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Review

An analysis of metrics used to measure performance in green and sustainable supply chains

Payman Ahi, Cory Searcy*

Department of Mechanical and Industrial Engineering, Ryerson University, Toronto, Canada M5B 2K3

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ABSTRACT

The purpose of this study is to identify and analyze the metrics that have been published in the literature on green supply chain management (GSCM) and sustainable supply chain management (SSCM). The metrics were identified based on a structured content analysis of 445 articles published up to the end of 2012. A total of 2555 unique metrics were identified. The majority of the metrics were used only once, which indicates a lack of agreement on how performance should be measured in these areas. Five metrics were used more than 20 times: quality (31 times), air emissions (28), greenhouse gas emissions (24), energy use (24), and energy consumption (21). As highlighted in that list, multiple metrics were used to measure similar issues in many cases. For example, a detailed analysis showed that 76 different metrics were identified for issues focusing on water. As a part of the analysis conducted, each metric was classified according to 13 key characteristics of SSCM drawn from the literature. The analysis showed that environmental issues were represented to the greatest extent. Over one-third of the identified metrics were classified as cross-cutting metrics, meaning that they addressed more than one key characteristic of SSCM. Based on the analysis conducted, an original conceptual framework for structuring the development of metrics in GSCM and SSCM is presented. This paper presents one of the first in-depth investigations of the use of metrics in GSCM and SSCM. It is anticipated that the analysis and framework will provide a strong basis for future academic and practitioner work.

1. Introduction

Over the past two decades, many organizations have taken steps to integrate the principles of sustainability into their long- and short-term decision-making. However, sustainability is an issue that extends beyond the boundaries of any one firm (Seuring and Gold, 2013). To that end, there is a rapidly growing body of literature that focuses on the integration of sustainability with supply chain management (SCM). Given the many players in a supply chain (e.g., suppliers, focal firm, distributors, retailers, customers, etc.), this is a more challenging issue than integrating sustainability into the operations of a single firm.

There are ongoing debates about what sustainability means in a supply chain context (Morali and Searcy, 2013). The concepts of sustainability and SCM have each provoked a multitude of discussions in the academic literature (Seuring et al., 2008; Chen and Paulraj, 2004) and a wide range of characteristics have been identified for both concepts (Dahlsrud, 2008; Stock and Boyer, 2009). Given the relatively new emphasis on the integration of sustainability and SCM, it is unsurprising that a number of different terms have been used to express this complex combination of concepts. Examples include green supply chain management (GSCM) (Srivastava, 2007), sustainable supply chain management (SSCM) (Carter and Rogers, 2008; Seuring and Muller, 2008), closed-loop supply chains (Quariguasi Frota Neto et al., 2009), green manufacturing and product recovery (Gungor and Gupta, 1999), and reverse logistics (Carter and Ellram, 1998; Fleischmann et al., 1997). It is recognized that these terms do not always completely overlap, but they are used interchangeably in many cases (Gurtu et al., 2012). Among these terms, GSCM and SSCM are the two terms with the most rapidly growing usage that most obviously promote the strong linkages between the sustainability and SCM concepts (Ashby et al., 2012).

GSCM and SSCM have been the subject of considerable research (Seuring and Muller, 2008). Much of the early work focused on developing definitions for GSCM and SSCM. A recent review of 22 published definitions of GSCM and 12 definitions of SSCM highlighted that there is a great range in the content and scope of these

* Corresponding author. Tel.: +1 416 979 5000x2095; fax: +1 416 979 5265.
E-mail address: cory.searcy@ryerson.ca (C. Searcy).

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definitions (Ahi and Searcy, 2013). As a result, questions remain on how these concepts may be applied in practice. In particular, there are ongoing questions with respect to how progress towards environmental or sustainability goals in a supply chain context may be measured. Generally, measuring performance can be described as the process of enumerating the efficiency and effectiveness of an action quantitatively and/or qualitatively (Neely et al., 1995). Key reasons for measuring performance at the supply chain level generally include assessing and controlling progress, highlighting achievements, enhancing understanding of key processes, identifying potential problems (e.g., bottlenecks), and providing insight into possible future actions, among others (Holmberg, 2000; Gunasekaran et al., 2004; Gunasekaran and Kobu, 2007). Moreover, with the increasing integration of sustainability into SCM "the question of how to measure supply chain wide sustainability performance is paramount" (Seuring and Gold, 2013, p. 3). Existing market indices that incorporate measures of sustainability, such as the Dow Jones Sustainability Index and FTSE4Good Index, do not fully capture the challenges of measuring sustainability at the level of the supply chain. A number of recent studies (e.g., Azevedo et al., 2013; Chang et al., 2013; Hsu et al., 2013; Nikolaou et al., 2013), highlight some of the challenges of incorporating sustainability requirements from the perspective of a supply chain into traditional models of business performance.

There is considerable debate regarding how performance should be measured in GSCM and SSCM. Even a cursory scan of the literature shows that a wide range of metrics have been used to measure performance in these areas (Hassini et al., 2012). However, there remains a need for a systematic review of the convergences and divergences in the literature on GSCM and SSCM performance measurement (Hassini et al., 2012). There is also a need to explore the extent to which the existing literature in this area addresses the key characteristics of SCM and sustainability (Ahi and Searcy, 2013). Addressing these issues would provide a needed basis for the development of metrics to measure performance in green and sustainable supply chains going forward.

The purpose of this paper is to identify and analyze the metrics that have been published in the peer-reviewed academic literature on GSCM and SSCM. This is accomplished through a content analysis of all articles on GSCM and SSCM published in the Scopus database up to the end of 2012. The paper makes several contributions to the literature. First, it provides the first comprehensive database of metrics that have been reported in the literature on GSCM and SSCM. Second, the analysis of the published metrics informs the development of an original conceptual framework for measuring performance in GSCM and SSCM. Third, the analysis and framework provide a strong basis for future academic and practitioner work. The paper highlights the need to develop a common understanding of what GSCM and SSCM entail, to develop metrics that address that common understanding, and to link metrics to the broader sustainability context in which supply chains operate. These requirements form the foundation of the conceptual framework presented in the paper. With that in mind, the remainder of the paper is organized as follows. First, a brief review of the literature on GSCM, SSCM, and sustainability metrics is provided. Second, a detailed overview of the methodology is presented. Third, the results are presented and analyzed in detail. Fourth, an original conceptual framework for measuring performance in GSCM and SSCM is provided. Finally, the paper concludes with a summary of the implications of the research and recommendations for future work.

2. Background

There is a large body of literature on GSCM and SSCM. There is also a large body of literature on sustainability metrics. Literature that focuses on the intersection of these topics, however, is relatively limited. A brief review of the literature in these areas is provided below.

2.1. Green and sustainable supply chain management

A number of literature reviews have recently been published on the topics of GSCM and SSCM (e.g., Abbasi and Nilsson, 2012; Ashby et al., 2012; Carter and Easton, 2011; Carter and Rogers, 2008; Gimenez and Tachizawa, 2012; Hassini et al., 2012; Linton et al., 2007; Sarkis et al., 2011; Seuring and Muller, 2008; Srivastava, 2007).These reviews underscore that there is now wide recognition in the literature that SCM has a meaningful impact on the natural environment (Mentzer et al., 2001) and broader society (Linton et al., 2007). Although there is general agreement on the broad goals and benefits of GSCM and SSCM, there remains an ongoing need to clarifying the content and scope of these activities.

Beamon (1999a) explained that a green supply chain focuses on the extension of traditional supply chains in order to minimize environmental impacts of a product throughout its entire life cycle. This could encompass green design, resource saving, harmful material reduction, and product recycling or reuse. The overall goal of these activities is to improve the environmental performance of the supply chain and industry as a whole (Holt and Ghobadian, 2009; Lau, 2011; Testa and Iraldo, 2010). SSCM is viewed, in many respects, as an extension of GSCM (Ahi and Searcy, 2013). As Svensson (2007) explained, SSCM requires that the concept of SCM is extended to incorporate the economic, ecological (environmental), and societal aspects of business practices and theory. Linton et al. (2007, p. 1080) further explained that "sustainability stretches the concept of supply chain management to look at optimizing operations from a broader perspective – the entire production system and postproduction stewardship as opposed to just the production of a specific product".

Many reasons have been offered as to why organizations should integrate environmental and sustainability principles into their SCM practices (e.g., Brindley and Oxborrow, 2014; Gaussin et al., 2013; Linton et al., 2007; Mosgaard et al., 2013; Ozkir and Basligil, 2012). For instance, Zhu et al. (2005, p. 450) noted that GSCM has emerged "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." These benefits have been cited elsewhere in the literature (e.g., Buyukozkan and Cidci, 2012, p. 3000). As a second example, Rao and Holt (2005) suggested that greening the supply chain encourages efficiency and synergy between partners, facilitates environmental performance, minimal waste, and cost savings. A key challenge in achieving these benefits, however, is overcoming perceptions that they are outweighed by the short-term costs of GSCM and SSCM. This argument was acknowledged by Setthasakko (2005), who wrote that "the narrow focus of economic performance is a shortcoming in the creation of environmentally responsible organizations and green supply chain management" (p. 169). Other challenges associated with GSCM and SSCM could involve "fuller information dissemination, training of purchasing staff, and greater collaboration among supply chain members" (Preuss, 2009, p. 215). Many of the benefits and challenges of engaging in GSCM and SSCM have been further discussed in recent literature reviews on the topic (e.g., Abbasi and Nilsson, 2012; Carter and Rogers, 2008; Gimenez and Tachizawa, 2012; Hassini et al., 2012; Seuring and Muller, 2008; Walker et al., 2008; Wittstruck and Teuteberg, 2011).

