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Supply chain performance measures and metrics: A bibliometric study

Abstract

Purpose: The purpose of this study is to review the existing literature on supply chain performance measures and metrics (PMMs). It provides a critical evaluation of 234 articles published in past 24 years.

Design/methodology/approach: The paper examines the studies published from 1991 to 2014 by adopting the bibliometric technique of citation and co-citation analysis.

Findings: The analysis of the results indicate that the number of articles on supply chain PMMs is increasing at its fastest pace in the past few years. Furthermore, the study identifies some of the most influential articles on performance measurement and metrics. Finally, it concludes that there has been a transition from traditional to more sophisticated performance measurement system.

Research limitations/implications: This study focuses only on supply chain performance measurement and metrics and excludes research on performance management and control. Thus, researchers may explore and extend this area of research.

Originality/value: To the knowledge of the authors, this is the first study to review the literature on supply chain PMMs by using citation and co-citation analysis. The study includes 234 articles over the time period of 24 years (1991-2014).

Keywords: Performance measurement, Performance measures and metrics, Supply chain measurement systems, Citation and co-citation analysis.

Paper type: Literature review

1. Introduction

Over the last years, supply chain management (SCM) has emerged as a prime factor to increase organizational effectiveness and for accomplishment of organizational goals. With the considerable development in the area of SCM, both researchers and practitioners are interested in measuring supply chain performance. According to Neely (1994), “a performance measurement system can be defined as the set of metrics used to quantify both the efficiency and effectiveness of actions”. The significance of measurements is stated by Kaplan (1990) who claimed that “No measures, no improvement”. Gunasekaran and Kobu (2007) highlighted the purposes of a

performance measurement system: (a) identifying success; (b) identifying whether customer needs are met; (c) helping the organization to understand its processes and to confirm what they know or reveal what they do not know; (d) identifying where problems, bottlenecks, waste, etc. exist and where improvements are necessary; (e) ensuring decisions are based on facts, not on supposition, emotion, faith or intuition; and (f) showing if improvements planned actually happened (Parker 2000). Having appropriate measurement systems as well as measures and metrics in place allows for performance measurement that is ‘vital in strategy formulation and communication and in forming diagnostic control mechanisms by measuring actual results’ (Wouters, 2009).

However, so far only a handful of articles have reviewed the existing literature but to the best of our knowledge no study has provided a systematic review using citation/co-citation analysis for understanding the wide variety of research studies on the topic of supply chain PMMs. To address this gap, in this paper we review articles on supply chain PMMs. Since supply chain performance has grown significantly over the last 15 years, we include articles published from 1991 to 2014. In doing so, we aim to rediscover the concept of supply chain performance measures by fulfilling the following objectives: (i) understand the supply chain PMMs; (ii) systematically review the literature on supply chain PMMs using citation and co-citation analysis; (iii) synthesize the findings of the literature review; (iv) identify future research directions.

We have chosen the technique of bibliometrics of the articles published during 1991-2014 as it provides a way to quantitatively analyse the literature by studying citations and co-citations (Pilkington and Meredith, 2009). In order to examine the current structure of research on supply chain PMMs, we performed citation and co-citation analysis. Citation analysis is a quantitative technique that provides information on the degree of influence of a research article on a specific field whereas, co-citation analysis traces the linkage and connection between the authors and their areas of research. 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). Co-citation 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.”

Bibliometric analysis have been followed in fields adjacent to OM and SCM, such as Information Systems (Culnan, 1986), innovation (Cottrill et al., 1989), and strategic management (Nerur et al. 2008). Within the OM and SCM field, Pilkington and colleagues (Pilkington and Liston-Heyes, 1999; Pilkington and Fitzgerald, 2006; Pilkington and Meredith, 2009) have used citation and co-citation analyses to identify the evolution of research trends within the OM field. In later studies, Citation Network Analysis (CNA) was introduced in systematic literature review studies to pursue an objective approach for research domain classifications (e.g., Chen and Redner, 2010; Colicchia and Strozzi, 2012; Fan et al., 2012; Fahimnia et al., 2015). In this paper we follow the argument of Pilkington and Meredith (2009) and suggest that there is a need to look at the field of PMMs in SCM more objectively and answer, “what articles are actually cited in research studies? And to reveal the structure of the interrelationships among articles, what works are commonly cited together (co-cited)?” (p.186).

The remainder of the paper is as follows. The next section discusses the criteria used for classifying the literature on supply chain performance measures and metrics. It follows the theoretical background of supply chain PMMs and the presentation of the results of our citation and co-citation analysis. The fourth section discusses the current and future trends in supply chain performance measures and metrics based on our results, and the fifth section identifies the managerial implications from our review of the supply chain PMMs. The last section presents the limitations and concludes the study.

2. Methodology for reviewing the literature on supply chain performance measures and metrics

Our analysis was carried out in two stages:

Stage 1: Citation analysis was 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) emphasized that the impact of heavily cited articles on scientific research is greater than that of less cited articles. 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).

We collected raw data for citation and co-citation analysis from different online databases such as, ISI Web of Science (WoS) and Scopus. Since the number of journals in the database of WoS is limited as compared to Scopus, we restricted ourselves to select relevant papers from Scopus database only. In fact, the process of citation and co-citation analysis has been considerably simplified due to the advancement in IT and online data storage. Then we selected those publications that contained keywords including ‘*performance measurement*’, ‘*performance measures and metrics*’, ‘*supply chain performance measurement system*’ and ‘*performance measures*’ and their combination in their title, abstract and paper keywords. We divided the time period of 24 years (1991-2014) into three equal and consecutive 8-year sub periods; 1991-1998, 1999-2006, and 2007-2014. For the sake of clarity, we performed the same keyword search for all three sub-periods. The document search for the first period (1991-1998) resulted in 2,441 number of publications which were further analysed based on their relevance with the topic of our study. Similarly, we obtained 6,378 and 18,145 articles in second (1998-2006) and third (2007-2014) time periods, respectively. Following the objectives of our study, we restricted those articles to scientific publications (articles, reviews and conference papers) that appeared in renowned peer reviewed journals as these can be considered as “certified knowledge” (Rodriguez et al., 2004). For data purification, we excluded unpublished articles, working papers and newspaper articles from the database. This search resulted in 234 relevant documents comprising of 47, 91 and 96 articles in the three consecutive sub-periods. Later on, references and citations were recorded in a database for future analysis. The distribution of articles by journal title is depicted in Table 1.

Table 1: Distribution of the articles by journal title

Journals	Number of articles
International Journal of Operations and Production Management	70
International Journal of Physical Distribution and Logistics Management	1
Benchmarking: An International Journal	24
International Journal of Production Economics	27
International Journal of Production Research	33
Production, Planning and Control	15
Harvard Business Review	5
Business Horizons	5
Supply Chain Management: An International Journal	13
International Journal of Productivity and Performance Management	41
Total	234

Stage 2: Co-citation analysis was conducted to investigate 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. For that reason, we considered those publications based co-citation analysis. In this analysis, the number of scientific articles which have cited any particular set of two documents are recorded and researchers decipher it as a measure for resemblance of content of the two documents (Figure 1).

