A Framework for Metrics used to Measure Sustainable Supply Chain Management Performance

MBA Thesis

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Abstract

The aim of the paper is to identify and elaborate on the metrics that have already been published in the literature on sustainable supply chain management. Numerous metrics for gauging the effectiveness of sustainable supply chain management were acknowledged but a vast majority of these metrics were used only once or in only one academic paper; this showed a general disagreement of researchers over which metrics should be used to gauge the effectiveness of a sustainable supply chain. Moreover, a vast majority of metrics identified in the literature were used to gauge similar issues. Therefore, an extensive framework is developed for identification of metrics in accordance with the already established key characteristics of Sustainable Supply Chain Management. The research provides a thorough analysis on the appropriate use of metrics for sustainable supply chain management.

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1 Introduction

The concept of sustainability has gained pertinent importance in the field of Supply Chain Management over the last decade and it is still continuing to grow. The keen interest in this field of study may be attributed to the environmental pressures exerted by various stakeholders and pressure groups. Problems initiated by the concept of scarce resources are at their historical record level. The population of the world at this point of time is the highest in recorded history whereas the resources available to accommodate this ever growing population are depleting at a surprising rate. There is a global resource emergency. We would have to immediately shift towards sustainable production and manufacturing processes to ensure that goods and services are produced without depriving our future generations from the already available resources. In fact, a large number of organizations are striving hard to become sustainable. However, some organizations are proactively pursuing the goals for sustainability whereas others make superficial efforts to portray a green image.

The main problem in implementation of sustainable practices is the absence of any standardized measures or indicators for the evaluation the efficiency and affectivity of sustainable advancements (Searcy, McCartney, & Karapetrovic, 2009). Therefore, there is a need for a reliable set of performance indicators or metrics used to measure the sustainability of operations of any organization. Operations of any business entity can be comprehensively reflected in its supply chain. Thus, gauging of a firms sustainability efforts can be done by assessing the sustainability of different processes of the firm's supply chain. Hence, the term Sustainable Supply Chain Management.

This paper reviews the literature published on the subject and strives to formulate a comprehensive framework for metrics used for assessing the performance of Sustainable Supply Chain Management for any organization.

2 Literature Review

2.1 Definition of Sustainable Supply Chain Management

2.1.1 Supply Chain Definition

Supply chain is best defined as all the parties that are involved in fulfilling a customer order (Chopra & Meindl, 2007). As it is apparent in the definition, a typical supply chain consists of multiple decision makers engaged in making crucial decisions such as how to manage resources, information and processes that are within and out of control of the focal company. Likewise, supply chain management may be defined as the integration and control over the various diverse supply chain operations, resources and information with the prime objective of maximizing the supply chain profitability by widening the gap between all the costs associated with producing goods or services and the revenue generated by selling them to the customers.

2.1.2 Business Sustainability and Sustainable Supply Chain Management

Business sustainability can be defined as the capability of any business entity to carry out all its activities with an overall aspiration of preserving and securing the well being of the environment, society and economy.

Reviewing the research carried out on the topic of sustainable supply chain management; it is apparent that almost all researchers are in harmony with the general goals of sustainable supply chain management along with the basic benefits intended to reap from it. However, there is no clarity regarding the scope and contents of the activities that shape up the concept of sustainable supply chain management. Many are of the view that sustainable supply chain is merely an extension of the traditional concept of supply chain with the additional aspect of minimizing the adverse environmental impacts with respect to the entire life cycle of any good or service

(Beamon, 1999). The efforts associated with curtailing the adverse environmental effects can be of a wide range such as product recycling and reuse, environmental friendly product design, minimal use of harmful materials and resource conservation. The main objective of all these efforts is to enhance the environmental performance of any specific supply chain at a micro level and the whole industry at a macro level (Holt & Chobadian, 2009; Lau, 2011; Testa & Iraldo, 2010). Sustainable supply chain management is also perceived as a branch of the concept of green supply chain management (Ahi & Searcy, 2013). The concept of 'sustainability' is built upon the concept of supply chain management with the modification of operational goals shifting the focus from simple production of products to a wider prospective of accommodating the whole production system and post production stewardship (Linton, Klassen, & Jayaraman, 2007). It is built on the concepts of supply chain management extended to inculcate economic, environmental and social factors in business practices and theory (Svensson, 2007).

