 20 contributing countries.

Country	Number of papers	Country	Number of papers
United States	111	China	20
United Kingdom	76	Denmark	18
Germany	38	France	17
India	36	Spain	15
Italy	31	Brazil	15
Netherlands	30	Malaysia	11
Australia	30	Sweden	10
USA	28	Switzerland	10
Canada	27	Hong Kong	9
Taiwan	25	Finland	9

4.3 Keyword statistics

We performed a similar analysis in an attempt to identify the most commonly used words in the paper titles and the list of keywords. Table 8 and Table 9, shows the top 20 keywords used in the paper titles and most popular keywords from the list of keywords, respectively. On comparing these two tables, it can be clearly seen that there is a uniformity in the use of keywords in the title and the list of keywords. For instance, in both the tables the top keywords include a combination of supply chain, green, sustainable, environmental and performance measures. It is to be noted here that the most popular keywords which occur in Table 8 are actually the search keywords which we chose for this study.

Table 8

Top 20 keywords search results.

Word	Frequency	Word	Frequency
Supply chain management	328	Sustainable supply chains	79
Sustainable development	289	Life cycle	75
Supply chains	270	Chains	72
Environmental management	189	Industry	70
Sustainability	167	Manufacture	64
Green supply chain management	153	environmental performance	58
Environmental impact	144	Carbon footprint	55
Environmental sustainability	89	Greenhouse gases	53
Performance	82	logistics	50
Decision making	80	Reverse logistics	50

Table 9

Top 20 commonly used words in titles.

Word	Frequency	Word	Frequency
Supply	343	Practices	59
Chain	265	Study	58
Green	186	Analysis	55
Management	151	Approach	49
Environmental	136	Assessment	46
Sustainable	123	Industry	41
Sustainability	105	Life	40
Performance	86	Cycle	40
Chains	75	Food	36
Case	70	Supplier	35

5. Network Analysis

The most popular tools available for conducting network analysis include Pajek, VOSviewer, HistCite Graph Maker, and Gephi. In this work, we have used Gephi as it provides flexible visual aids, powerful filtering techniques, inherent toolkit for network analysis and capability to handle different data formats. However, other network analysis software lack one or the other quality of Gephi. For instance, HistCite graph maker accepts WoS data files, Pajek can only handle .Net files and VOS viewer has limited tools for performing network analysis.

Gephi is a leading open source software package which employs a 3D render engine for making large networks in real time (Gephi, 2013). Due to its flexible and multi-task architecture, it can deal with complicated datasets and generate insightful visualization. As per Bastian et al. (2009), Gephi provides "easy and broad access to network data and assist in specializing, filtering, navigating, manipulating and clustering of data". For visualization and mapping in Gephi, it is necessary to generate a dataset which includes published papers and their citations (Mishra et al., 2016a, b). Here, published papers are represented as nodes and citations as arcs or edges between the nodes. Hence, the bibliographic data that is downloaded from Scopus and saved in RIS format cannot be used directly. In that case, BibExcel software acts as a mediator which reformats the original data file to graph dataset or .NET file. This file is saved for future network analysis in Gephi.

5.1 Citation analysis

Citation analysis is performed to evaluate the citation frequency on a particular document. According to Garfield (1972), the total number of citations on a scientific journal indicates its significance in that area of research. Moreover, scholars (Sharplin and Marby, 1985; Culnan, 1986; Mishra et al., 2016a, b) emphasized that the impact of heavily cited articles on scientific research is greater than that of less cited articles. Citation analysis enables researchers to understand when the major articles in a field were published and how their popularity has evolved over time, and hence if an article is still useful for current research (Pilkington and Meredith, 2009). Despite the critics of citation analysis, it is still regarded as one of the most commonly used techniques for analysing literature and identifying the most influential author, journal, or work in that particular area of research (Mac Roberts and Mac Roberts 1989, 2010; Vokurka 1996).