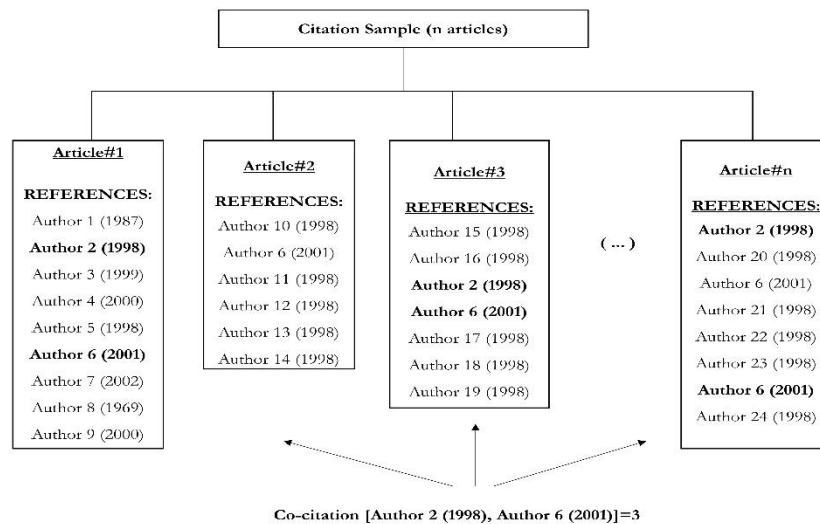


Figure 1: Co-citation count (adopted by Rodriguez et al., 2004)

The co-citation analysis was conducted as follows. We analysed the citations of scientific articles received from Step 1 to find out if any pair of reference has been cited together. This co-occurrence gives an indication that these scientific articles apparently share similar thoughts. In this regard, Pilkington and Meredith (2009) pointed that this collection of articles may be termed as “structural knowledge group”. As per Leydesdorff and Vaughan (2006), such groups delineate the intellectual structures of a field. The co-citation analysis was conducted using Bibexcel version 2014-03-25. It is a bibliometric toolbox developed by Olle Persson (Persson et al., 2009) through which connection with other software’s such as, Pajek, Excel and SPSS becomes easy and trouble-free network diagrams were drawn in Pajek 2.05 software. These diagrams were further refined by removing very thin lines and a Kamada-Kawai diagram was finally drawn. In the diagrams, the vertices (nodes) represent the co-cited articles and the arcs (connecting lines) represent the strength of their relationship. Thick arcs reflect that those works have been co-cited the most and they likely share common thoughts. As thickness reduces, the connection between articles becomes weak.

2. Review of supply chain performance measures and metrics

In this section we report on our literature review on supply chain PMMs. Furthermore, we identify those articles that highlight the need for performance measurement systems, and we provide and discuss a comparison of traditional and modern supply chain PMMs.

2.1 Performance measures and metrics: Definitions and concepts

As per Neely et al. (1995), performance measure is “a set of metrics which helps in quantifying the efficiency and/or effectiveness of an action”. Performance measurement can be defined as the process of quantifying the efficiency and effectiveness of action (Neely et al., 1995). The Global Logistics Research Team at MSU (1995) identified performance measurement as one of the major key competencies for achieving world class performance. There are well known theories explaining the origin of the concept of performance measurement. According to Johnson and Kaplan (1987), the concept originated at the time of industrial revolution. However, Morgan (2004) believed that modern performance measurement came into existence during the fifteenth century in Venice. Further, Kaplan and Norton (1997) pointed that a performance measurement system (PMS) should contribute in providing adequate information to managers on issues related to finance, customer internal processes and innovation and improvement.

Neely et al. (1995) noted that a “metric” is merely not a formula to compute the measure. However, it involves the title of the measure, how it will be calculated, who will be carrying out the calculation, and from where the data will be obtained. The most challenging task is to find out key performance measures that add value to the organization and also identify the factors that have an impact on core business operations.

2.2 Supply chain performance measures and metrics

The concept of “supply chain performance measures” has captured the interest of academics over the past few decades (Taticchi et al., 2010). Due to advancements in technology and globalization, firms these days are forced to alter the manner in which they perform in the market (Bititci et al., 2008). Therefore, it is very important to develop an effective supply chain performance measurement systems so that firms can utilize their resources economically while at the same time satisfy their customers (Neely et al., 2005). Nonetheless, the task of controlling and enhancing the performance of a supply chain is becoming more and more intricate (Cai et al., 2009). The rationale behind this intricacy lies in the fact that performance measures may vary in terms of their context and are determined by the strategy and structure of the supply chain and the characteristic of products. As a result, supply chain PMMs and subsequently performance measurement systems

need to be critically evaluated before being generalised for any particular industry. This gives a justification for the importance of timely development and improvement of supply chain PMMs.

Indeed, PMMs have undergone a huge transformation from conventional to advanced and balanced techniques for measuring supply chain performance. The traditional approach was to consider financial metrics as performance measures. These metrics provided information on organizational performance at present but did not provide projections on future performance. As noted by Kaplan and Norton (1992), financial performance measures may have worked well in the early years, but are now part of a wider agenda that organizations need to consider in order to become competitive. They suggested “balanced scorecard” as a way to achieve strategic alignment by maintaining a balance between financial and nonfinancial measures (Kaplan and Norton, 1992). From the beginning to the end of 1980s and early 1990s, researchers provided different sorts of frameworks to manage firm performance such as, performance measurement matrix (Keegan et al., 1989), performance pyramid (Lynch and Cross, 1991), results-determinants framework (Fitzgerald et al., 1991), balanced scorecard (Kaplan and Norton, 1992) and the Cambridge Performance Measurement Process (Neely et al., 1995). Later on, the performance prism was proposed by Neely et al. (2001; 2002). In this direction, Supply Chain Council had made a remarkable contribution by developing a supply chain operation reference (SCOR) model which provides a way to characterize those practices and processes associated with supply chain management which lead superior performance.

Although various supply chain PMMs have been proposed (Gunasekaran et al. 2004, 2005, Folan and Browne 2005, Fynes et al. 2005), very few, if any, have attempted to propose a minimal number of metrics in measuring the performance of a SCM system. Thus, there exists a need to determine a set of metrics that can be used to measure a SCM system’s performance with maximum effectiveness and minimum operating cost. Scholars (Beamon, 1999; Gunasekaran et al., 2001; 2004) noted that decision makers should lay more focus on development of PMMs. In view of Chan (2003), performance measurement acts as a feedback on activities concerning customer expectations and strategic objectives, thereby providing a way to improve the areas where the performance is not satisfactory. The seminal work of Gunasekaran et al. (2004) developed a framework on supply chain performance measurement and validated it using survey data. They further provided a classification of measurement and metrics of a supply chain.

Gunasekaran and Kobu (2007), in their review and classification of supply chain PMMs, classified literature on the basis of balanced scorecard, components of measures, location and nature of measures, measurement base, traditional versus modern measures and decision levels. Furthermore, they grouped various metrics into different classes such as, order planning, supplier evaluation, production level, delivery and customer service and allocated importance ratings inside each class via empirical research. They also highlighted the interest captured on performance measurement and metrics by academicians and practitioners. The argument provided in their research was further supported by McCormack et al. (2008). In a later study, Martin and Patterson (2009) offered three classes of PMMs, that is, inventory, cycle time and financials. At the same time, they conducted a survey based study and investigated the influence of supply relations on PMMs.

3. Supply chain performance measures and metrics: citation and co-citation analysis

In this section we identify the influential scientific contributions in the field of supply chain PMMs. This section is divided in two sub-sections. In the first, we discuss the results of our citation analysis, whereas in the second section we present and comment on the results of the co-citation analysis for each of the three periods.

3.1 Citation analysis

3.1.1 Early 1990's to late 1990's (1991-1998)

The most influential article in this era is the seminal work published by Kaplan and Norton (1992) which has been cited 3839 times. The authors pioneered a performance measurement system known as “balanced scorecard” which provides a quick and comprehensive perspective of the business to top management. This measurement system helps the managers to get rid of the inadequate traditional performance measurement system. The next important contribution has been made by Neely et al. (1995) where the authors focused on the process of performance measurement system design and provided a comprehensive review of the literature. This work received 662 citations which reflects the significance of the article in the field of performance measurement. Furthermore, the first article of this era by Eccles (1991) devoted to the study of performance measurement has been cited 447 times. Only 8 of the remaining articles have been cited more than 100 times and seventeen percent of the articles have received less than 10 citations. The peaks of Figure 2 demonstrate the influential works published between 1991 and 1999. These papers are also briefly reviewed in Table 2A (Appendix).