While the goals, benefits, and challenges of GSCM and SSCM are broadly recognized, the literature highlights a great range of perspectives on how these concepts should be defined. In fact, much of the literature on GSCM and SSCM has focused on clarifying the definition and scope of these concepts. For example, Srivastava (2007, p. 54) suggested that GSCM entails "Integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life." Seuring and Muller (2008, p. 1700) defined SSCM as "The management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements." Many other well-cited definitions of GSCM and SSCM are available in the literature (e.g., Badurdeen et al., 2009; Carter and Rogers, 2008; Haake and Seuring, 2009; Hervani et al., 2005; Wee et al., 2011). This profusion of definitions is helpful given that research on GSCM and SSCM is in its relatively early stages. The large number of published definitions ensures that a variety of perspectives on GSCM and SSCM are available and that these concepts are approached from a number of different angles. However, despite the many definitions available, several authors have highlighted that there continue to be some difficulties in determining the content and scope of GSCM and SSCM as well as in avoiding overlap with other concepts, such as reverse logistics (H'Mida and Lakhal, 2007).

To provide a basis for future research, Ahi and Searcy (2013) analyzed 22 definitions of GSCM and 12 definitions of SSCM with respect to 7 key characteristics of business sustainability (i.e., "economic, environmental, social, stakeholder, volunteer, resilience, and long-term focuses") and 7 key characteristics of SCM (i.e., "flow, coordination, stakeholder, relationship, value, efficiency, and performance focuses"). These characteristics were derived based on a review of peer-reviewed literature in the areas of business sustainability and SCM. Vast bodies of literature are available in each of these areas. The analysis found that the key characteristics of business sustainability and SCM were addressed to varying degrees by the existing definitions. In an effort to address all of the identified characteristics in a single definition, Ahi and Searcy (2013) offered the following definition of SSCM:

> "The creation of coordinated supply chains through the voluntary integration of economic, environmental, and social considerations with key inter-organizational business systems designed to efficiently and effectively manage the material, information, and capital flows associated with the procurement, production, and distribution of products or services in order to meet stakeholder requirements and improve the profitability, competitiveness, and resilience of the organization over the short- and long-term" (Ahi and Searcy, 2013, p. 339).

Ahi and Searcy (2013, p. 339) further explained that, given their view of SSCM as an extension of GSCM, "a definition of GSCM would be similar to the suggested definition of SSCM, but would exclude the integration of economic and social considerations." As explained later in the paper, this definition is utilized as a basis for the analysis of the metrics extracted from the literature. It also forms one of the foundations of the original conceptual framework presented towards the end of the paper. Finally, the terminology used in this definition (e.g., the "focuses" of the key characteristics), is also used in this paper for consistency.

Overall, much of the existing research on GSCM and SSCM has focused on laying the foundation for future work. Research on goals, benefits, and definitions of these concepts provides a basis for the development of approaches to implement them in practice. The measurement of performance in GSCM and SSCM is one application-focused area that has been receiving increasing attention in the literature.

2.2. Sustainability metrics

The terms "metrics" and "indicators" are frequently used interchangeably in sustainability measurement discussions (Tanzil and Beloff, 2006). Drawing on a dictionary definition, a "metric" may be defined as "a standard of measurement" (Merriam-Webster, 2014a) and an "indicator" may be defined as "a sign that shows the condition or existence of something" (Merriam-Webster, 2014b). More generally, sustainability metrics typically focus on quantitative measurement. Sustainability indicators typically have a broader focus. Indicators may be used to evaluate and motivate progress toward sustainability objectives (Veleva and Ellenbecker, 2001), covering both quantitative measures and narrative description of important sustainability issues (Tanzil and Beloff, 2006). However, it should be noted that these distinctions are not made in all cases. Sustainability metrics and indicators may be applied with different levels of complexity (Turnhout et al., 2007) and are increasingly being recognized as practical tools for policy, decision making, and communication purposes in many contexts, including GSCM and SSCM. They play a particularly critical role in measuring progress towards defined goals. This paper specifically focuses on the identification of *both* quantitative and qualitative metrics published in the peer-reviewed literature on GSCM and SSCM.

Corporate sustainability metrics are widely available and have been used by numerous organizations all over the world (Searcy, 2012). These metrics are frequently shared with the public in corporate sustainability reports. Previous research has shown that there is a great range in the types of metrics reported, though many metrics for all three areas of the triple bottom line are available (Roca and Searcy, 2012). The majority of metrics may be classified as either absolute or relative metrics. Absolute metrics "express operational performance in terms of what overall levels of performance are in specific areas of interest (e.g., water use) for an organization as a whole" (McElroy and van Engelen, 2012, p. 62) while relative metrics "express operational performance in terms of how performance in one area (e.g., water use) correlates to performance in another area (e.g., revenue or total production)" (McElroy and van Engelen, 2012, p. 63). Examples of absolute and relative metrics are widely available, including through the Global Reporting Initiative (GRI), which provides a list of over 90 indicators (GRI, 2013a). One of the key characteristics of metrics that focus on sustainability, however, is that they should be linked to the broader sustainability context in which an entity operates.

Sustainability context is one of the GRI's key principles for defining the content of sustainability reports, along with stakeholder inclusiveness, materiality, and completeness (GRI, 2013a). The sustainability context principle states that organizations should present their "performance in the wider context of sustainability" (GRI, 2013a, p. 17). The implication is that reporting solely on absolute or relative metrics fails to address the underlying issue of sustainability context. As the GRI notes, this means that performance should be assessed "in the context of the limits and demands placed on environmental or social resources at the sector, local, regional, or global level" (GRI, 2013a, p. 17). Furthermore, the GRI implementation manual explicitly notes that supply chain topics should be considered in the consideration of sustainability context (GRI, 2013b).

Building on the GRI's sustainability context principle, McElroy and van Engelen (2012) argued that there is an urgent need to develop context-based metrics of sustainability. They defined context-based metrics as those that "express organizational performance in terms of impacts on vital capitals, relative to norms, standards or thresholds for what such impact ought to be (for specific periods of time) in order to be sustainable (e.g., total water consumed per employee per year compared with a fair or equitable allocation of available renewable supplies)" (McElroy and van Engelen, 2012, p. 65). As McElroy and van Engelen (2012) argued, the development of metrics that consider the broader sustainability context is frequently overlooked. This paper therefore specifically focuses on the identification of context-based metrics, in addition to absolute and relative metrics, published in the peer-reviewed literature on GSCM and SSCM.

2.3. Metrics for GSCM and SSCM

A number of studies have focused on the broad issue of performance measurement in supply chains. As noted earlier, the key issues that have been explored in this area include evaluating and monitoring progress, reporting of performance, identifying achievements, promoting improved process understanding, identifying critical issues, confirming priorities, and providing guidance for future actions, among other topics (e.g., Akyuz and Erkan, 2010; Beamon, 1999b; Cuthbertson and Piotrowicz, 2008, 2011; Gopal and Thakkar, 2012; Gunasekaran and Kobu, 2007; Gunasekaran et al., 2004). Suggested metrics for measuring supply chain performance are also widely available.

There is less research that focuses specifically on measuring performance in green or sustainable supply chains, but there is evidence of growing interest in this area. For example, Hervani et al. (2005) provided an overview of the issues related to environmental (green) supply chain performance measurement. They argued that the objective of a green supply chain is to eliminate or minimize negative environmental impacts (air, water, and land pollution) and waste of resources (energy, materials, products) from the extraction or acquisition of raw materials up to final use and disposal of products. Hervani et al. (2005) proposed the use of ISO 14031 as a basis for the performance management of GSCM (i.e., GSCM/PM). As a second example, Bai et al. (2012) suggested a seven-step methodology for joint environmental and business performance measurement. By employing gray-based neighborhood rough set theory, they highlighted a core set of essential business and environmental performance measures for sustainable supply chains. They also employed the supply chain operations reference (SCOR) model for developing both business and environmental measures for supply chain sourcing. As a third example, Bjorklund et al. (2012) conducted a review of literature on logistics management and performance measurement that was coupled with a discussion of environmental logistics theory. They highlighted that, although there are growing environmental demands and pressures from a number of different stakeholders (e.g., government, society, the market and industry), few attempts have been made to investigate how the outcomes from environmental measurement activities are externally communicated. They further underlined that there is a large concentration on measuring current effects of historical decisions rather than developing measures to support future management. Moreover, Bjorklund et al. (2012) argued that there is a requirement to incorporate measures across different managerial levels and to apply more process-oriented measures in the supply chain. However, few empirical examples are available to show how these can be accomplished. As a fourth example, Miemczyk et al. (2012) conducted a structured literature review on sustainability in purchasing and supply management. They focused on interorganizational analysis at the three levels of dyad, supply chain, and network. They argued that research in these areas is more focused on internal or dyadic issues than on environmental considerations. They also highlighted that the social aspect of sustainability has received considerably less attention than the other dimensions. Their approach is limited to a purchasing perspective, and hence, some of the important supply chain issues (e.g., logistics and transportation) were excluded in their study. As a final illustrative example, it is interesting to note the recent special issue on performance measurement of sustainable supply chains in the *International Journal of Productivity and Performance Measurement* (e.g., Pazirandeh and Jafari, 2013; Reefke and Trocchi, 2013; Taticchi et al., 2013; Wang and Sarkis, 2013).