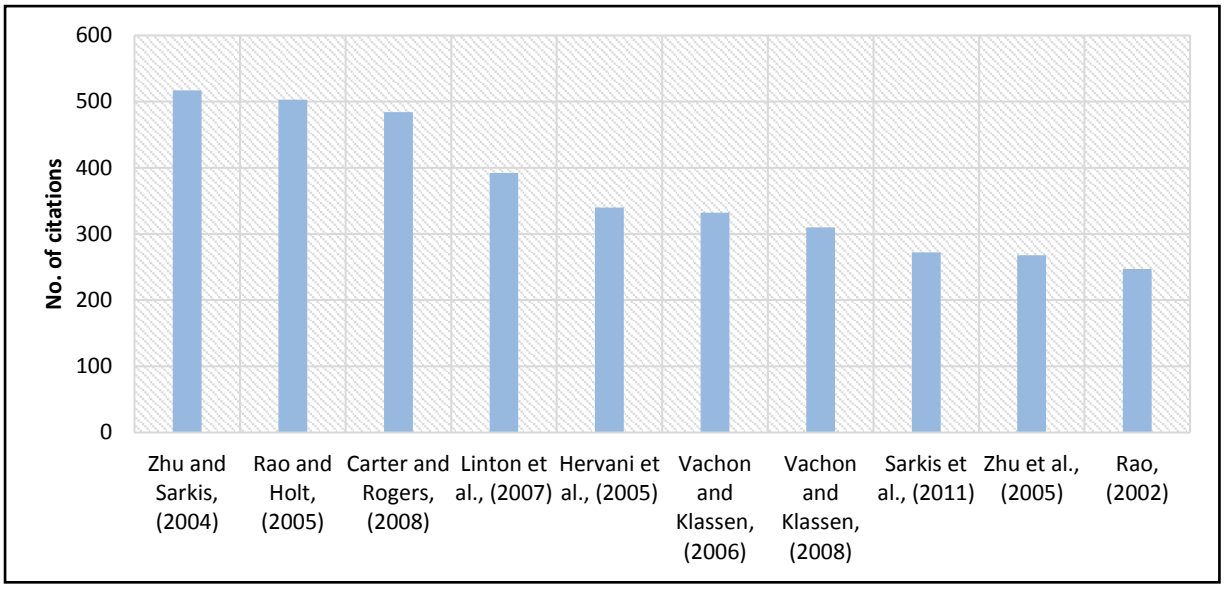

Figure 4. Frequency distribution of top 10 cited articles.

Figure 4 demonstrates the top ten influential works published between 1995 and 2016. The most influential article during this period, having received 517 citations, is the work published by Zhu and Sarkis (2004). The authors used moderated hierarchical regression analysis to examine the relationships between GSCM practice and environmental and economic performance. Another important contribution was made by Rao and Holt (2005) who established the link between GSCM practices and increased competitiveness and improved economic performance by empirically investigating a sample of organizations in South East Asia. This work received 503 citations which reflects the significance of the article in this field. Furthermore, the article by Carter and Rogers (2008) which has been cited 484 times, used conceptual theory building approach to introduce the concept of sustainability to the field of SCM and also developed a theoretical framework to provide a basic understanding of SSCM to supply chain managers. Table 10 shows the numbers of citations received by the influential articles.

Table 10

Top 10 articles based on citations.

Author (year)	Citations
Zhu Q. and Sarkis J. (2004)	517
Rao P. and Holt D. (2005)	503
Carter C.R. and Rogers D.S. (2008)	484
Linton J.D., Klassen R. and Jayaraman V. (2007)	392
Hervani A.A., Helms M.M. and Sarkis J. (2005)	340
Vachon S. and Klassen R.D. (2006)	332
Vachon S. and Klassen R.D. (2008)	310
Sarkis J., Zhu Q. and Lai K.-H. (2011)	272
Zhu Q., Sarkis J. and Geng Y. (2005)	268
Rao P. (2002)	247

5.2 PageRank analysis

The importance of a paper can be measured by different methods. Citation analysis which has been discussed above is one of the most commonly used methods (Cronin and Ding, 2011). In this regard, Ding et al. (2009) and Mishra et al. (2016a, b) claimed that popularity of a paper which is measured by the number of citations is not the only criteria to identify the significance of that paper. Prestige which reflects how many times a paper has been cited by highly cited papers, is also an important criteria. Although these measures may be positively correlated in some cases, it is not mandatory that a highly cited paper is also a prestigious paper. PageRank can be used as a measure for both popularity and prestige. It was introduced by Brin and Page (1998) as an excellent way to prioritize the results of web keyword searches.