The same is advocated by Elkington's (1997) Triple Bottom Line (TBL) principle. The TBL principle places any firm's sustainability practices on the three pillars of profit, planet and people. Vast acceptance and popularity of the TBL principle is obvious from the periodic issue of TBL reports by various companies in order to enlighten their stakeholders of their sustainability practices. Therefore, sustainable supply chain management may well be accredited as supply chain management with the aim of maximizing supply chain profitability with the added aspect of reducing the overall ecological impacts and ensuring the maximum attainable wellbeing of the society. However, this places a huge burden on the companies for achieving multiple conflicting goals and objectives. On one hand, the core objective of maximizing of profits is achieved by minimizing all costs whereas minimizing the overall negative impacts on

the environment and maximizing the overall well being of the society, on the other hand, calls for additional expenses; increasing the supply chains operational costs and reducing profitability.

Ahi & Searcy (2013) have reviewed and scrutinized over twenty definitions of Green Supply Chain Management and more than ten definitions for Sustainable Supply Chain Management in lieu with the seven characteristics for sustainability and Supply Chain Management. By merging all the reviewed definitions and integrating them with the pertinent sustainability and Supply Chain Management characteristics; they have devised a comprehensive definition for Sustainable Supply Chain Management:

"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 & Searcy, 2013 Page 339).

This definition is used as a foundation to build upon the investigation of Sustainable Supply Chain metrics identified from the available literature on the topic.

2.2 Review of articles published on the topic

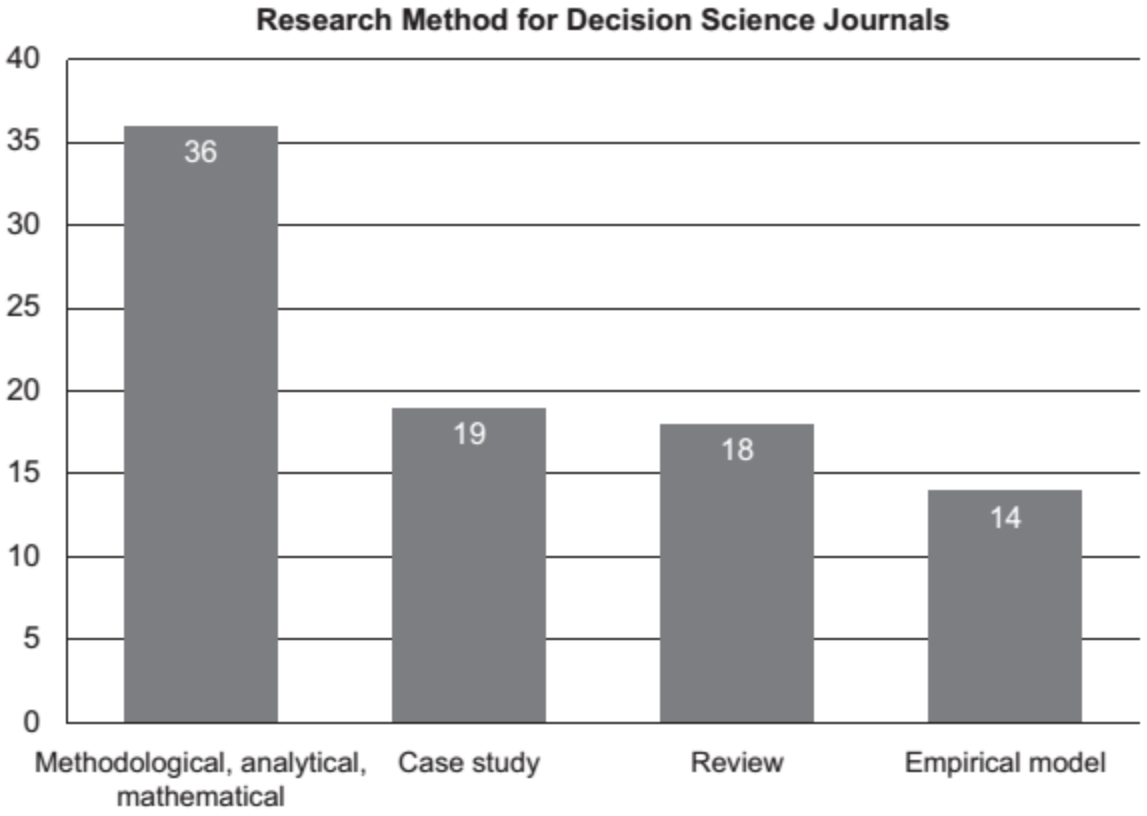
Green Supply Chain Management and Sustainable Supply Chain Management have been the centre of attention for numerous literature reviews published in the past few years (Abbasi & Nilsson, 2012; Ashby, Leat, & Hudson-Smith, 2012; Carter & Easton, 2011; Carter & Rogers, 2008; Gimenez & Tachizawa, 2012; Hassini, Surti, & Searcy, 2012; Linton, Klassen, & Jayaraman, 2007; Sarkis, Zhu, & Lai, 2011; Seuring, 2013; Srivastava, 2007). Recently, two