Despite the many published studies, including those noted above, no comprehensive inventory of metrics applied to GSCM and SSCM is yet available. This is a significant gap given the growing recognition that sustainability impacts extend beyond the boundary of any one firm (Seuring and Gold, 2013). There is a need to expand the definition of corporate sustainability performance to account for these broad impacts. Moreover, the lack of frameworks to develop reasonably practical sets of metrics may contribute to the confusion and uncertainty regarding the appropriate scope in the theory and practice of GSCM and SSCM initiatives. Research on metrics for GSCM and SSCM can therefore help guide the application of these concepts while also reinforcing the need to reframe measurements of traditional business performance to incorporate the supply chain.

3. Research approach

A systematic research literature review was conducted to identify peer-reviewed articles that focus on GSCM and SSCM. Systematic literature reviews are transparent, evidence-based activities (Tranfield et al., 2003) that clearly delineate the decisions, procedures, and conclusions made by those conducting the reviews (Cook et al., 1997). Literature reviews have been widely used for data collection and evaluation purposes in GSCM and SSCM research (e.g., Abbasi and Nilsson, 2012; Burgess et al., 2006; Carter and Easton, 2011; Gold et al., 2010; Seuring and Muller, 2008).

Given the broad nature of the GSCM and SSCM concepts, the systematic literature review in this study applied several screening criteria to identify relevant articles. The systematic literature review focused on all peer-reviewed articles published in the English language in the Scopus database. Scopus was selected because it provides a broad coverage of sustainability, supply chain, management, and engineering journals. Conference papers were excluded from the search. The screening of articles within Scopus was then based on a two-stage keyword search. The first sets of keywords were "green supply chain management" and "sustainable supply chain management". To identify articles within that sample that focused on performance measurement, the second set of keywords focused on a search for the terms of "metrics", "indicators", and "performance measures". The data range was set for the articles published from "All years" to "2012", inclusive. Additionally, the "All Fields" category as well as all of the "Subject Areas" available in Scopus were chosen for the search. References cited in the articles identified through the Scopus search were also used as secondary sources to identify additional relevant publications.

Using the procedures discussed above, a total of 354 articles were originally identified through the Scopus search. It was not possible to access 10 articles in the identified sample through either an online search or an interlibrary loan. Therefore, the total number of articles identified through the Scopus search was 344. All of the articles in this sample were carefully analyzed to identify the published metrics on GSCM and SSCM. Metrics were identified based on an application of the definitions provided in Section 2.2. In most cases, the authors of the articles analyzed explicitly identified them through the use of the terms "metric", "indicator", or "measure". All metrics that were highlighted in charts, tables, figures, boxes, bulleted lists, numbered lists, bold characters, or italics characters were also recorded. In all cases, the exact wording of the metric, as it appears in the paper, was recorded. The source of each metric was also recorded. If the metric cited in the paper was drawn from another source, the original article was also examined and considered as the basis of the metric. This process led to identification and analysis of 101 additional publications (over and above those identified in the original Scopus search). The total number of sources examined in this study was therefore 445 (i.e., $344 + 101 = 445$). Accordingly, all citations to the original source of an identified metric were recorded to provide an accurate accounting for the frequency a metric appeared in the literature. It is important to acknowledge that many of the identified metrics were similar. For example, two otherwise identical metrics may include the words "data base" and "database" or "use" and "usage" or "emissions" and "emissions of." To address these issues, each metric was analyzed using a word-for-word content analysis (Seuring and Gold, 2012; Krippendorf, 2004). In cases where two researchers independently agreed the metrics were essentially the same, they were combined. All of the same metrics were then added to determine the frequency count.

In addition to computing the frequency counts, detailed analyses were conducted to determine the key features of the identified metrics. A number of sustainability frameworks were considered to guide the analyses of the metrics, including the GRI, ISO 14031, and ISO 26000. However, it was soon recognized that the application of these frameworks would be problematic since they were not designed primarily to address the measurement of sustainability in a supply chain context. The definition of SSCM offered by Ahi and Searcy (2013) was therefore used as a basis for an analysis of the extent to which the metrics addressed the key characteristics of SSCM. A thematic analysis based on keywords used by the metrics was also conducted.

It is important to emphasize that different interpretations have been provided to describe SSCM in the literature. Many definitions of SSCM, such as those offered by Seuring and Muller (2008) and Carter and Rogers (2008), among others, have been well-cited and have provided a solid foundation upon which much useful research has been conducted. The decision to use the definition offered by Ahi and Searcy (2013) was made for several reasons. First, that definition was derived following an in-depth analysis of 22 published definitions of GSCM and 12 published definitions of SSCM. The definition was based on a review of the recent literature and captures the current state-of-the art in SSCM. Second, the definition was explicitly based on an analysis of the underlying characteristics of business sustainability and SCM. Using a definition of SSCM based on these primary principles provided insight into the key aspects of business sustainability and SCM addressed by the published metrics analyzed in this paper. In other words, the definition provided a strong starting point for determining what issues should be measured when assessing SSCM performance. Third, the use of a definition recently published in the *Journal of Cleaner Production* provides some continuity in the ongoing discussions in this journal.

Following the logic developed in Ahi and Searcy (2013), each metric identified in the literature search was evaluated to determine whether it addressed the 7 key characteristics of business sustainability (i.e., "economic, environmental, social, stakeholder, volunteer, resilience, and long-term focuses") and 7 key characteristics of SCM (i.e., "flow, coordination, stakeholder, relationship, value, efficiency, and performance focuses") they identified. Since the stakeholder focus appeared in both lists of characteristics, the metrics were analyzed against a total of 13 key characteristics of SSCM. The rationale was that this analysis would provide a reasonable basis for determining the extent to which core sustainability and SCM issues were addressed by the metrics. The analysis included an assessment of the extent to which the metrics addressed multiple key characteristics of SSCM. Finally, it should be noted that the metrics were also classified as to whether they were (1) quantitative or qualitative and (2) absolute, relative, or context-based metrics. This process was carried out by two researchers independently and the outcomes were finalized based on their mutual agreement.

4. Results and discussions

The results are presented and discussed in four sub-sections. First, background information on the sample of papers analyzed is provided. Second, a frequency analysis of all metrics appearing in the literature is provided. Third, an analysis of the metrics reported by the key characteristics of SSCM is presented. Fourth, an analysis of the metrics by the themes they address is provided. To demonstrate the great range of metrics used to measure similar issues, the thematic analysis includes an example analysis of the metrics that explicitly address water-related issues.

4.1. Background information on the sample

The yearly distribution of the 445 articles reviewed in this study is shown in Fig. 1.The figure shows that the number of articles published with relevance to GSCM and SSCM metrics has rapidly increased over time, with a particular acceleration in these publications occurring since 2007. Many of the early publications provided metrics that would be referenced in later research.

As illustrated in Fig. 1, the first publication dealing with relevant metrics was published in 1989. In that article, Lockyer and Wynne (1989) presented two key metrics: "environmental costs" and "inventory cost". Although these metrics were not specifically focused on GSCM and SSCM, they were later used in numerous publications in these areas (e.g., Azevedo et al., 2012; Hervani et al., 2005). After a gap of several years, relevant publications again began appearing in the mid-1990s. In 1994, Graham et al. (1994) presented a metric focused on "quality". As will be seen in the next sub-section, this metric was relatively widely-used in subsequent research on GSCM and SSCM (e.g., Buyukozkan and Cifci, 2011; Gold et al., 2010; Kuo et al., 2010; Zhu et al., 2010). Metrics focused on quality underline the attention that buyers pay to the incoming quality of products provided by suppliers. Other metrics appearing early on in the literature included "information processing cost" (Stewart, 1995) and "air emissions" (Hart and Ahuja, 1996; Klassen and McLaughlin, 1996). These metrics were later widely used in articles specifically focused on GSCM and SSCM. In their article focused on the impact of environmental management on firm performance, Klassen and McLaughlin (1996) introduced many other metrics that would later be referenced in publications on GSCM and SSCM (e.g., Azevedo et al., 2012; El Saadany et al., 2011; Zhu et al., 2008), including "solid wastes", "energy used", "buying environmental friendly materials", "process innovation", "environmental policies and audits", and "recovery cost (±)", among others. Noci's 1997 article on assessing supplier performance introduced many other metrics that would later be referenced (e.g., Kuo et al., 2010), including "green competencies", "current environment efficiency", "supplier's green image", and "net life cycle cost". These early publications provided a basis for the relatively steady growth in relevant publications beginning in 1998, and rapidly accelerating after 2007.