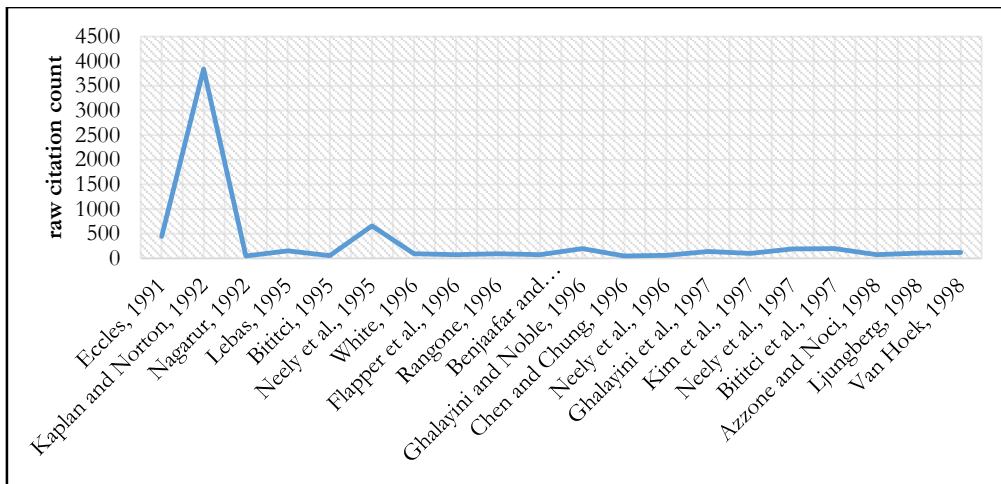


Figure 2: Frequency distribution of most cited articles (1991-1998)

3.1.2 Late 1990's to mid 2000's (1999-2006)

Beamon (1999) made a revolutionary contribution by developing a universal framework for selecting supply chain performance measures. The author identified three types of PMMs: resource, output and flexibility, which are the necessary constituents of any supply chain performance measurement system. The article by Beamon (1999) with 713 citations has been the most influential work of this era. A fine piece of work by Gunasekaran et al. (2001) that received 650 citations becomes the second most important article of this time period. In their work, a framework for measuring the performance of a supply chain at three levels (strategic, tactical and operational) was developed and a set of key performance metrics was presented. The third most significant work of this era was by Gunasekaran et al. (2004) who developed a framework and highlighted the importance of SCM PMMs. Their idea of viewing performance measures and metrics through the lens of SCM has stimulated scholars to further explore this emerging area. The impact of their work can be identified from the fact that till now 582 scientific articles have been published based on their work. Out of the remaining articles, 5 have been cited over 200 times and 12 articles have received more than 100 citations. Interestingly, only 11 percent articles have less than 10 citations. The three major peaks of Figure 3 demonstrate the influential works published between 1999 and 2006. These papers are also briefly reviewed in Table 2B (Appendix).

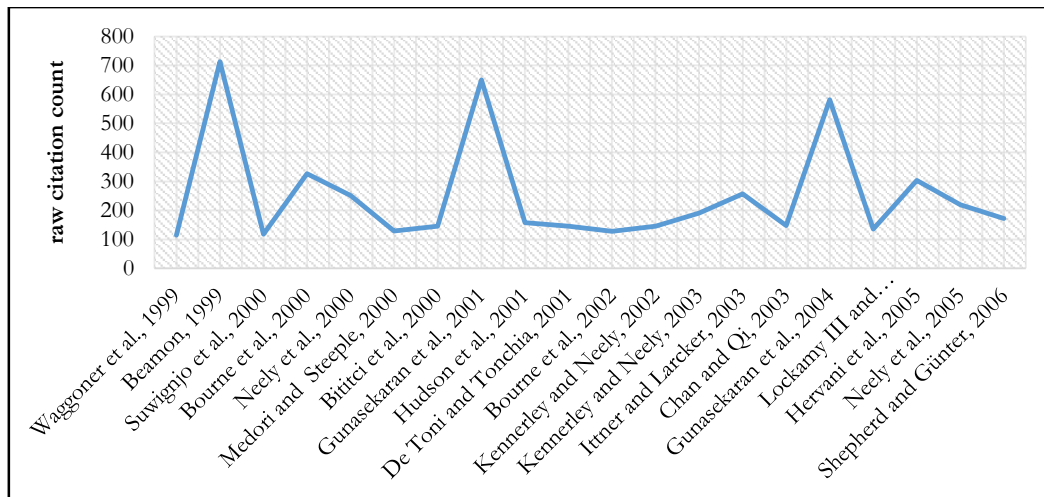


Figure 3: Frequency distribution of most cited articles (1999-2006)

3.1.3 The recent years (2007-2014)

In the third era, the most significant scientific work on the issue of performance measures and metrics was published by Gunasekaran and Kobu (2007) and since then, it has been cited 149 times. Their work is an important contribution as it specifically addressed the key performance measures and metrics in supply chain and logistics operations. Furthermore, other scholars including Lee et al. (2007), Giannakis (2007), as well as Hassini et al. (2012) have also been influential. In particular, Lee et al. (2007) have studied the relationship between the links in the supply chain and performance, as defined by cost-containment and reliability of partners. Following a survey they conducted with relevant stakeholders, they found that with regards to cost-containment internal integration was the most important factor, while supplier integration was vital to achieving reliable performance. Their study called for further investigation of both financial and other PMMs for supply chain, which would provide innovative insights for managing supply chains but also for planning and executing supply chain strategies. At the same year, Giannakis (2007) has proposed an analytical model for assessing supplier relationships' performance. Giannakis underlines the importance of considering both hard and soft features of business (and hence supplier) relationships. The soft PMMs include, for instance, the perceptions of the participating parties regarding their partners' performance to the relationship. The model can be used with both qualitative and quantitative data and help suppliers in selecting appropriate strategies that minimise the gap in partners' perceptions of particular relationships. In a later study, Hassini et al. (2012) have reviewed the literature on sustainable supply chain management and recognised the importance of PMMs for maintaining supply chain practices. In their illustrative case study, they showed the practical side of PMMs, that is, the industry demands such indicators

and acknowledges their complex nature; and they developed a framework for PMMs in sustainable supply chains. The framework illustrates the need for further research on PMMs in each of the economic, environmental, and societal pillars of sustainability and for each of the different supply chains partners (Supplier, manufacturer, distributor, retailer, and customer). These papers are also briefly reviewed in Table 2C (Appendix).

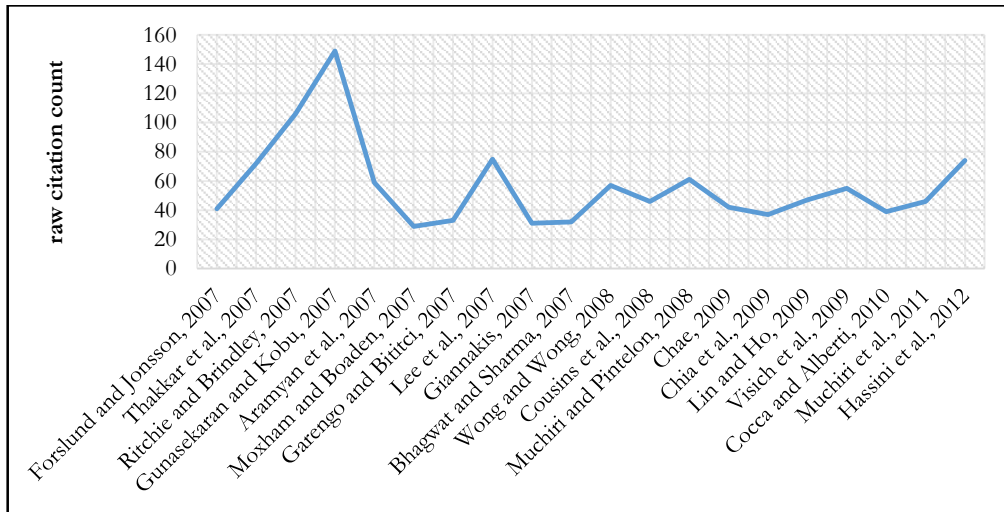


Figure 4: Frequency distribution of most cited articles (2007-2014)

The citation frequency of influential articles of each era can be seen in Table 3 (Appendix). Figure 5 demonstrates the changing pattern of publications in each year, starting from 1991 till the end of 2014. As can be clearly seen from the figure that major work on performance measurement system initiated in 1992 with the advent of “balanced scorecard”. During years 1993 and 1994, the number of publications on performance measurement increased slowly. A similar pattern can be noticed between the years 1996 to 2004. Interestingly, a dramatic rise in publications of this field can be observed thrice that is in years 1995, 2005 and 2014. Therefore, we can sum up that after a number of ups and downs, this area has been able to retain the interest of scholars and practitioners.