Assume that paper A has been cited by papers T_1, …, T_n. Define a parameter d as the damping factor, which represents the fraction of random walks that continue to propagate along the citations. The value of parameter d is fixed between 0 and 1. Now, define C (T_i) as the number of times paper T_i has cited other papers. The PageRank of paper A, denoted by PR (A), in a network of N papers is calculated as follows:

$$PR(A) = \frac{(1-d)}{N} + d\left(\frac{PR(T_1)}{C(T_1)} + \cdots + \frac{PR(T_n)}{C(T_n)}\right)$$

It is important to note that if C (T_i) = 0, then PR (T_i) will be divided to the number of papers instead of C (T_i). Brin and Page (1998) argued that in the original Google PageRank algorithm, the value of parameter d was fixed at 0.85. According to Chen et al. (2007), d=0.5 is a more appropriate choice for carrying out PageRank analysis in citation networks.

The top 10 papers using PageRank analysis are shown in Table 11. On comparing Table 10 and Table 11, it is observed that the topmost paper based on citations, namely, Zhu and Sarkis (2004) has shifted to second position in the list of top ten high-PageRank papers. The second highly cited paper Rao and Holt (2005) shifted to third position whereas the third highly cited paper Carter and Rogers (2008) came down to the third last position in Table 11. In return, tha paper by Vachon and Klassen (2006) which was earlier at sixth position in Table 10 jumped to first position in Table 11. Also, the works by Seuring and Miller (2008) and Srivastava (2007) can be seen among the top ten high PageRank papers.

Table 11

Top 10 articles based on PageRank.

Author (year)	Page Rank	Citations
Vachon and Klassen, 2006	0.00488	332
Zhu and Sarkis, 2004	0.00487	517
Rao and Holt, 2005	0.00477	503
Seuring and Müller, 2008	0.00474	829
Srivastava, 2007	0.00473	861
Vachon and Klassen, 2008	0.00473	310
Rao, 2002	0.00468	247
Carter and Rogers, 2008	0.00465	484
Sarkis, 2003	0.00443	482
Zhu et al., 2005	0.00457	268

Thus, in order to get a better idea about the significance of the paper, citation analysis is not sufficient as it does not refer to the prestige of the paper which is clearly reflected by the PageRank measure.

5.3 Co-citation analysis

Co-citation analysis investigates the relationships between authors, topics, journals or keywords, thus elucidating how these groups are related with each other (Small, 1973; Pilkington and Liston Heyes, 1999). Chen et al. (2010) claimed that co-citation analysis can be conducted either on the basis of authors or publications, where, the former helps in manifesting the social structure and the latter reveals the intellectual structure of research field. This analysis can reveal the major research clusters within a particular field and how they evolve and vary across different journals over time. Leydesdorff and Vaughan (2006: in Pilkington and Meredith, 2009) suggest that data received through co-citation "can be considered as such linkage data among texts, while cited references are variables attributed to texts…one should realize that network data are different from

attributes as data. From a network perspective, for example, one may wish to focus on how the network develops structurally over time."

For performing co-citation analysis, .NET file obtained for 653 articles in BibExcel is opened in Gephi. This software generates a random map which has no visible pattern, when the .NET file is opened for the first time. However, different layouts can be created by using various algorithms of Gephi. In this study, we have used Force Atlas layout which is highly recommended by developers as it is easy to understand. In such networks, edges attract and nodes repulse each other. Bastian et al. (2009) noted that the values of repulsion strength, gravity, speed, node size and other characteristics can be altered manually. By using this algorithm, the nodes which are strongly connected move to the center of the network whereas, the less connected nodes move out to the boundaries. The Force Atlas layout of 589 node citation map is shown in Figure 5.

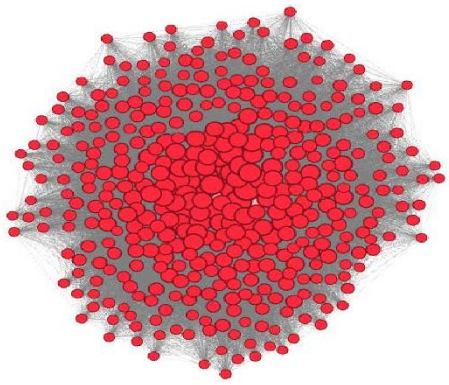

Figure 5. Force Atlas layout of 589 nodes.