prominent papers on the subject area have strived to present a detailed and comprehensive research on all academic research on the framework on sustainable supply chains; Seuring and Muller (2008) based there study on the review of almost two hundred journal articles ranging from a wide time span from 1994 to 2007 whereas Carter and Rogers (2008) based their study on the theoretical review of over 150 journals along with an practical insight by interviewing supply chain managers of twenty eight fortune 1000 companies. The keen interest of researchers in this field reflects upon the fact that the activities associated with Supply Chain Management do in fact have a great impact on the society (Linton, Klassen, & Jayaraman, 2007) and the environment (Mentzer, et al., 2001).

2.2.1 Research Methods

Figure 1 represents the bifurcation of academia researched according to the methodologies used in it. As we place a lot of stress on decision sciences publications, one should not get surprised that a great number of the reviewed papers use analytical models. Problem solving which is associated with facility location (Srivastava, 2007; Dou & Sarkis, 2010), scheduling (Lejeune, De Pablo, & Ganaulis, 2008), supplier selection, policy assessment, etc. is the focal point of these studies. This comprises, application of optimization concepts (Cannon, Kouvaritakis, & Huang, 2005), Analytic Hierarchy Process (AHP) (Che, 2010), heuristics such as genetic algorithm (Wang & Hsu, 2010), simulation (Van Der Vorst, Tromp, & Van Der Zee, 2009), exergoeconomics (Ji, 2008) and Fuzzy decision making (Tsai & Hung, 2009). Life Cycle Assessment (LCA) or Life Cycle Costing is another well-liked decision support method used in evaluating the entire environmental effects of products on our ecosystem starting from the extraction of natural resources from the environment and ending on the final dumping into landfill unless it is completely recycled (Matos & Hall, 2007). The second most frequently tried

method is that of case study. It holds its differences to the evolution in operations management literature where the case study research method has not been adopted effectively. The sustainability area is a comparatively new research field in Operations Management, taking up to case study work frequently can assist the researchers in developing their appreciation of the genuine issues and problems. As case study method is ideal in this context, therefore, more application of this method of working can provide greater insight into the subject matter (McCutcheon & Meredith, 1993).



Source: A literature review and a case study of sustainable supply chains with a focus on metrics, Hassini et al. (2012)

Figure 1. Distribution of Reviewed Papers by Research Methodology

2.2.2 Classification by industry sector

It has been observed that a large number of the reviewed literature is devoted to focus on manufacturing sectors. In spite of the fact that the Green Ratings of the 2010 NewsWeek rated

six of the top ten companies in the US being ICT companies (Week, 2010). We do not find evidence of study where attention is paid towards the Information and Communication Technologies. It is hence established that the focal point of sustainability in the manufacturing sector can be explicated into two features. First of all, past research has laid attention on production and manufacturing concerns, therefore, sustainable supply chain research has been traditionally based on that research.