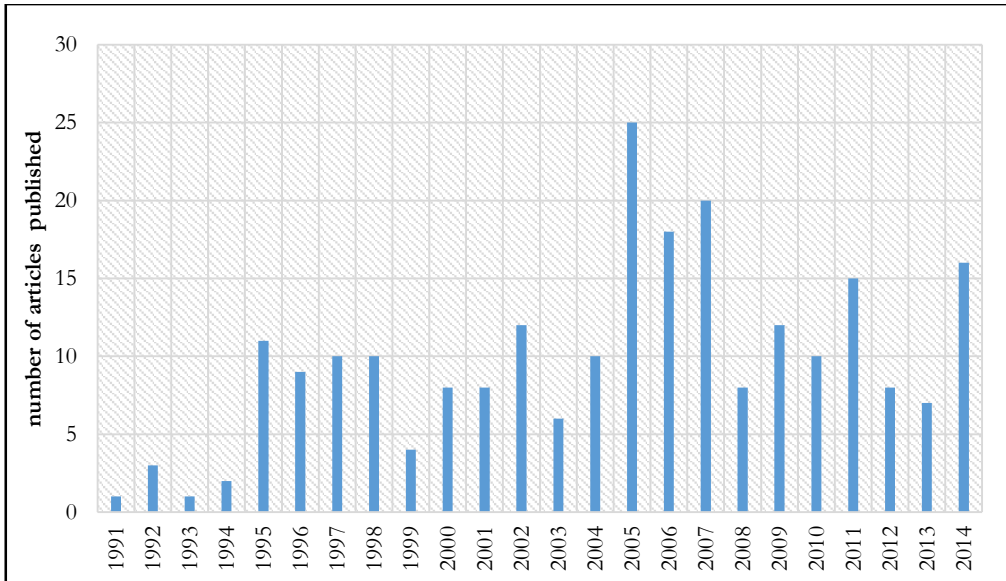


Figure 5: Frequency distribution of number of articles published during 1991-2014

Turning our focus now to identify the journal contribution to this particular area, we analyse the number of publications in 10 chosen journals during the time period 1991-2014. It is evident from the shape of the graph that the highest peak represents International journal of operations and production management (IJOPM) which reflects that this journal has given the maximum contribution to this field.

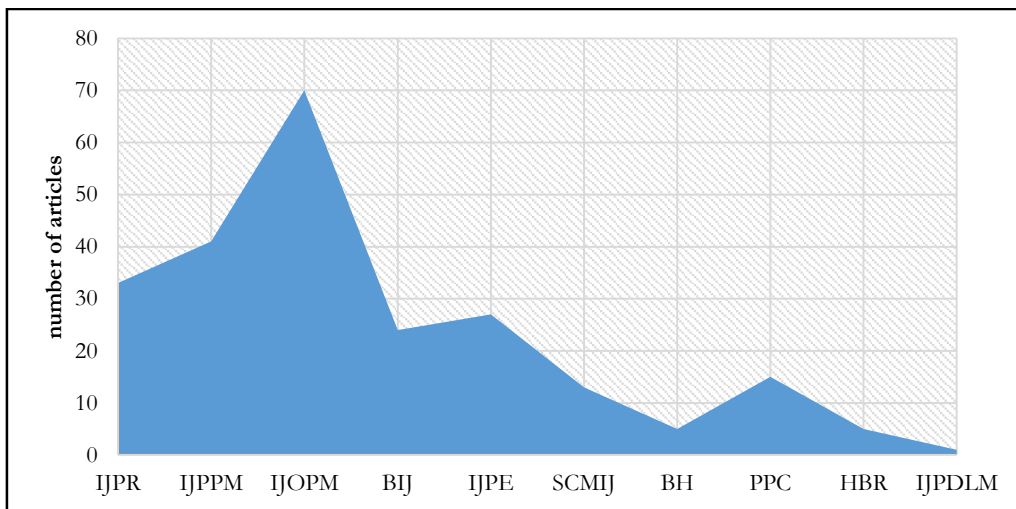


Figure 6: Frequency distribution of number of articles published in selected journals

Also, the graph illustrates that Benchmarking: An International journal (BIJ) and International Journal of Productivity and Performance Management (IJPPM) are among the emerging journals which are contributing by publishing articles on this area.

3.2 Results of Co-citation analysis

In this section we report the results of co-citation analysis for each of the 3 clusters of studies on supply chain PMMs. Figure 7, 8 and 9 present the co-citation analysis for the three eras (1991-1998, 1999-2006 and 2007-2014). In the figures the different research works are presented as nodes and their relationships in arcs that have different width. This reflects the difference in the nature of relationship between these articles. The thick arcs extrapolates the strong relationship between the two co-cited articles. In contrast, the thin arcs indicate that the co-cited articles apparently do not share common ideas. The maximum co-citation value of the publications can be seen in Table 4 (Appendix).

3.2.1 Early 1990's to late 1990's (1991-1998)

Figure 5 presents the co-citation analysis for the first cluster that includes the years 1991-1998. In the figure the different research works are presented as nodes and their relationships in arcs that have different width. This reflects the difference in the nature of relationship between these articles. For instance, the arc between Kaplan (1983) and Kaplan and Norton (1992) is thick; extrapolates the strong relationship between the two co-cited articles. A similar observation can be made for the case of Crawford and Cox (1990) and Fry and Cox (1989). In contrast, the arc between Neely et al. (1995) and Fry and Cox (1989) or, between Neely et al. (1995) and Crawford and Cox (1990) is thin, indicating that these articles apparently do not share common ideas.

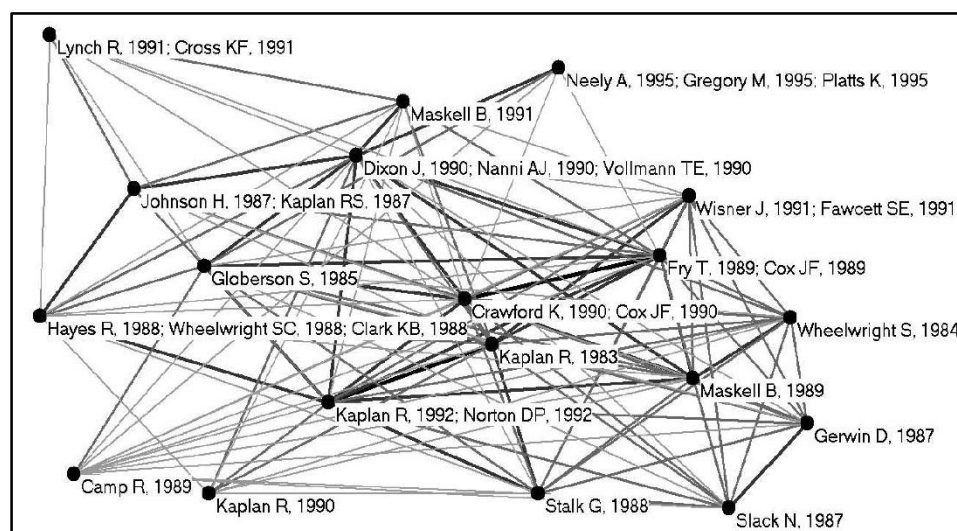


Figure 7: Co-citation analysis for the first cluster (1991-1998)

3.2.2 Late 1990's to mid 2000's (1999-2006)

The relationship between the co-cited articles of era 2 (1998-2006) can be seen in Figure 6. It is clear from the diagram that the arc between Kaplan and Norton (1992) and Kaplan and Norton (1996) is thick which depicts that there exists a strong relationship between the two co-cited articles. A similar relationship can be seen in the case of Kaplan and Norton (1992) and Dixon et al. (1990). However, it is apparent from the arc between Neely (1998) and Wisner and Fawcett (1991) or, between Neely (1998) and Lynch and Cross (1991) is thin which indicates that these articles have weak relationship.