The Force Atlas layout of 589 node co-citation map is shown in Fig. 5. The co-cited articles are connected with each other while, the poorly connected nodes shift away from the center. Moreover, the nodes which are isolated from rest of the network, also termed as 'outliers', are excluded for the purpose of data clustering, done in the next section. On excluding these outliers we are left with a network having 589 nodes and 1025 edges.

5.3.1 Data clustering

Data clustering is a technique that helps in grouping a set of articles (Radicchi et al., 2004; Mishra et al., 2016a, b). In a network, the nodes which represent the articles can be grouped into clusters such that the edges between the nodes of the same cluster are denser as compared to those of different clusters (Clauset et al., 2004; Leydesdorff, 2011; Radicchi et al., 2004). Blondel et al. (2008) observed that Modularity, which measures the density of links inside communities versus the links between communities, is gaining attention in the research community. In Gephi, the default

modularity tool is based on Louvain algorithm. The value of modularity index varies between -1 and +1. Blondel et al. (2008) gave the formula for calculating modularity index which is:

$$Q = \frac{1}{2m} \sum_{ij} \left[A_{ij} - \frac{k_i k_j}{2m} \right] \delta (c_i, c_j),$$

where A_{ij} represents the weight of the edge between nodes i and j, k_i is the sum of the weights of the edges attached to node i ($k_i = \sum_j A_{ij}$), c_i is the community to which vertex i is assigned, δ(u, v) is equal to 1 if u = v and 0 otherwise, and finally $m = (1/2) \sum_{ij} A_{ij}$.

On applying this algorithm to 589-node network, four major clusters were created and the modularity index was found to be 0.19. This indicates strong inter-relationships between clusters which is also clear from Figures 6a and 6b. This indicates a strong inter-relationship between the nodes of each cluster as well as between the nodes of different clusters.

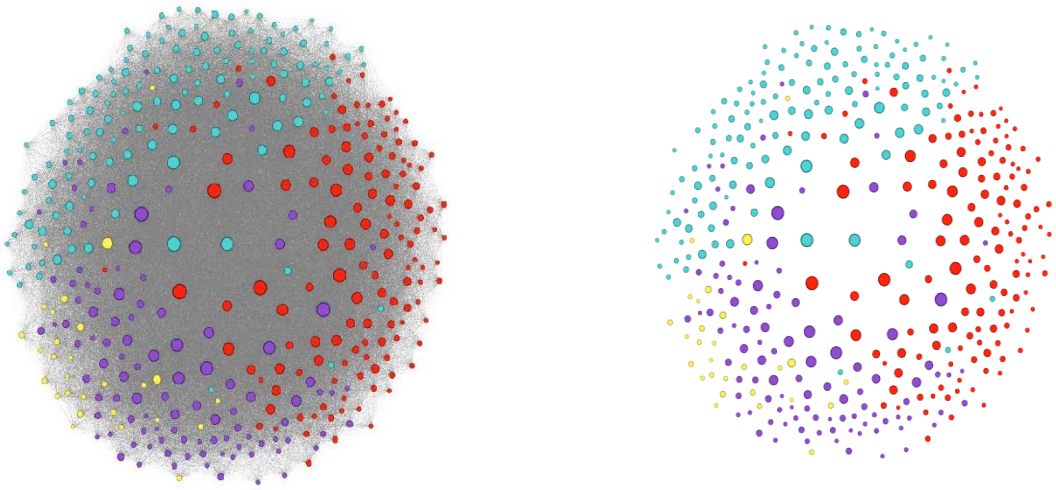

Figure 6. Structure of four clusters (a) with arcs (b) without arcs.

When two or more papers are often cited together, they are likely to share same area of interest (Hjørland, 2013). Hence, a detailed analysis of papers belonging to one cluster can help in identifying the research area of that cluster. As the number of papers in each cluster is high, we considered only the top publications of each cluster which were identified on the basis of their co-citation PageRank. Table 12 shows the top publications of each cluster.