This observation is affirmed by the academia that states, organizations which adopt lean manufacturing strategies are inclined to adopt sustainability practices (King & Lenox, 2001). Moreover, environmental regulations have stressed upon the idea of manufacturing plants since quite some time (e.g., pollution control).

2.2.3 Firm size and sustainability

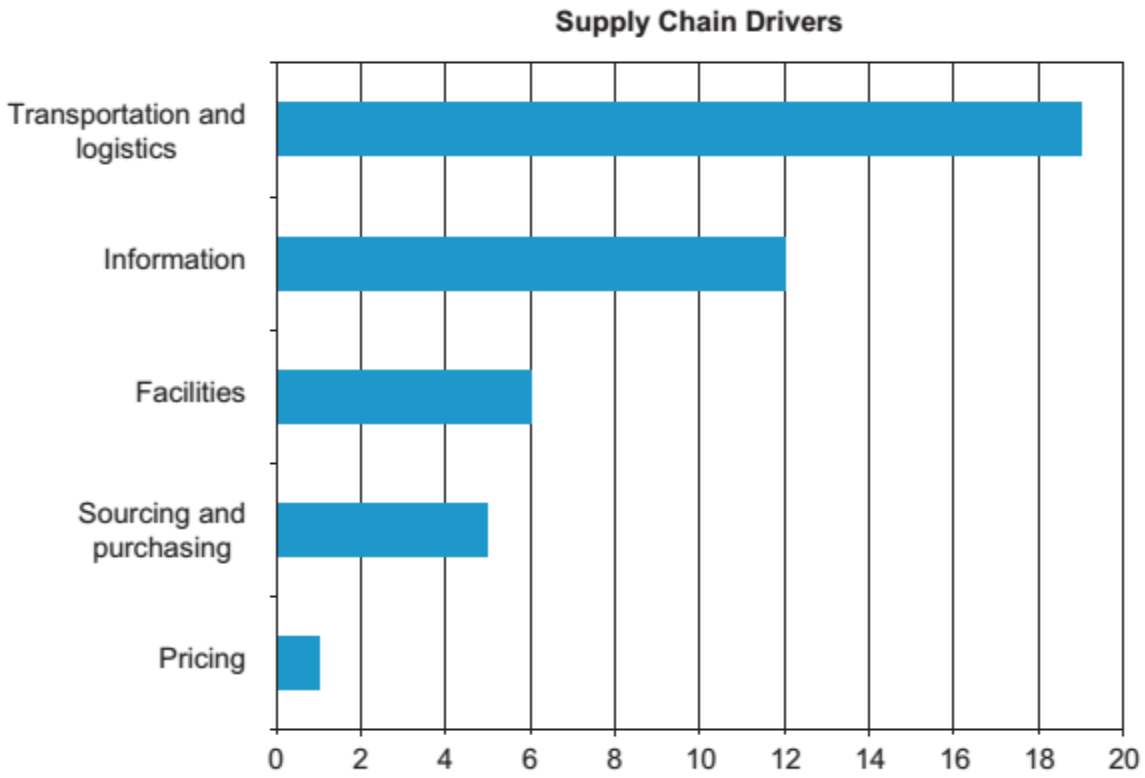
Lee & Klassen (2008), Moore & Manring (2009), Lee (2008) and Tomomi (2010) have researched on the implementation of environment friendly or sustainable practices in Small and Medium Enterprises (SMEs). The striking initial cost of greening is the most eminent out of the few key hindrances that SMEs comes across in terms of the adoption of sustainable practices in the supply chain. Sarkis (2006) declared that improved investment in environment risk management and its timely adoption did not reflect positively in enhancing performance for small and medium sized firms when referring to the metal finishing industry. Testa & Iraldo (2010) advocated the same while imploring on the determinants and incentives for the execution of green practices at services in OECD countries. They summarize these practices as being complementary to the complex management practices whereas their impact upon the profitability of the entity is unclear. Whilst, it is an established fact that it is advantageous for the large firms to adopt sustainable practices more than Small and Medium Enterprises whereas Small and

Medium Enterprises essentially require it for a long term focus, these findings discovered that when adopted at an early stage, the rate of return on sustainable practices is insufficient. Consequently, it can be concluded that more research is essential in this area.