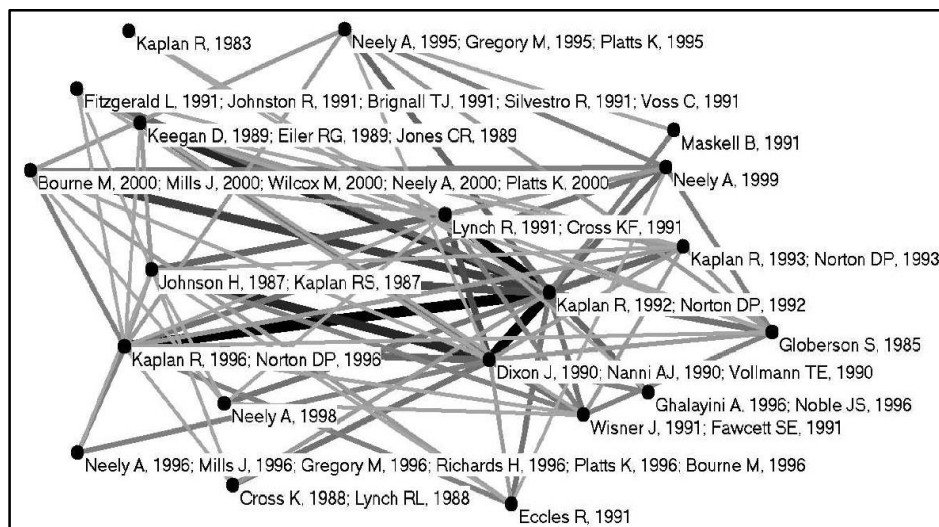


Figure 8: Co-citation analysis for the second cluster (1999-2006)

3.2.3 The recent years (2007-2014)

The figure below shows the relationship between the co-cited articles of era 3 i.e., 2007-2014 (Figure 7). Here, the thick arc between Kaplan and Norton (1996) and Kaplan and Norton (1992) as well as between Gunasekaran and Beamon reflects a stronger relationship between the two co-cited articles, as compared to a thinner arc between Keenerley and Neely (2003) and Neely et al. (2002) which shows a weaker relation.

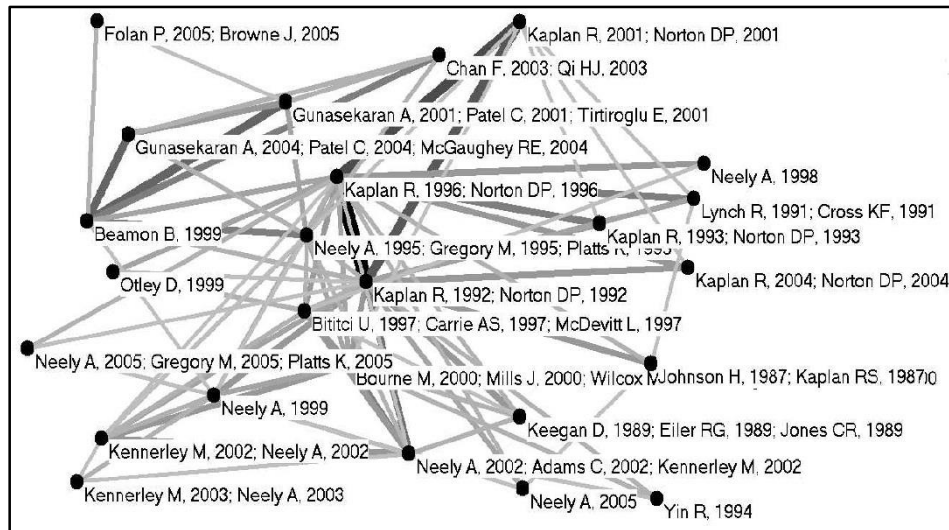


Figure 9: Co-citation analysis for the third cluster (2007-2014)

4. Current and future trends in supply chain performance measures and metrics

Our results reveal that the nature of performance measures and metrics has changed over the years. It was with the beginning of era 1 when the conventional performance measurement system was replaced with a new and flexible performance measurement system (Kaplan and Norton, 1992). This era marked the development of frameworks to overcome the criticism faced by earlier financial measures by providing a balance between financial and operational measures. No matter if the seminal paper by Kaplan and Norton argued for a broader view of PMMs, the papers in this era were either empirical papers that perpetuated the use of tangible PMMs, or conceptual papers that stated the need to include both tangible and intangible PMMs in measuring supply chain performance. The review articles published during that period, especially by Neely, Bititci, and colleagues illustrate the need to adopt new/alternative lenses to explain supply chain performance related phenomena, and make the case for different methodologies and methods (both quantitative and qualitative) to be applied (Table 2A). This is also shown in the co-citation analysis, represented by the arcs amongst the works of Kaplan (1983) and Kaplan and Norton (1992), as well as Neely and colleagues (Figure 5).

The second era presents an attempt to resolve these issues, where various processes and methods are developed (Table 2B). The number of reviews and conceptual articles here is relatively lower than in era 1, since here scholars aim to apply and explore the use of PMMs within performance measurement systems, and discuss the challenges in their application, as well as lessons to be learnt from the successful or unsuccessful application (e.g. Bourne et al., 2002). Furthermore, researchers explore relationships between different PMMs as well as expanding the use of PMMs in adjacent SCM fields, such as green SCM (Hervani et al., 2005). However, there are limited, if any, studies

here that (i) use mixed methods to apply PMMs; (ii) apply alternative theories and lenses to explain the application of PMMs; (iii) propose practice-based frameworks that may inform research on PMMs in SCM and bridge the gap between academia and practice; and (iv) suggest mathematical modelling and techniques to study PMMs and their application in supply chain. The co-citation analysis (Figure 6) suggests that still the works of Kaplan and Kaplan and Norton are influential across domains and journals as research on PMMs evolves, but the aforementioned challenges are yet to be fully addressed.

In the third era the number of empirical studies that use non-financial measures on PMMs and follow qualitative methods to study their application is popular, as inferred from Table 2C. The review studies are limited, and this shows that in this era scholars are investigating the applications of PMMs and conduct empirical studies. Finally, there are studies that distinguish the application of PMMs in different contexts (e.g. SMEs) (Garengo and Bititci, 2007) and adjacent fields, e.g. the study of Hassini et al. (2012) on sustainable supply chain performance that provide expand current thinking. Still, the same challenges remain as in era 2, including the application of mixed methods and alternative theories, as well as the use of purely mathematical techniques (e.g. modelling). Scholars carry out empirical analysis of the proposed frameworks (Gunasekaran et al., 2004). The co-citation analysis (Figure 7) reveals the impact of Kaplan and Norton papers across domains and journals, which is reflected in the need for applying different types of PMMs in diverse contexts and discuss the related challenges.

4.1 Future trends in supply chain performance measures and metrics

Based on our previous review, we propose the following as some of future research directions:

1. We provide a classification of supply chain PMMs over time and split the period 1991-2014 in three sub-periods. Future works could classify those papers differently; for instance, they could follow Fan et al. (2012) who inductively classified articles on occupational health and safety in OM and produced a map of knowledge that shows the evolution of articles/research.
2. Based on our review of supply chain PMMs, scholars could develop further frameworks that classify PMMs at different levels, e.g. strategic, tactical and operational (Gunasekaran et al., 2015).
3. Our review suggests that both financial and non-financial PMMs are important. Therefore, we would endorse researchers to study PMMs and their relationships and develop and test particular frameworks.