In order to find out the area of research focus of each cluster, we carefully examined the contents and research areas of the leading papers. Table 13 briefly outlines the areas of research focus for

each of the four clusters. The classification of literature presented in Table 13 exhibits that researchers belonging to clusters 1-2 have contributed by giving theoretical, conceptual and empirical studies which mainly focus on improving environmental and economic performance of supply chains. Despite the fact that both cluster 1 and 2 contribute to theory development, the focus of cluster 1 mainly lies in initial development of concepts and theories which may be more analytical in nature. It can also be observed that majority of the works in this cluster are focused on studying and exploring the concept of sustainability in supply chains. The aim of the 2nd cluster is to move ahead with well-established theories and validate them with statistically rigorous techniques. These works discuss the results of the empirical investigation that was carried out to test the proposed hypotheses.

Table 12 Top 10 papers of each cluster: co-citation PageRank measure.

Cluster 1	Cluster 2	Cluster 3
Seuring and Muller, 2008	Vachon and Klassen, 2006	Zhu et al., 2008
Carter and Rogers, 2008	Zhu and Sarkis, 2004	Vachon, 2007
Linton et al., 2007	Rao and Holt, 2005	Kainuma and Tawara, 2006
Pagell and Wu, 2009	Rao, 2002	Holt and Ghobadian, 2009
Gold et al., 2010	Zhu et al., 2005	Lu et al., 2007
Seuring, 2013	Zhu and Sarkis, 2006	Vachon and Mao, 2008
Hassini et al., 2012	Min and Galle, 2001	Ciliberti et al., 2008
Kleindorfer et al., 2005	Zhu and Sarkis, 2007	Testa and Iraldo, 2010
Carter and Easton, 2011	Zhu et al., 2008	Vachon and Klassen, 2008
Matos and Hall, 2007	Walker et al., 2008	Zsidisin and Siferd, 2001
Cluster 4		
Bai and Sarkis, 2010		
Noci, 1997		
Kuo et al., 2010		
Hsu and Hu Ah, 2008		
Awasthi et al., 2010		
Zadeh, 1965		
Ho et al., 2010		
Handfield et al., 2002		
Lee et al., 2009		
Humphreys et al., 2003		

Although 2nd and 3rd clusters overlap with empirical studies, the authors in 3rd cluster were mainly interested in developing and validating measurement models so as to find out how well the GSCM practices are being implemented in different firms. Lastly, the majority of researchers belonging to 4th cluster concentrated at designing, planning and practical applications of GSCM in different industrial sectors. It can be observed that first and second clusters are the most popular ones, whereas there is a scope of future work in cluster 3rd and 4th. Without doubt, this four cluster classification may guide scholars as to where to look for current research topics and future research opportunities.

Table 13

Four major research clusters.

Cluster	Research area
1	Conceptual and theory development
2	Empirical studies (Testing hypothesis and theories)
3	Measurement and evaluation
4	Design, planning and implementation methods

6. Discussion

Our interest in undertaking the bibliometric and network analysis on GSC-PM was triggered by two facets. First, the GSCM literature is growing exponentially but literature focusing on the assessment of the green supply chain performance, is still underdeveloped. Second, there is strong urge among developing economies for embracing green performance measures in supply chains, however the literature focusing on developing economies is scant. As an initial effort in this direction, the present study explored the use of bibliometric and network analysis to objectively evaluate the literature on GSC-PM and identified the leading authors, works and major research areas.

The findings suggest that most of the influential studies were conducted by only a few researchers. However, with the considerable development of the field, several scholars have also helped to expand this body of research in diversified areas. This field started to gain momentum during the middle of the 2000s as it was around this time when the leading papers came into existence. It is worth mentioning, however, that the more recent publications have a reduced opportunity to capture attention as the management and business research in general needs a longer time period for building citations.

We observed that while most of the cited works were done either in Europe or North America, its diffusion into Asia has already started to occur. However, the contribution to the growing literature from African and Middle East affiliated institutions is still very low. In recent years it has been observed that the influence of African and Middle East on world economy is significant. Based on cluster analysis as explained in Table 13 we observe that there are four emerging clusters. However, further detailed analysis of the clusters reveals that major contributions in GSC-PM literature still lacks adequate theoretical development. Sarkis et al. (2011) made an attempt to classify the literature on the basis of organizational theories. However still, most of the organizational theories were found to be underutilized. Pagell and Wu (2009) is one such contribution that falls into cluster 1, where it attempts to generate a comprehensive theory to provide better explanation when organizational theories fail to provide better explanation. However, with some exception, there is significant dearth of such work that attempts to generate theory.