Fig. 2 provides a summary of the 15 journals that have published at least 6 articles on GSCM or SSCM performance measurement. As highlighted earlier, the Scopus search engine covers a wide range of peer-reviewed journals in the scientific, technical, and social

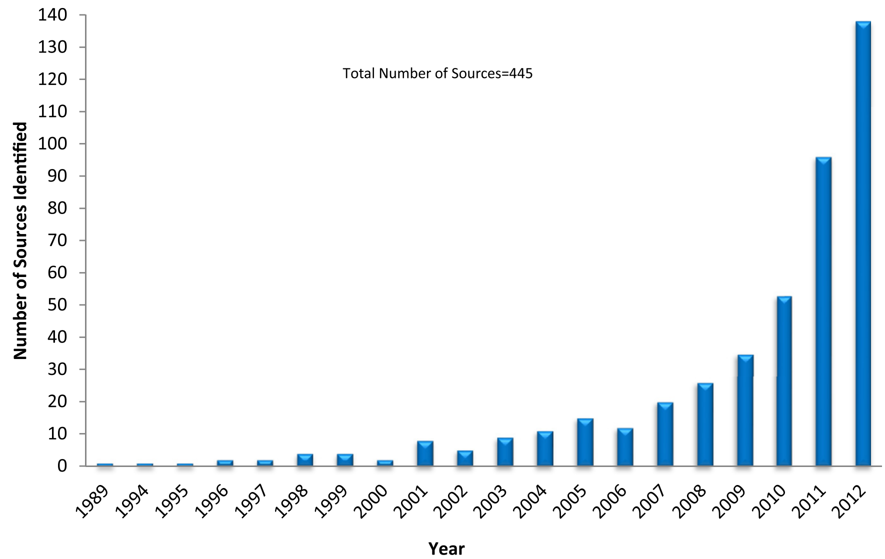

Fig. 1. Yearly distribution of the sources reviewed.

sciences. Given the research methodology conducted (i.e., employing Scopus as the primary means of identifying relevant articles), many engineering-, business-, ethics-, supply chain-, and sustainability-oriented journals were examined. Accordingly, Fig. 2 highlights the multidisciplinary nature of the systematic literature review carried out in this study (Burgess et al., 2006; Tranfield et al., 2003). The majority of the papers were published in either specialty sustainability or supply chain journals, though it is important to note that they appeared in publications covering broader interests as well.

4.2. Frequency analysis

A total of 2555 unique metrics were identified in the review. The frequency of use of the metrics is summarized in Table 1. As highlighted in that table, approximately two-thirds of the metrics (1683) appeared in the literature only once. Considering the number of metrics that appeared two (611) or three (87) times, respectively, it is observed that approximately 93% of the metrics appeared fewer than four times. Table 1 also highlights that just five (0.2%) metrics were used more than twenty times.

Fig. 2. Distribution of the articles analyzed for GSCM and SSCM metrics by journal.

Table 1
Frequency rates of use of the identified metrics.

Frequency of use	No. of unique metrics
1	1683
2	611
3	87
4	**75**[a]
5	28
6	20
7	10
8	9
9	5
10	3
11	9
12	4
13	1
14	1
15	1
18	1
19	2
21	1
24	2
28	1
31	1
Total	**2555**

[a] e.g., 75 unique metrics were addressed in 4 different sources.

Table 2 presents the complete list of metrics that appeared ten or more times. Table 2 underlines the great variety of metrics that appeared in the literature. The metrics are varied in their coverage of quantitative and qualitative measurements. The analysis shows that over two-thirds of the identified metrics (i.e., 1801metrics or 70.5% of the total) were found to have a primarily quantitative nature. Less than one-third of the metrics (29.5%) were classified as qualitative. Examples of both quantitative and qualitative metrics are available in Table 2. Table 2 also provides examples of metrics classified as absolute, relative, and context-based metrics. Overall, 2126 metrics (83.2% of the total) were classified as absolute metrics, 429 (16.8%) were classified as relative metrics, and no metric was classified as a context-based metric.

The results highlight the great variety of approaches for measuring GSCM and SSCM. It is clear that no general agreement on what should be measured in these areas exists. This may be due to lack of agreement on the definitions of GSCM and SSCM. There is still considerable debate about what should even be included in GSCM or SSCM (Ashby et al., 2012), much less how they should be measured. Given that GSCM and SSCM are still in their relatively early stages of development, the great variety of metrics is healthy as they present a multitude of approaches for measuring aspects of these concepts. However, it is likely that there will need to be some convergence on how GSCM and SSCM should be measured over time if they are to continue their advance into mainstream organizational management. Although there will always be a need for metrics that address the unique circumstances of any particular supply chain, a lack of reasonably consistent metrics will greatly impede efforts to compare performance between different supply chains. The results also highlight that the overwhelming majority of the metrics are not tied to the broader sustainability context in which supply chains operate. Although there are a multitude of metrics focused on the measurement of absolute or relative performance, there are few metrics that make any effort to link to the broader environmental (e.g., Rockstrom et al., 2009) or social (e.g., McElroy et al., 2008) context and none that meet the definition of context-based metrics provided earlier. In particular, none of the metrics addresses the part of the definition of context-based metrics focused on “what such impact ought to be (for specific periods of time) in order to be sustainable” (McElroy and van Engelen, 2012). Building on arguments by McElroy and van Engelen (2012), this is a significant gap in sustainability measurement that must be addressed to get a sense of whether supply chains are truly sustainable or not in the short- and long-term. Organizations must undoubtedly pay attention to their absolute and relative

Table 2
Identified metrics of green and sustainable supply chain management.

Metrics[a]	Frequency rate	Types				
		Quantitative	Qualitative	Absolute	Relative	Context-based
Quality	31	√			√	
Air emissions	28	√		√		
Energy use	24	√		√		
Greenhouse gas emissions	24	√		√		
Energy consumption	21	√		√		
Recycling	19	√		√		
Solid waste(s)	19	√		√		
Flexibility	18		√	√		
Environmental management system	15		√	√		
Customers' satisfaction	14	√		√		
Carbon footprint	13	√		√		
Life cycle assessment (LCA)	12	√		√		
Profit	12	√		√		
Cost	12	√		√		
Water consumption	12	√		√		
Product characteristics	11	√		√		
Energy efficiency	11	√			√	
Environmental costs	11	√		√		
Market share	11	√		√		
Reduction of air emission(s)	11	√		√		
Reduction of solid wastes	11	√		√		
Return on investment	11	√			√	
Operational cost (Operating cost)	11	√		√		
ISO 14001 certification	11		√	√		
Level of process management	10	√		√		
CO_2 emissions	10	√		√		
Water waste	10	√		√		

[a] Only metrics with the frequency rate of 10 or more are provided.

Table 3
Distribution of SSCM key characteristics addressed by the identified metrics.

Metrics	SSCM characteristics[a]												
	Economic focus[b]	Environmental focus[c]	Social focus[d]	Volunteer focus[e]	Resilience focus[f]	Long-term focus[g]	Stakeholder focus[h]	Flow focus[i]	Coordination focus[j]	Relationship focus[k]	Value focus[l]	Efficiency focus[m]	Performance focus[n]
Quality	√	√	√										
Air emissions		√											
Energy use		√											
Greenhouse gas emissions		√											
Energy consumption		√											
Recycling		√											
Solid waste(s)		√											
Flexibility	√												
Environmental management system		√											
Customers' satisfaction	√		√				√						
Carbon footprint		√											
Life cycle assessment (LCA)		√				√							
Profit	√										√		
Cost	√												
Water consumption		√											
Product characteristics	√	√	√										
Energy efficiency		√										√	
Environmental costs	√	√											
Market share	√										√		
Reduction of air emission(s)		√											
Reduction of solid wastes		√											
Return on investment	√												
Operational cost	√												
ISO 14001 certification		√											
Level of process management	√	√											
CO_2 emissions		√											
Water waste		√											

[a] All the definitions are adopted from Ahi and Searcy (2013).
[b] Economic focus: "The definition includes language related to the economic dimension of sustainability."
[c] Environmental focus: "The definition includes language related to the environmental dimension of sustainability."
[d] Social focus: "The definition includes language related to the social dimension of sustainability."
[e] Volunteer focus: "The definition includes reference to the voluntary nature of business sustainability."
[f] Resilience focus: "The definition includes reference to resilience, defined as "an ability to recover from or adjust easily to misfortune or change" (Merriam-Webster, 2014c)". Note that metrics specifically addressing risk were considered to address this focus as well.
[g] Long-term focus: "The definition includes reference to the long-term nature of sustainability. Reference to end-of-life management, reuse, product recovery, reverse logistics, the closed-loop supply chain, and the product life cycle were taken as indications of a long-term focus."
[h] Stakeholder focus: "The definition includes explicit reference to stakeholders, including (but not limited to) customers, consumers, and suppliers."
[i] Flow focus: "The definition includes language related to the flows of materials, services, or information. Reference to the supply chain was considered to implicitly refer to this focus area."
[j] Coordination focus: "The definition includes reference to coordination within the organization or between organizations. Reference to the supply chain, the product life cycle, or activities across channels was considered to implicitly refer to this focus area."
[k] Relationship focus: "The definition includes reference to the networks of internal and external relationships. This includes mentioning the coordination of inter-organizational business processes."
[l] Value focus: "The definition includes reference to value creation, including increasing profit or market share and converting resources into usable products."
[m] Efficiency focus: "The definition includes reference to efficiency, including a reduction in inputs."
[n] Performance focus: "The definition includes reference to performance, including applying performance measures, improving performance, improving competitive capacity, monitoring, and achieving goals."

performance metrics. These are essential in monitoring their own performances over time. However, they must also link their performances to the broader sustainability context in which they, and their supply chains, operate. Comprehensive measurement of GCSM or SSCM requires the use of absolute, relative, and context-based sustainability metrics.

4.3. Analysis of metrics by key characteristics of SSCM

Each of the metrics was classified according to the 13 key characteristics of SSCM suggested by Ahi and Searcy (2013). Cases where metrics addressed multiple characteristics were noted. A summary of the results of this analysis is provided in Table 3. Definitions of each characteristic from Ahi and Searcy (2013) are also provided in the table.

Analysis of the results shows that approximately 60% of the metrics focused on a single key characteristic of SSCM. The emphasis on metrics that address one characteristic is not necessarily surprising as metrics are often created to measure progress and guide decision-making on a specific issue. Over one-third of the metrics (i.e., 782 metrics or 30.6% of the total) were found to focus exclusively on environmental issues, 435 (17%) were found to focus on economic issues, and 310 (12.1%) were found to focus on social issues. “Air emissions” (28 times), “Energy use” (24), and “Greenhouse gas emissions” (24) were some of the high frequency environmental metrics utilized. “Cost” (12 times), “Return on investment” (11), and “Operational cost” (11) were among the highest frequency economic metrics utilized. Examples of high frequency social metrics include “Discrimination” (6 times), “Health and safety incidents” (5), and “Regulatory and public services” (4). Additional examples are provided in Table 3.