4. Our review of the literature suggests that there are very limited, if any, studies (that are highly cited) that use suitable mathematical and simulation models for modelling and analysis of supply chain PMMs. Therefore, we argue that more research should be conducted in developing and testing appropriate models that are inclusive and easy to use by both scholars and practitioners. These models may assist in the prioritisation of PMMs across levels and in their application in different types of organization (e.g. SMEs vs. MNCs).
5. There is lack of research on alternative lenses to the study of phenomena related with the application of supply chain PMMs. We would endorse scholars to use theories and lenses from other disciplines (Taylor and Taylor, 2009) to explain such phenomena.
6. There is lack of research on mixed methods when conducting studies on supply chain PMMs. More research is needed in using mixed methods when applying different supply chain PMMs and frameworks.
7. We would argue for more applied frameworks on PMMs that stem from the interaction of academia (and literature reviews) with practice, that is, by gaining the insights of practitioners through e.g. interviewing to understand how different the metrics they use are from the ones revealed by literature reviews.
8. More research is needed in identifying suitable organizational structures for applying PMMs, as well as appropriate champions and leaders who would facilitate these changes (Gunasekaran et al., 2015).

5. Managerial implications

We underline the importance for managers to attend to the diverse supply chain PMMs, which should be inclusive of financial and non-financial aspects, as well as tangibles and intangibles. These PMMs need to adapt to the multifarious business objectives, risks, stakeholder agendas and requirements, as well as costs entailed when measuring PMMs. Therefore, managers have to consider those factors in order to develop and test performance measurement systems based on PMMs and make informed decisions whether particular PMMs need to change or particular changes need to occur in the processes or structure that these PMMs represent. PMMs are dependent on the type of industry, client, the organizational goals and objectives, the nature of the market, and the technological competence of the organization (Gunasekaran and Kobu, 2007). Finally, robust data collection and analysis, infrastructure investments and human resources and competencies are needed to put appropriate PMMs and frameworks into practice. Frequent auditing is also needed to ensure the frameworks and PMMs are working appropriately or need to be updated/adjusted. To ensure this update and adjustment is conducted in a fair way, appropriate

stakeholders and senior executives should participate in determining the PMMs (Gunasekaran et al., 2015).

6. Conclusions and limitations

In this paper we have attempted to review the literature on supply chain PMMs from 1991-2014 using a bibliometric analysis. To our knowledge this is the first study attempting to classify highly cited and co-cited works within supply chain PMMs. Our findings can help researchers in (i) understanding the evolution of research trends in the field, and those articles that have been influential in shaping research in particular periods; and (ii) reveal the major research clusters in the field in each of these periods. It is vital for managers to attend to supply chain PMMs and adapt them based on the organizational context and stakeholder needs and views. A careful evaluation, however, of the relevant PMMs by managers is vital for the achievement of organizational objectives.

The paper has the following limitations:

1. The findings of the review are based on academic journals. The literature stemming from practitioner journals was excluded for accessibility limitations (Eksoz et al., 2014; Gunasekaran et al., 2015).
2. Our review covered the years 1991-2014, which is representative of the supply chain PMMs. The list is not exhaustive, but comprehensive, covering a significant list of scientific journals and highly-cited and co-cited articles.
3. Our method of conducting co-citation analysis is not the only method (Fahimnia et al., 2015). There are different methods to conduct co-citation analysis (Pilkington and Fitzgerald, 2006; Pilkington and Meredith, 2009; Colicchia and Strozzi, 2012; Fan et al., 2012). In this paper we follow Pilkington and Meredith (2009).
4. The findings were based on searches using particular keywords. This technique has been used in the past by scholars (e.g. Eksoz et al., 2014; Gunasekaran et al., 2015). All authors have interacted on the literature review and classifications (Chen et al., 2014). We controlled for quality focusing on peer-reviewed articles (Esposito and Evangelista, 2014).

Notwithstanding the aforementioned limitations we believe our study provides food for thought and encouragement for scholars to further explore supply chain PMMs.

5. Acknowledgements

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Appendix Table 2A: Articles in the first era (1991-1998)

Article	Topic	Research strategy	Research Method
Eccles (1991)	Underlines the need to shift from financial to a broader set of PMMs	Conceptual	N/A
Kaplan and Norton (1992)	Proposes Balanced Scorecard (BSC) to measure performance	Empirical (Case study)	Multi-source
Nagarur (1992)	Examines flexibility and reliability, and proposes producibility, as the extent to which a system fulfills its purpose. Furthermore it develops mathematical models to compute this measure.	Empirical	Survey and multi-source
Lebas (1995)	Performance needs to be constructed by both the management system and managers.	Review	N/A
Bititici (1995)	Presents the analysis, modelling and design of performance measurement systems.	Empirical (Case study)	Multi-source
Neely et al. (1995)	Reviews the literature on performance measurement and proposes a future research agenda.	Review	N/A
White (1996)	Reviews the literature on manufacturing performance measurement and lists 125 different strategy-related measures.	Review	N/A
Flapper et al. (1996)	Attends to the relationships between performance indicators for effective and consistent performance management systems.	Empirical	Multi-source
Rangone (1996)	Illustrates the potential of the analytical hierarchy process (AHP) for assessing and comparing the manufacturing performance of different departments, demonstrating the issues and challenges that may occur due to the potential application.	Empirical (Case study)	Multi-source
Benjaafar and Ramakrishnan (1996)	Introduces different representation and measurement schemes for sequencing flexibility and discusses the usefulness and limitations of each.	Conceptual	N/A

Ghalayini and Noble (1996)	Reviews and analyses the limitations of traditional approaches and current trends to performance measurement. Discusses characteristics of performance measurement necessary for world-class manufacturing performance.	Review	N/A
Chen and Chung (1996)	Investigates the relationship between flexibility and performance, reviews the literature on flexibility and proposes alternative measures for assessing machine and routine flexibility. Furthermore, it provides to examples to illustrate the applicability of measures.	Empirical	Multi-source
Neely et al. (1996)	The paper surveys 850 companies from various industries to gather data on performance measurement and system design processes. Illustrates that performance measurement is achieved when companies have decided a priori what to measure and how to measure it; have collected data; and have eliminated any conflicts in their measurement systems.	Empirical	Survey
Ghalayini et al. (1997)	Presents an integrated dynamic performance measurement system (IDPMS), which is developed with a private company. It proposes that the integrated system can be achieved by linking processes in management, process improvement team, and factory shop floor.	Empirical (Case study)	Survey

Kim et al. (1997)	Critically evaluate current PMMS and propose a new performance measurement system using activity-based costing to consider financial and non-financial criteria simultaneously.	Empirical (Case study)	Multi-source
Neely et al. (1997)	Develops and tests a framework that can help in designing performance measures	Empirical (Case study)	Multi-source
Bititci et al. (1997)	Proposes the viable systems model (VSM) to assess the integrity of the performance measurement system. Develops a model to be used in order to design and audit performance measurement systems.	Conceptual	N/A
Azzone and Noci (1998)	Illustrates techniques and architecture for performance measurement systems that assist in the implementation of feasible “green” manufacturing strategies, and shows the application of these techniques.	Empirical (case study)	Multi-source
Ljungberg (1998)	Discusses how companies can obtain information on the magnitude and reason for machinery losses. This information is then provided to inform planning activities of machinery losses and provide base for planning activities in the total productive maintenance framework.	Empirical (case study)	Survey
Van Hoek (1998)	Proposes a preliminary framework to enable measuring un-measurable performance that allows supply chain competitiveness and directs management attention to those areas for supply chain optimization.	Conceptual	N/A

Table 2B: Articles in the second era (1999-2006)