Even in cluster 1 where we have obtained significant literature, detailed analysis reveals that cluster 1 is clearly dominated by review based articles or conceptual papers. However, articles which stem from alternative research methods approaches like case research, action research, ethnographic research or appreciative inquiry is low. Thus the diversity in research methods is clearly missing. Top scholars (see Eisenhardt, 1989; Voss et al. 2002; Boyer and Swink, 2008; Seuring, 2008; Barratt and Choi, 2011; Childe, 2011) consistently call for the use of alternative methods to expand the literature (see Pagell and Wu, 2009; Testa and Iraldo, 2010; Azevedo et al. 2011; Caniato et al. 2012; Hassini et al. 2012). Unfortunately, if we analyze the research using Boyer and Swink's (2008) multiple-research methods angle, the literature is scant. Although in recent years some attempts were made to follow Boyer and Swink's (2008) suggestions (see Jabbour et al. 2014; Dubey et al. 2015), we believe that use of multiple-research methods approach can take the current research to a next level.

The use of bibliometric and network analyses in recent years has attracted significant attention (Fahimnia et al. 2015a, b; Ahi et al. 2016; Mishra et al., 2016a, b). However, the focus such bibliometric analyses has been on broader themes (Fahimnia et al. 2015a) such as supply chain risks (Fahimnia et al. 2015b) or in sustainable supply chains (Ahi et al. 2016). Hence, in our current attempt we have undertaken bibliometric and network analyses from a more specific, performance measures angle. Though there is significant literature focusing on performance measures in green supply chains, a bibliometric and network analyses offers multiple insights to existing GSC-PM

literature. We believe that our current efforts can help young scholars, reviewers and editors to embrace flexibility towards selection of topics or avoid bias towards particular methods as our findings suggest that there is lack of diversity in terms of methods and authorships. Hence our current attempt further supports similar attempts by other scholars (see Fahimnia et al. 2015a, b and Ahi et al. 2016).

6.1 Managerial Implications

The findings can be used by practitioners to analyze and improve their existing performance measurement systems (PMS). Second, the study can offer managers a direction to explain the complex nature of their green supply chains using organizational theories (see Sarkis et al. 2011). This may help them to improve their green supply chain performance. Third, due to poor understanding of relationships between resources, capabilities, agents and network, supply chain managers sometimes fail to leverage their resources to enable green supply chain performance. Presumably, it is in the best interest for such managers to create and maintain robust PMSs, and we believe the articles outlined in the clusters analysis can offer direction for those struggling to successfully develop their PMS.

6.2 Limitations and Further Research Directions

Though we adopt rich techniques to undertake extensive review of existing literature, we also acknowledge some limitations of the current study. First, the current study used citation and co-citation analysis as one of the techniques, and hence we feel that some of the articles which may be robust but published recently may not emerge as one of the significant articles on the basis of page rank analysis. Secondly, the reputation of the journals plays a significant role in page rank analysis, and the reputation of journals often changes with time. Our analyses is based on our study that was conducted during late 2015 and early 2016, and hence the page rank analyses output reflects those articles which held importance at the time of analysis. Thus, we argue that other methods may not carry similar reputations but provide enough guidelines such as SCImago Journal Rank (SJR) and Source Normalized Impact per Paper (SNIP) that can provide significant directions. In the future, we suggest exhaustive analyses using these techniques to provide in-depth comparison among results obtained using each technique. This can further help various agencies that are trying to rate the performance of the journals and evaluate the impact of literature published in these journals. Furthermore, our analysis suggests that there is a pressing need for diversity in terms of methods and authorships. Currently the GSC-PM literature is heavily skewed towards one direction and we would recommend multiple-methods approaches focusing on global

issues. Finally, we believe that this work might be of interest to scholars who wish to carry out research in this field by working with different researchers and at different universities. By adopting the data clustering technique, we observed that several conceptual and empirical studies have been conducted in the past and researchers are now taking interest in design, planning and implementation methods.

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