Analysis of the results also highlights that over 40% of the metrics addressed more than one key characteristic of SSCM. This is of note given that a sustainability perspective is intended to promote an examination of the interrelationships between issues. A summary of the SSCM characteristics that were addressed by any one metric is provided in Table 4. As summarized in Table 4, 1527 metrics addressed just one characteristic, 744 addressed two characteristics, 247 addressed 3 characteristics, 29 addressed 4 characteristics, and 8 addressed 5 characteristics. No one metric addressed 6 or more characteristics of SSCM.

The analysis shows that in any combination of addressing various SSCM characteristics, at least one of the economic, environmental, and social focuses was involved. As noted above, 744 metrics (29.1% of the total) addressed two of the SSCM characteristics. For illustrative purposes, a breakdown of the metrics that addressed two characteristics is provided in Table 5.

Analysis of Table 5 shows that the economic and environmental focuses of SSCM were the most frequently addressed among those metrics that covered two characteristics (i.e., 168 metrics or 6.6% of the total). The social and stakeholder focuses (107 metrics or 4.2%), environmental and social focuses (78 metrics or 3.1%), and economic and social focuses (70 metrics or 2.7%) were next. It is also interesting to note that several combinations of characteristics were not covered by any metric. For example, the social focus did not have any explicit overlap with the long-term, flow, or coordination characteristics. Examples of the specific metrics that addressed two SSCM characteristics are also provided in Table 5.

Returning to the information summarized in Table 4, a number of cross-cutting metrics addressed more than two different characteristics of SSCM. In cases where 3 characteristics were simultaneously addressed by a single metric (i.e., 247 metrics or 9.7% of the total), the most common combination was for metrics

Table 4
Summary of SSCM characteristics addressed by any one metric.

Categories		Number of SSCM characteristics addressed in each Category												
No. of characteristics addressed by any one metric	No. of metrics	Economic focus	Environmental focus	Social focus	Volunteer focus	Resilience focus	Long-term focus	Stakeholder focus	Flow focus	Coordination focus	Relationship focus	Value focus	Efficiency focus	Performance focus
1	1527	435	782	310	0	0	0	0	0	0	0	0	0	0
2	744	369	410	281	4	9	64	160	3	4	4	64	20	96
3	247	165	205	149	0	1	25	95	2	13	5	24	9	48
4	29	23	27	16	0	6	8	16	0	4	1	6	1	8
5	8	7	7	4	0	0	5	5	3	2	0	1	1	5
Total	**2555**	**999**	**1431**	**760**	**4**	**16**	**102**	**276**	**8**	**23**	**10**	**95**	**31**	**157**

Table 5
Number and examples of the metrics that addressed two SSCM characteristics.

SSCM Characteristics	Economic focus		Environmental focus		Social focus	
	No. of Metrics	Examples of Metrics	No. of Metrics	Examples of Metrics	No. of Metrics	Examples of Metrics
Economic focus						
Environmental focus	168	Environmental costs (11), Buying environmentally friendly materials (7)				
Social focus	70	Customer's satisfaction (14), Customer returns (6)	78	Environmental social concerns (4), Cooperation with customers for green packaging (2)		
Volunteer focus	0	---	0	---	4	Participation in voluntary programs (2), Number of individual volunteering (1)
Resilience focus	1	Risks and recoverability (%; %) (1)	5	Risk of severe accidents (2), Environmental risks (1)	3	Corruption risk (2), Health status and risks (1)
Long-term focus	7	Net life cycle cost (2), Long-term debt, including current portion (1)	57	Life cycle assessment (LCA) (12), Cumulative energy demand (primary energy used over the life cycle of a product or a process) (5)	0	---
Stakeholder focus	12	Returning customers ratio (2), Level of supplier preprocessing of raw materials (1)	41	Environmental partnership with suppliers (2), Choosing suppliers according to environmental criteria (2)	107	Stakeholder engagement (4), Stakeholder empowerment (4)
Flow focus	2	Cash flow (1), Cash flow provided by operating activities (1)	1	Annual mass-flow of different materials used (excluding energy carriers and water) (in tons) (1)	0	---
Coordination focus	1	Cooperation degree (1)	3	Collaborating with other companies and organisations for environmental initiatives (1), Improving opportunities for reducing waste through cooperation with other actors (1)	0	---
Relationship focus	1	Networks (2)	1	Interaction and harmony co-exist with natural systems on production and consumption systems (1)	2	Relationship (3), After sales service (2)
Value focus	59	Profit (12), Market share (11), Sales (4)	3	Energy requirement per unit of net value added (1), Global warming contribution per unit of net value added (1)	2	Publicly available missions and values statement(s) (2), Value added and community benefits (1)
Efficiency focus	5	Existing efficiency vs. cost of upgrading (2), Increased cost efficiency (1)	14	Energy efficiency (11), Recycling efficiency (3)	1	Institutional efficiency (1)
Performance focus	43	Cost savings (8), Operational performance (4)	39	Process optimization for waste reduction (8), Optimization of process to reduce air emissions (4)	14	Optimization of process to reduce noise (4), Health and safety performance measurement systems (1)

that addressed the economic, environmental, and social focuses of SSCM (i.e., 65 metrics or 2.5% of the total). Examples for this group of metrics are "Quality" (31 times), "Product features" (9), and "Major environmental, social, and economic impacts associated with the life cycle of products and services" (2). A number of other metrics addressed either 4 (i.e., 29 metrics or 1.1% of the total) or 5 (8 metrics or 0.3% of the total) of the key SSCM characteristics. Among those metrics that simultaneously addressed 4 characteristics of SSCM, the combination of economic, environmental, social, and stakeholder focuses was most common (i.e., 6 metrics or 0.2% of the total). Examples for this group of metrics are "Arranging for funds to help suppliers to purchase equipment for pollution prevention, waste water recycling, etc." (1 time), "Consumer concern towards sustainable practices" (1), and "Level of management effort to enlighten consumers on sustainability"(1). Finally, in cases where 5 characteristics were simultaneously addressed, the economic, environmental, long-term, flow, and performance focuses were the most frequently addressed characteristics (i.e., 2 metrics or 0.08% of the total). "Capacity to manage reverse flows" (2 times) and "Managing reverse material flows to reduce transportation" (1) are the metrics representing this combination. A summary of the number of times each characteristic was addressed is illustrated in Fig. 3. Note that the figure includes cross-cutting metrics, which is why the total is greater than 2555.

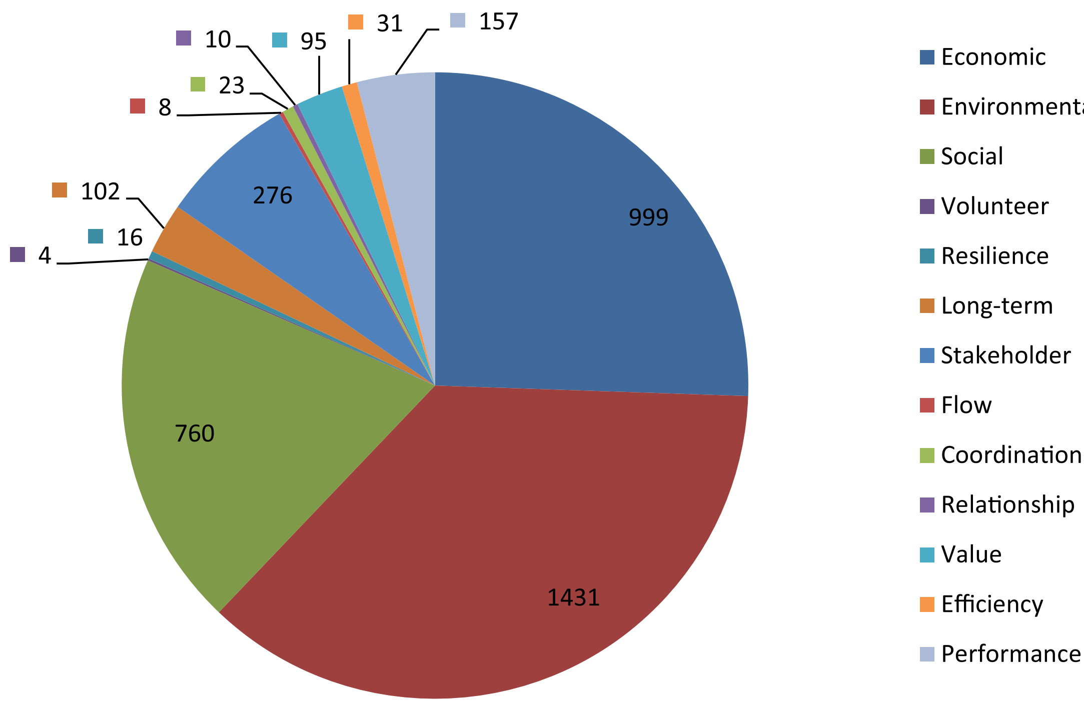

Fig. 3. Number of metrics addressing each key characteristic of SSCM.