Article	Topic	Research strategy	Research Method
Waggoner et al. (1999)	Illustrates those forces that shape the evolution and change of organisational performance measurement systems. These forces are then classified in 'internal' influences, 'external influences', 'process issues' and 'transformacion ' uses.	Review	N/A
Beamon (1999)	Assesses the performance measures used in supply chain models and presents a framework for the selection of PMMs for manufacturing supply chains.	Conceptual	N/A
Suwignjo et al. (2000)	Develops Quantitative Models for Performance Measurement Systems (QMPMS) using cognitive maps, cause and effect diagrams, tree diagrams, and the analytic hierarchy process.	Empirical (Case study)	Multi-sources
Bourne et al. (2000)	Proposes a framework for analyzing the implementation of a performance measurement system. It underlines the importance of aligning the performance measurement system with strategy.	Conceptual	N/A

Neely et al. (2000)	Illustrates the development and testing of a structured methodology for the design of performance measurement systems. Proposes a framework that helps organizations identify those characteristics that need to be part of the design framework.	Empirical (Case study)	Action research
Medori and Steeple (2000)	Illustrates the need to incorporate both financial and non-financial measures when designing PMMs. Proposes a framework that aids manufacturing organisations to select and implement PMMs.	Empirical (case study –ethnography)	Ethnographic methods
Bititci et al. (2000)	Makes the case for dynamic performance measurement systems and reviews the literature. Develops a model for integrated and dynamic performance measurement systems.	Empirical (case study)	Reports
Gunasekaran et al. (2001)	Reviews the literature on PMMs in SCM. It develops a framework for measuring the strategic, tactical and operational level performance in a supply chain. Finally, it presents a list of key performance metrics.	Review	Literature survey
Hudson et al. (2001)	Proposes measures of operational performance that enable the achievement of strategic objectives. It therefore helps develop effective performance measurement in SMEs.	Empirical (case study)	Action research
De Toni and Tonchia (2001)	Argues for the abandonment of the PMS models that based on keeping traditional cost performance separate from the non-cost measures; for integration with other firm systems; and for consideration of human resources.	Empirical	Survey

Bourne et al. (2002)	Discusses the success and failure of performance measurement system design interventions.	Empirical (case study)	Interviews
Kennerley and Neely (2002)	Argues for organizations to have in place systematic processes to manage the evolution of their performance measurement systems, and explores the forces that shape the evolution of measurement systems. It presents a framework that discusses those forces that shape the evolution of measurement systems	Empirical (multiple case study)	Interviews
Ittner and Lacker (2003)	Assesses the extent to which companies are using non-financial performance measurements.	Empirical (multiple case method)	Multi-sources
Chan and Qi (2003)	Proposes an innovative performance measure measurement system that contributes to the literature of Supply Chain Management. This allows to build models that are holistic and measure the performance of the supply chain.	Empirical	Multi-sources
Gunasekaran et al (2004)	Proposes a framework that provides a better understanding of SM papers Performance measurement and metrics pertaining to SCM that have not received adequate attention from researchers or practitioners.	Review	N/A

Lockamy and McCormack (2004)	Explores the relationship between supply-chain management planning practices and supply chain performance. This is done based on the four decision areas by SCOR Model Version 4.0 (Plan, Source, Make, Deliver) and on interviews conducted with nine supply-chain management experts and practitioners on management planning practices.	Empirical	Survey (interview)
Hervani et al. (2005)	Aims to raise awareness with regards to the issues on green SCM and green SCM measurement. Context (inter-organizational, environment) plays an important role.	Review	Literature survey
Neely et al. (2005)	Argues for performance measurement system design, than the detail of specific measures. It includes a comprehensive review of the relevant literature, and proposes a research agenda.	Conceptual	N/A
Shepherd and Günter	Reviews the literature and provides a taxonomy of performance measures followed by a critical evaluation of measurements. Despite the considerable advancement in the literature, a number of problems have not been yet solved. It provide a taxonomy and implications for future research.	Conceptual	N/A

Table 2C: Articles in the third era (2007-2014)

Article	Topic	Research strategy	Research Method
Forslund and Jonsson (2007)	Discusses the impact of two PMMs, that is, forecast information access and forecast information quality of supply chain performance.	Empirical	Survey
Thakkar et al. (2007)	Proposes an integrated qualitative and quantitative approach to the development of a balanced scorecard (BSC) for measuring SC performance	Empirical (Case study)	Interviews
Ritchie and Brindley (2007)	Proposes a framework that considers both risk and performance in supply chains and provides a classification of risk drivers.	Empirical (Case studies)	Interviews and documentation
Gunasekaran and Kobu (2007)	Reviews the literature on PMMs and suggests that they should be reviewed in light of the new knowledge economy where activities are not easily identifiable. Discusses challenges related to the measuring of intangibles and nonfinancial performance measures in the knowledge economy.	Review	Literature survey
Aramyan et al. (2007)	Proposes and tests a conceptual framework for measuring performance in the agri-food supply chain.	Empirical (Case study)	Interviews
Moxham and Boaden (2007)	Identifies the applicability and impact of applying business performance measurement frameworks to voluntary organizations.	Empirical (Case study)	Interviews

Garengo and Bititci (2007)	Discusses the factors that shape performance measurement practices in SMEs.	Empirical (Case study)	Interviews
Lee et al. (2007)	Examines the relationship between supply chain linkages and supply chain performance, as measured by cost-containment and reliability of supply chain partners.	Empirical	Survey
Giannakis (2007)	Develops an analytical model to assess the performance of supplier relationships, based on the nature and the performance of each partner to the relationship.	Conceptual	N/A
Bhagwat and Sharma (2007)	Proposes analytical hierarchy process (AHP) methodology to help in reaching SCM evaluation decisions	Empirical	Survey
Wong and Wong (2008)	Discusses the challenges related to the past literature and the use of data envelopment analysis (DEA) modeling approach in supply chain benchmarking.	Review	Literature survey
Cousins et al. (2008)	Develops and tests a model that underlines the importance of socialization mechanisms as mediators in the relationship between supplier performance measures and performance outcomes.	Empirical	Survey
Muchiri and Pintelon (2008)	Suggests “overall equipment effectiveness (OEE)” as a performance-measurement tool that measures different types of production losses and indicates areas of process improvement; proposes a framework for classifying and measuring production losses for overall production effectiveness.	Review	Literature survey

Chae (2009)	Proposes particular key performance indicators (KPI) to measure supply chain performance based on industry by adopting SCOR's four meta-level processes, and offers a practical approach to developing PMMs.	Conceptual	N/A
Chia et al. (2009)	Examines how supply chain executives measure and perceive PMMs from a BSC perspective.	Empirical	Survey
Lin et al. (2009)	Examines the factors that influence the adoption of RFID and the impact of RFID on supply chain performance.	Empirical	Survey
Visich et al. (2009)	Investigates the benefits of RFID adoption on supply chain performance.	Empirical	Survey
Cocca and Alberti (2010)	Proposes a framework to be used by small and medium size enterprises (SMEs) to assess their performance measurement system (PMS).	Empirical	Survey
Muchiri et al. (2011)	Suggests that PMMs should result out of a careful analysis of the interaction of maintenance with organizational functions and in particular production; proposes a framework for choosing maintenance function PMMs.	Conceptual	N/A
Hassini et al. (2012)	Reviews the literature on sustainable supply chains (2000-2010), provides a framework for PMMs in sustainable supply chains, and illustrates how a company sets PMMs in this context.	Review	Literature survey