Overall, the environmental characteristic was by far the most addressed by the published metrics. Given the fact that SSCM can be arguably considered as an extension of GSCM (Ahi and Searcy, 2013), it is unsurprising that the environmental characteristic of SSCM would represent the greatest portion of metrics identified. This is further supported by the fact that GSCM has a longer history of research than SSCM. Moreover, the fact that many countries require that organizations meeting certain thresholds publicly report on aspects of their environmental impacts (e.g., through the Toxic Release Inventory Program in the United States) may have encouraged the relatively high level of focus on this characteristic. Several researchers (e.g., Glock et al., 2012; Hasle and Jensen, 2012; Miemczyk et al., 2012; Sarkis et al., 2010; Seuring, 2013) have noted that social issues are generally underrepresented in the study of GSCM and SSCM. This could be due, in part, to the fact that social issues are often difficult to measure. The relatively high number of qualitative metrics used to measure social issues may indicate that there are few obvious quantitative metrics available in this area. The findings presented above lend some credence to that argument, in that social issues are represented less than environmental and economic issues, though it is important to note that social issues have certainly not been completely neglected. In fact, when compared to the other characteristics of SSCM, social issues are relatively well represented. Other characteristics of SSCM that had a sizeable number of representative metrics included the stakeholder, performance, long-term, and value focuses.

A number of characteristics, however, were not broadly addressed by the metrics. These less-represented characteristics of SSCM included the efficiency, coordination, resilience, relationship, flow, and volunteer focuses. While there were few explicit measures of these characteristics, it is important to acknowledge that some of them may be implicitly represented. For example, though there are few metrics that specifically focus on voluntary initiatives, it is not mandatory to report on the overwhelming majority of the metrics identified in most jurisdictions around the world. Many of the metrics would, therefore, be measured on a voluntary basis if they were applied in practice. As a second example, issues related to the coordination and relationship characteristics may be addressed through other aspects of a company's strategic plan. These examples highlight that issues related to sustainability and supply chains may be addressed through a variety of mechanisms within any particular firm. Sustainability and supply chain issues are often addressed within a firm through a multitude of initiatives that are not explicitly integrated. Moreover, not all of these initiatives are supported by metrics. It is also important to recognize that individual metrics do not necessarily need to address all characteristics of SSCM. Metrics are often created to specifically focus on a particular goal and are therefore explicitly not intended to simultaneously address multiple issues. Although it is desirable to have some cross-cutting metrics in order to promote an integrated view of sustainability measurement in supply chains, creating individual metrics that simultaneously address 13 characteristics is not particularly realistic. Composite metrics would likely be needed to achieve such a goal. In any case, the important point is that the metric systems applying to a particular supply chain should strive to capture all the 13 key characteristics of SSCM. While an individual metric is unlikely to capture all of those characteristics, a metric system should be capable of collectively addressing them.

4.4. Analysis of metrics by theme

A review of Table 2 indicates that a number of key themes were addressed by the metrics. For example, although a number of different metrics were used, it is clear that many metrics were used to highlight issues related to quality. To determine the key themes that were addressed by the metrics, a keyword analysis was conducted. A detailed analysis of the metrics showed that they collectively addressed over 50 different themes. A summary of the major themes addressed by 10 or more metrics is provided in Table 6. Examples of metrics that address each major theme are also provided in the table. It is recognized that the classification of the metrics by theme is open to some interpretation.

Table 6
Representative examples of major themes addressed by the identified metrics of GSCM and SSCM.

Major themes[a]	No. of metrics	Examples of metrics (frequency rates)
Product(s)	261	Product characteristics (11), Product design for remanufacturing (6)
Cost(s)	176	Cost (12), Environmental costs (11)
Waste(s)	148	Solid waste(s) (19), Reduction of solid wastes (11)
Recycle/Reuse	140	Recycling (19), Recycling revenues (7)
Material(s)	131	Decrease of consumption for Hazardous/Harmful/Toxic materials (8), Buying env. friendly materials (7)
Labor/Employment/Workforce	130	Labor productivity (5), Employee satisfaction (3)
Energy	113	Energy use (24), Energy consumption (21)
Emission(s)	91	Air emissions (28), Greenhouse gas emissions (24)
Transportation	84	Transportation network efficiency (2), Transportation modes (2)
Water	76	Water consumption (12), Water use (9)
Process	72	Process optimization for waste reduction (8), Process innovation (6)
Customer(s)	69	Customers' satisfaction (14), Customer returns (6)
Policy(ies)/Regulation(s)	55	Env. policies and audits (6), Number of regulatory violations by type (2)
Quality	45	Quality (31), Quality improvement (4)
Training/Education	38	Percentage of employees trained (4), Supporting educational institutions (4)
Pollution	36	Pollution control (7), Pollution prevention (5)
Service(s)	36	Service infrastructure (4), After sales service (4)
Investment(s)	34	Return on investment (11), Capital investment (5)
Technology	34	Buying env. friendly technology (7), Competence for environmental technologies (2)
Health and Safety	31	Health (5), Health and safety practices (4)
Supply	30	Supply redundancy (3), Supply chain finance (2)
Order	30	Economic order quantity (2), Number of back orders (2)
Disposal	27	Disposal method (5), Potential liability for disposal of hazardous materials (2)
Market	27	Market share (11), New market opportunities (4)
Time (Cycle Time/Lead Time)	27	Delivery lead time (5), Total supply chain cycle time (3)
Sale(s)	24	Sales (4), Sale of excess capital equipment (2),
Profit	24	Profit (12), Profitability (2)
Life Cycle/End of life	24	Life cycle assessment (LCA) (12), Formal, written commitments requiring an evaluation of life cycle impacts (2)
Compliance	23	Magnitude and nature of penalties for non-compliance (2), Environmental compliance and auditing programs (2)
Community	23	Supporting Community Projects (4),# Community complaints (3),
Saving(s)	23	Saving resources (1), Savings rate (1)
Price	21	Price of final products (2), Price performance value (1)
Income/Wage/Salary	20	Net income (3), Ratio of lowest wage to provincial minimum (2)
Accident(s)	20	Decrease of frequency for environmental accidents (9), Accidents or spills (4)
Public	19	Number of public consultation opportunities (2), Significant improvement in terms of public relation (1)
Demand	18	Demand rate (1), Percentage increase in demand flexibility (1)
Image	18	Green image (6), Marketing and green image (5)
Risk(s)	17	Risk (2), Corruption risk (2)
Revenue(s)	15	Recycling revenues (7), Revenues from "green" products (5)
Biodiversity	14	Existence of an up-to-date biodiversity policy (2), Effects on biodiversity (2),
Consumer(s)	14	Retention of green consumers (2), Green consumer perception (2)
Competition	14	Increasing competitiveness (2), Durable competitive advantage (2)
Opportunity(ies)	14	Job opportunities (4), Perceived opportunity for advancement (2)
Expense/Expenditure	13	Percentage of proactive vs reactive expenditures (4), $ Operating expenditures (3)
Taxing/Custom	10	Taxes (4), Tax breaks (2)

[a] Only the major themes addressed by 10 or more metrics are provided.

Table 6 highlights that different themes were addressed to differing degrees. This is not surprising given the large numbers of identified metrics and sources from which they were drawn. It is clear, however, that the metrics tended to measure a relatively small number of core themes from a variety of perspectives. For example, of the 113 metrics that specifically focused on energy, the majority focused on issues related to energy consumption and energy efficiency. Overall, the examples in Table 6 serve to further reinforce the general lack of agreement on how the key GSCM and SSCM issues should be measured. Although metrics focused on the same theme appear repeatedly in the literature, they approach the measurement of that theme from a wide range of different perspectives.

To provide an illustration of the point that a number of different metrics may be used to measure similar underlying issues, consider an analysis of all metrics addressing water issues. Water was selected for this illustration because its use is generally recognized as a major sustainability issue and metrics pertaining to water issues are widely available. For example, water is one of the key environmental aspects addressed by the GRI (GRI, 2013a), which has 5 metrics that directly contain the word "water" (i.e., EN8, EN9, EN10, EN22, and EN26) and 3 others that implicitly consider impacts on water based on the detailed description of the metric (i.e., EN11, EN12, and EN24). Water was also the example used by McElroy and van Engelen (2012) to demonstrate the difference between absolute, relative, and context-based metrics.

A total of 76 unique metrics focusing on water issues in GSCM and SSCM were identified. A broad range of issues related to water were addressed by the metrics, including consumption, efficiency, quality, usage, conservation, emissions, waste, contaminants, and pollution. The most frequently used metrics were "Water consumption" (12 times), "Water waste" (10), "Water use" (9), "Reduction of waste water" (8), "Water emissions" (5), "Water efficiency" (4), "Optimization of process to reduce water use" (3), and "Water recovery" (2).

The majority (i.e., 54 metrics) of the water-related metrics focused exclusively on the environmental characteristic of SSCM. Among the many examples were "Water consumption" (12 times), "Water waste" (10), "Water emissions" (5), "Discharges to receiving streams and water bodies" (2), and "Waste water emissions" (2). There was only one metric identified that focused primarily on social issues, namely "Housing quality (having electricity and portable water service)", which was addressed only 1 time. There was no water-related metric identified that focused primarily on economic issues. However, it is important to note that the authors of the metrics analyzed may have considered economic issues to be implicit in some of those published. For example, a metric such as "Water waste" could implicitly encompass economic motivations, particularly in literature published in the management realm. In fact, in their extensive review of peer-reviewed literature on SSCM, Seuring and Muller (2008) assumed that the economic dimension was covered since all of the papers in their analysis were drawn from management-related journals. Multiple characteristics of SSCM were addressed by 21 water-related metrics. A total of 14 cross-cutting metrics addressed 2 characteristics, 5 metrics highlighted 3, and 2 metrics covered 4 characteristics. A complete summary of the water-related metrics that addressed multiple characteristics of SSCM is provided in Table 7. No water-related metric was identified that addressed 5 or more characteristics of SSCM.

The examples above demonstrate the many ways that issues pertaining to one core SSCM issue, in this case water, may be addressed in performance measurement. A large number of metrics were devoted to this particular issue, with an emphasis on absolute metrics (i.e., 56 metrics or 73.7% of the total number of water-related metrics) and relative metrics (i.e., 20 metrics or 26.3%). No context-based metrics was developed to address water-related issues. Moreover, a majority of the metrics reported were quantitative (71 representing 93.4% of the total number of water-related metrics), though a small number of qualitative metrics were also developed (5 representing 6.6%). In any case, although a large number of metrics were utilized, they did tend to centre on a much smaller number of core themes. Issues such as water consumption and water pollution were addressed by many different forms of metrics.

The focus on a relatively small number of core themes per issue in the illustration based on water-related metrics may be seen in other instances, such as metrics pertaining to energy, emissions, or biodiversity. Therefore, although the data presented in this paper shows that there is little agreement on the specific metrics that should be utilized to measure performance in GSCM and SSCM, it is clear that there is some agreement on the core issues that should be measured. This may provide a basis for consolidation of the number of metrics used going forward. Moreover, the analysis shows that there is a broad coverage of key sustainability issues in the metrics for GSCM and SSCM. The key gap is not that any sustainability issues have obviously been missed, but rather that the connection to the broader sustainability context has not been made. The need for this connection is further highlighted in the conceptual framework presented in the next section.

5. A conceptual framework for measuring performance in GSCM and SSCM

The analysis presented above highlighted several fundamental points. First, there is clear need for metrics that address the broader sustainability context in which a supply chain operates. None of the identified metrics addressed the definition of context-based metrics provided earlier in the paper, particularly the aspect focused on "what such impact ought to be (for specific periods of time) in order to be sustainable" (McElroy and van Engelen, 2012). Second, there is a need for metrics that address the entire spectrum of SSCM. The analysis showed that there are metrics available that cover all 13 key characteristics of SSCM identified by Ahi and Searcy (2013). However, several of these characteristics receive relatively little attention. This underscores that core aspects of SSCM may be overlooked in current measurement efforts. Third, many of the published metrics do not explicitly address all of the key players in

Table 7
Overview of metrics that addressed multiple SSCM characteristics for water-related issues.

Categories	SSCM characteristics	No. of metrics	Examples of cross-cutting metrics (frequency rates)
2 Characteristics	Environmental and Long-term focuses	5	Industrial water reuse ratio (1), Total volume of water recycled/reused (m3/yr) (1)
	Environmental and Economic focuses	2	Purchase of water for own consumption per enterprise (2), Water used in process (1)
	Environmental and Social focuses	2	Drinking water (1), Water consumption and quality (1)
	Environmental and Efficiency focuses	2	Water efficiency (4), Improvement of efficiency of waste water collection (1)
	Environmental and Performance focuses	2	Optimization of process to reduce water use (3), Water saving (1)
	Environmental and Stakeholder focuses	1	[Suppliers] help us during the transition phase toward more environmental friendly material (e.g., ink change, water-based adhesive) (1)
3 Characteristics	Environmental, Economic and Value focuses	3	Industrial waste water generation per added industrial value (1), Water consumption per net value added (1)
	Environmental, Economic and Social focuses	1	Water (2)
	Environmental, Economic and Performance focuses	1	Use of cleaner technology processes to make savings (water) (1)
4 Characteristics	Environmental, Economic, Social and Stakeholder focuses	1	Arranging for funds to help suppliers to purchase equipment for pollution prevention, waste water recycling, etc. (1)
	Environmental, Economic, Value and Performance focuses	1	Output value of products utilization of waste gas, water & solid wastes (1)

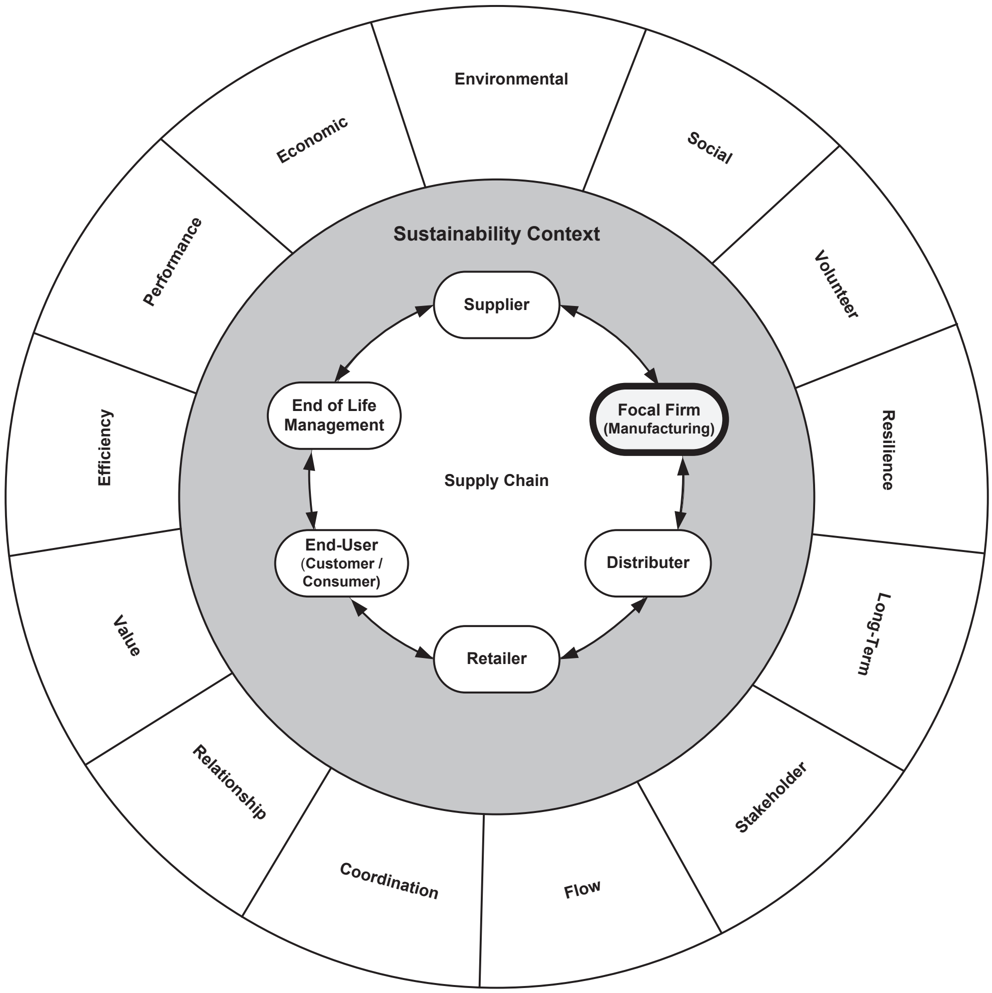

Fig. 4. Proposed conceptual framework for measuring performance in GSCM and SSCM.

the supply chain. While the focal firm is implicitly considered in virtually all of the metrics, other key players (such as suppliers, distributors, and retailers) receive considerably less attention. The analysis therefore supports the need to develop a conceptual framework for measuring sustainability performance in supply chains that addresses these fundamental issues.

With the above in mind, a conceptual framework for measuring performance in green and sustainable supply chains is proposed in Fig. 4. The purpose of the framework is to provide a starting point for academics and practitioners seeking to develop metrics for GSCM and SSCM. The framework is based on three fundamental propositions linked to the issues raised in the analysis as explained above:

P1. Metrics for GSCM and SSCM must address the key players in the supply chain.

P2. Metrics for GSCM and SSCM must address the broader sustainability context of the supply chain.

P3. Metrics for GSCM and SSCM must address the key characteristics of GSCM and SSCM.

Building on Proposition 1, the framework highlights six key players in a sustainable supply chain, namely the supplier, focal firm, distributor, retailer, end-user (i.e., customer), and end-of-life management (i.e., recyclers, reusers, and disposers). These six players roughly mirror the findings in Hassini et al. (2012), who structured a sustainable supply chain as a wheel encompassing six spokes of a supply chain: sourcing, transformation, delivery, value proposition, customers, and recycling. The key differences are that the framework in this paper explicitly highlights the centrality of the focal firm to the chain and it adopts a broader view of the final player in the chain (i.e., through an emphasis on end-of-life management rather than recycling alone). In Fig. 4, the focal firm is shaded and highlighted in bold to indicate that any metrics for GSCM or SSCM must be designed with its needs in mind. Although the metrics may have other uses, one key purpose of any metric will be to inform decision-making within the focal firm. Double-headed arrows between the players highlight the need to accommodate both forward and reverse flows throughout the supply chain.

Building on Proposition 2, the framework highlights that all of the players in the supply chain are explicitly embedded in a broader sustainability context. This highlights that any supply chain must be designed to take into account the economic, environmental, and social impacts of the chain on the local, regional, and global environments in which it operates. Moreover, it explicitly emphasizes that any effort to measure performance in green and sustainable supply chains must take sustainability context into account. As indicated in the analysis in the previous section, the broader sustainability context has been largely overlooked in the existing metrics for GSCM and SSCM. The proposed conceptual framework is the first to explicitly incorporate the notion of sustainability context as advocated by the Global Reporting Initiative.