Table 3: Publication citation frequencies in each eras

Era 1 (1991-1998)		Era 2 (1999-2006)		Era 3 (2007-2014)	
Publication	Maximum citation count	Publication	Maximum citation count	Publication	Maximum citation count
Eccles, 1991	447	Waggoner et al., 1999	115	Forslund and Jonsson, 2007	41
Kaplan and Norton, 1992	3839	Beamon, 1999	713	Thakkar et al., 2007	72
Nagarur, 1992	48	Suwignjo et al., 2000	118	Ritchie and Brindley, 2007	106
Lebas, 1995	150	Bourne et al., 2000	326	Gunasekaran and Kobu, 2007	149
Bititci, 1995	55	Neely et al., 2000	251	Aramyan et al., 2007	59
Neely et al., 1995	662	Medori and Steeple, 2000	129	Moxham and Boaden, 2007	29
White, 1996	94	Bititci et al., 2000	146	Garengo and Bititci, 2007	33
Flapper et al., 1996	78	Gunasekaran et al., 2001	650	Lee et al., 2007	75
Rangone, 1996	97	Hudson et al., 2001	158	Giannakis, 2007	31
Benjaafar and Ramakrishnan, 1996	74	De Toni and Tonchia, 2001	145	Bhagwat and Sharma, 2007	32
Ghalayini and Noble, 1996	199	Bourne et al., 2002	128	Wong and Wong, 2008	57
Chen and Chung, 1996	52	Kennerley and Neely, 2002	145	Cousins et al., 2008	46
Neely et al., 1996	65	Kennerley and Neely, 2003	191	Muchiri and Pintelon, 2008	61
Ghalayini et al., 1997	142	Ittner and Larcker, 2003	257	Chae, 2009	42
Kim et al., 1997	101	Chan and Qi, 2003	148	Chia et al., 2009	37
Neely et al., 1997	189	Gunasekaran et al., 2004	582	Lin and Ho, 2009	47
Bititci et al., 1997	197	Lockamy III and McCormack, 2004	136	Visich et al., 2009	55
Azzone and Noci, 1998	73	Hervani et al., 2005	303	Cocca and Alberti, 2010	39
Ljungberg, 1998	107	Neely et al., 2005	219	Muchiri et al., 2011	46
Van Hoek, 1998	118	Shepherd and Günter, 2006	172	Hassini et al., 2012	74

Table 4: Most frequently co-cited articles (1991-2014)

Era 1 (1991-1998)		
Publication	Maximum co-cited value	Publication most co-cited with
Kaplan R, 1983	5	Kaplan R, 1992; Norton DP, 1992
Crawford K, 1990; Cox JF, 1990	5	Fry T, 1989; Cox JF, 1989
Dixon J, 1990; Nanni AJ, 1990; Vollmann TE, 1990	4	Maskell B, 1991
Crawford K, 1990; Cox JF, 1990	4	Maskell B, 1989
Dixon J, 1990; Nanni AJ, 1990; Vollmann TE, 1990	4	Neely A, 1995; Gregory M, 1995; Platts K, 1995
Fry T, 1989; Cox JF, 1989	4	Kaplan R, 1983
Fry T, 1989; Cox JF, 1989	4	Globerson S, 1985
Dixon J, 1990; Nanni AJ, 1990; Vollmann TE, 1990	4	Johnson H, 1987; Kaplan RS, 1987
Dixon J, 1990; Nanni AJ, 1990; Vollmann TE, 1990	4	Globerson S, 1985
Dixon J, 1990; Nanni AJ, 1990; Vollmann TE, 1990	4	Kaplan R, 1992; Norton DP, 1992
Dixon J, 1990; Nanni AJ, 1990; Vollmann TE, 1990	4	Maskell B, 1989
Dixon J, 1990; Nanni AJ, 1990; Vollmann TE, 1990	4	Fry T, 1989; Cox JF, 1989
Fry T, 1989; Cox JF, 1989	4	Kaplan R, 1992; Norton DP, 1992
Kaplan R, 1983	4	Wisner J, 1991; Fawcett SE, 1991
Kaplan R, 1983	4	Stalk G, 1988
Kaplan R, 1992; Norton DP, 1992	4	Maskell B, 1989
Maskell B, 1989	4	Wheelwright S, 1984
Kaplan R, 1992; Norton DP, 1992	4	Stalk G, 1988
Hayes R, 1988; Wheelwright SC, 1988; Clark KB, 1988	4	Kaplan R, 1992; Norton DP, 1992
Fry T, 1989; Cox JF, 1989	4	Wisner J, 1991; Fawcett SE, 1991
Fry T, 1989; Cox JF, 1989	4	Maskell B, 1989
Gerwin D, 1987	4	Slack N, 1987
Hayes R, 1988; Wheelwright SC, 1988; Clark KB, 1988	4	Johnson H, 1987; Kaplan RS, 1987
Globerson S, 1985	4	Kaplan R, 1992; Norton DP, 1992
Crawford K, 1990; Cox JF, 1990	4	Kaplan R, 1992; Norton DP, 1992
Crawford K, 1990; Cox JF, 1990	4	Dixon J, 1990; Nanni AJ, 1990; Vollmann TE, 1990
Crawford K, 1990; Cox JF, 1990	4	Globerson S, 1985
Era 2 (1999-2006)		
Dixon J, 1990; Nanni AJ, 1990; Vollmann TE, 1990	14	Kaplan R, 1992; Norton DP, 1992
Kaplan R, 1992; Norton DP, 1992	14	Lynch R, 1991; Cross KF, 1991
Kaplan R, 1992; Norton DP, 1992	14	Kaplan R, 1996; Norton DP, 1996
Dixon J, 1990; Nanni AJ, 1990; Vollmann TE, 1990	12	Johnson H, 1987; Kaplan RS, 1987
Kaplan R, 1992; Norton DP, 1992	12	Keegan D, 1989; Eiler RG, 1989; Jones CR, 1989
Bourne M, 2000; Mills J, 2000; Wilcox M, 2000; Neely A, 2000; Platts K, 2000	11	Kaplan R, 1992; Norton DP, 1992
Dixon J, 1990; Nanni AJ, 1990; Vollmann TE, 1990	10	Lynch R, 1991; Cross KF, 1991
Johnson H, 1987; Kaplan RS, 1987	10	Kaplan R, 1992; Norton DP, 1992
Fitzgerald L, 1991; Johnston R, 1991; Brignall TJ, 1991; Silvestro R, 1991; Voss C, 1991	9	Kaplan R, 1992; Norton DP, 1992
Kaplan R, 1992; Norton DP, 1992	9	Kaplan R, 1993; Norton DP, 1993
Kaplan R, 1992; Norton DP, 1992	9	Neely A, 1999
Ghalayini A, 1996; Noble JS, 1996	9	Kaplan R, 1992; Norton DP, 1992
Kaplan R, 1992; Norton DP, 1992	9	Neely A, 1995; Gregory M, 1995; Platts K, 1995
Johnson H, 1987; Kaplan RS, 1987	9	Lynch R, 1991; Cross KF, 1991
Dixon J, 1990; Nanni AJ, 1990; Vollmann TE, 1990	9	Kaplan R, 1996; Norton DP, 1996
Era 3 (2007-2014)		
Kaplan R, 1992; Norton DP, 1992	18	Kaplan R, 1996; Norton DP, 1996
Kaplan R, 1996; Norton DP, 1996	13	Kaplan R, 2001; Norton DP, 2001
Kaplan R, 1992; Norton DP, 1992	12	Kaplan R, 2001; Norton DP, 2001
Beamon B, 1999	11	Gunasekaran A, 2004; Patel C, 2004; McGaughey RE, 2004
Beamon B, 1999	11	Gunasekaran A, 2001; Patel C, 2001; Tirtiroglu E, 2001
Kaplan R, 1992; Norton DP, 1992	10	Neely A, 2002; Adams C, 2002; Kennerley M, 2002
Kaplan R, 1996; Norton DP, 1996	9	Lynch R, 1991; Cross KF, 1991
Beamon B, 1999	9	Neely A, 1995; Gregory M, 1995; Platts K, 1995
Beamon B, 1999	9	Chan F, 2003; Qi HJ, 2003
Bourne M, 2000; Mills J, 2000; Wilcox M, 2000; Neely A, 2000; Platts K, 2000	9	Neely A, 2002; Adams C, 2002; Kennerley M, 2002
Kaplan R, 1993; Norton DP, 1993	9	Kaplan R, 1996; Norton DP, 1996

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