Building on Proposition 3, Fig. 4 shows that the key characteristics of SSCM encircle the entire framework. The key characteristics of SSCM were derived based on the extensive bodies of research on business sustainability and SCM. They provide a sound foundation for structuring the development of metrics going forward. As noted in the earlier discussions, measuring GSCM would require addressing the same characteristics of SSCM, with the exception of the economic and social characteristics. Although it is recognized no one metric may simultaneously address all of the key characteristics of GSCM or SSCM, it is important that any system of metrics collectively addresses them if the intent is to measure performance in those realms. Embedding the framework in these characteristics underlines that any metrics used to measure GSCM or SSCM must be explicitly based on a definition of those concepts.

The framework is intended to be broadly applicable. However, it is important to emphasize that different metrics may be used for different supply chains. Any effort to measure SSCM performance must address the specific circumstances of the particular chain being assessed. It is therefore recognized that priorities will vary from chain to chain and these will change over time. Ultimately, it will be up to the decision-makers in the focal firm to determine how those choices will be made, though consultation with key internal and external stakeholders (with particular emphasis on those stakeholders representing other players in the supply chain) should serve as an input to the prioritization process. As Fig. 4 illustrates, it is important that each player in the chain, the broader sustainability context, and the key characteristics of SSCM are considered in the development of metrics. Overlooking any of these elements could mean that important issues of SSCM are missed. It is unlikely that any one metric will simultaneously address all elements of the framework. However, the framework underscores that it is necessary for all elements to be addressed by the collective set of metrics.

The framework can be used as a basis for developing new metrics for measuring performance in green and sustainable supply chains or for evaluating existing metrics. For example, although the literature provides a sound starting point for the development of metrics, the framework highlights several areas where those metrics could be improved. Among the 2555 metrics identified in the literature, it is clear that there are metrics available that address all six of the main players in the supply chain. Table 6 also showed earlier that there is a broad coverage of the key themes relevant to GSCM and SSCM. There are also metrics that address all 13 of the key characteristics of SSCM identified by Ahi and Searcy (2013), though it is important to stress once again that the characteristics are addressed to widely varying degrees. However, the review of published metrics also showed that there are no metrics that address the broader sustainability context of GSCM and SSCM. This is further highlighted by the framework, which underscores that this is a key oversight.

The key strength of the framework is its ability to structure thinking and discussion regarding the measurement of performance in green and sustainable supply chains. The framework certainly does not invalidate other frameworks in GSCM and SSCM, but it is the first to explicitly incorporate the key characteristics of SSCM and the notion of sustainability context with respect to performance measurement. The framework explicitly builds on the analysis in this paper, which itself was rooted in the previously published literature. The key characteristics of SSCM, the concept of sustainability context, and the key players in the supply chain have all been discussed in the academic literature. The uniqueness of the framework is rooted in the fact that it has explicitly brought these concepts together in an integrated way in order to address the issue of measuring performance in SSCM. In doing so, the framework provides a needed starting point for the development of metrics that comprehensively address GSCM and SSCM.

6. Conclusions

This paper presents the most comprehensive analysis of metrics published in the literature on GSCM and SSCM. A systematic research literature review was conducted to provide a needed reference point on the great variety of metrics highlighted in these areas. The results showed that a total of 2555 unique metrics have been addressed in the literature published up to the end of 2012. The metrics were analyzed in depth from a number of different perspectives. The analysis provided a basis for the development of an original conceptual framework for measuring performance in green and sustainable supply chains. It is recognized that there are some limitations to the study. First, although Scopus covers a wide range of peer-reviewed journals in the scientific, technical, and social sciences, it does not include all reputable peer-reviewed journals. Therefore, using different search terms and additional databases beyond Scopus may have resulted in the identification of additional metrics. Second, although the conceptual framework flows logically from the analysis, it has not been tested in practice. However, despite these limitations, the analysis yielded several important insights with respect to the measurement of GSCM and SSCM. The key implications of the research are discussed below. It is argued that the paper presents an important starting point for both academics and managers interested in measuring the sustainability performance of supply chains. The paper closes with a discussion of the potential avenues of future research.

6.1. Academic and practical implications

The paper provides a number of important academic and practical implications. One of the key points to emerge from the analysis is that there was a great range in the frequency of use of the metrics. The majority of the metrics were used only once, while the most frequently utilized metric was highlighted just 31 times in the papers analyzed. The great range of metrics utilized indicates that a general lack of agreement on what should be measured in GSCM and SSCM remains. Although an extensive array of metrics in these areas is available, this presents challenges in determining the metrics most appropriate to measuring green or sustainable performance in a particular supply chain. The wide range in the published metrics provides challenges for both academics and practitioners. From an academic perspective, there is a need to develop clearly defined metrics that use relatively standard language when measuring the same core issue. As the analysis indicated, in many cases, a number of different metrics were used to measure essentially the same thing. From a practical perspective, the need to use clearly defined metrics with relatively standardized terminology is needed in order to promote greater comparability in assessing the sustainability performance of different supply chains. While different supply chains will undoubtedly require metrics unique to their particular circumstances, there are also likely some metrics (e.g., emissions) that could be compared across chains if they were defined and measured in the same way. Overall, the analysis underlines the need to find common ground regarding the key areas to be measured in GSCM and SSCM.

Although there was a tremendous number of metrics available in the literature, the paper also highlights the need for new metrics that comprehensively address SSCM. This need was explicitly highlighted by the proposed conceptual framework. As shown in the analysis, all 13 key characteristics of SSCM suggested by Ahi and Searcy (2013) (i.e., economic, environmental, social, volunteer, resilience, long-term, stakeholder, flow, coordination, relationship, value, efficiency and performance focuses) were addressed to some extent by the metrics. Environmental issues were by far the best represented. A number of cross-cutting metrics that address multiple characteristics of SSCM were also identified and analyzed. However, a number of characteristics received relatively little attention. In particular, few metrics were developed for the resilience, relationship, coordination, and flow characteristics. One of the key points of this paper is that definitions of GSCM and SSCM provide a critical reference point for application-based initiatives. Greater emphasis on these relatively overlooked characteristics is therefore needed to ensure that the full scope of GSCM and SSCM are addressed in practice. Both academics and practitioners should therefore pay greater attention to these characteristics going forward. The paper also highlighted that no context-based metrics for GSCM or SSCM have been proposed in the literature. The overwhelming majority of the metrics published were classified as absolute metrics while a much smaller group of metrics were categorized as relative metrics. These forms of metrics are needed to measure progress over time within organizations and their associated supply chains. However, the lack of context-based metrics means that current measurement efforts are largely self-referential. There is little connection to the broader local, regional, and global context within which supply chains operate. This finding highlights the need for both academics and practitioners to develop context-based sustainability metrics for GSCM and SSCM.

6.2. Recommendations for future research

There are several opportunities to extend the research presented in this paper. Fundamentally, there is a need to develop a common understanding of what exactly GSCM and SSCM entail (Ashby et al., 2012). Building on that point, there is also a need for research on how organizations can select metrics most appropriate to their circumstances. The conceptual framework underlines that focal firms need to consider all of the main players in the supply chain, must strive to address the 13 key characteristics of SSCM, and must be careful not to overlook the need for context-based metrics. The conceptual framework therefore provides a clear starting point for all organizations, though it is recognized that there are a multitude of potential metrics that may be used to fulfill these requirements.

It is important to recognize that no one metric, or set of metrics, will apply equally well in all circumstances. While the conceptual framework provides a clear starting point for this process, it leaves the prioritization of specific metrics to the decision-makers in the focal firm. Moreover, the conceptual framework has not been tested in practice nor does it provide a set of specific metrics. A consolidated set of scientifically-sound metrics that have been tested in the real world would provide a useful reference point for organizations seeking to measure their GSCM or SSCM efforts. Given the fact that SSCM can be arguably considered as an extension of GSCM, metrics that address multiple key characteristics of SSCM are of particular interest. Although many examples of integrated metrics are available in the literature, the emphasis has overwhelmingly been on presenting metrics that address a single characteristic of SSCM. The development of scientifically-sound integrated metrics will help in promoting stronger linkages among various key characteristics of SSCM. Such linkages may help further drive the incorporation of green and sustainable practices into supply chain management. The paper also underlined that additional effort is needed on the development of context-based metrics for GSCM and SSCM. It is acknowledged that there are many challenges in developing such metrics, particularly in determining the appropriate level of impact or contributions that individual organizations or supply chains must make in order to be deemed sustainable or not (McElroy and van Engelen, 2012). Nonetheless, such research is needed to underscore the connection that supply chains have to the broader context within which they operate.

Finally, it should be explicitly noted that the research presented in this paper focused on reviewing the metrics published in the peer-reviewed literature. One additional avenue of future research could be to analyze the metrics published and used by corporations engaged in the measurement of sustainability in their supply chains. A review of publicly available sustainability reports would provide insight into the metrics focused on this issue that corporations are choosing to share with their stakeholders. Interviews with managers at these corporations would provide an opportunity to explore questions related to how the metrics were developed, how they are used, and plans for developing new metrics going forward. The interviews could explicitly address questions related to the key challenges in developing metrics that address the 13 key characteristics of SSCM, metrics that link to the broader sustainability context in which the corporation and its supply chain operate, and metrics that address all key players in the supply chain. Moreover, in-depth case studies with a selected number of companies could permit a detailed, long-term exploration of these issues and provide an opportunity to test the conceptual framework proposed in this paper. This research would provide greater insight into the metrics that are being applied in practice and the key challenges academics face in advancing research on the measurement of sustainability in supply chains.

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