2.3 Supply Chain Drivers

Six major drivers for supply chain performance have been explained by Chopra & Meindl (2007): **transportation, inventory, facilities, information, pricing, and sourcing**. Furthermore, they present a structure for supply chain analysis that begins by developing understanding of the supply chain aggressive strategy and its compatibility with the operational strategy. It further unfolds how they can be positioned by each driver. Therefore, it is quite predictable that a company that places emphasis on sustainability in its competitive strategy is most likely to replicate it in each of the six drivers of the supply chain. To examine how this is revealed in the papers we have analyzed, Figure 2 showing the distribution of the reviewed papers by driver.

This has been observed that a great number of studies paid special attention towards transportation (including logistics and distribution) and information drivers. It is noteworthy to mention here that no studies have ever focused on the inventory driver. However, one can find evidence of one paper that reveals information about the pricing driver. There were many papers out of which (29) highlighted closed-loop supply chains; nevertheless, one could not find any information related to inventory predominantly as an eminent driver for the supply chain performance.



Source: A literature review and a case study of sustainable supply chains with a focus on metrics, Hassini et al. (2012)

Figure 2. Distribution of Reviewed Papers by Supply chain Drivers

2.4 Major factors for the adoption of sustainable supply chain practices

Researchers have presented many reasons arguing why organizations need to incorporate environmental and sustainability principles into their SCM practices. For example, (Zhu, Sarkis, & Geng, 2005) stated that GSCM has evolved "as a significant fresh archetype for enterprises to acquire profit and market share objectives by decreasing their environmental risks and impacts as they raise their ecological effectiveness." These advantages have been cited elsewhere in the literature (Buyukozkan & Cifci, 2011). As another example, Rao and Holt (2005) advocated that greening the supply chain supports effectiveness and great synergy between associates, encourages environmental performance, minimum waste, and cost savings. Yet, a major challenge in attaining these benefits is conquering prevailing observations that support the idea that they are overshadowed by the short-term costs of GSCM and SSCM.

Additional challenges linked with GSCM and SSCM could engage, "Fuller information dissemination, training of purchasing staff, and greater collaboration among supply chain members" (Preuss, 2009) page 215.

Source: A literature review and a case study of sustainable supply chains with a focus on metrics, Hassini et al. (2012)

Figure 3. Factors in Sustainable Supply Chain

Figure 3 proves the main external and internal pressures that may drive a supply chain to adopt sustainable operations. **Market forces factors** include consumers, retailers, OEMs who possibly will require products which are thought to be environment friendly from their provider. **Financial stakeholders** like mutual funds and pensions funds entail he requirement that company should pursue sustainable practices as depicted by them or some third party. In addition, the future access to capital markets may be limited only to businesses that are believed to be highly principled or environment friendly. In conclusion, **competition** in the marketplace

may necessitate a company to offer products considered as socially responsible, green or sustainable. **Policy and regulations** features originate from governments through legislation or through a regulator necessitating companies to adhere to specific environmental standards. If a certain environmental disaster arises (example BP), governments may retroactively initiates legislation or regulation to curb certain business practices. Moreover, **industry standards** (such ISO 14001) demand suppliers to execute audits and certifications. For example, Klassen and Vachon (2003) established that adoption of ISO 4001 is considerably linked with companies' hard work to invest more in environmental management practices.
The **science and technology** factor originates from the need to use R&D to locate materials and processes that are non toxic, use less energy or discover appropriate alternatives without compromising use. The **product development** factor engages the greening of the available product (e.g., using more recycled content, using biodegradable materials or alternative sources of fuels and materials) and developing new green sustainable products (e.g., reverse logistics, design for disassembly, using renewable resources, and using biodegradable materials).
The **process capability** factor calls for greening the existing process (e.g., energy efficient machines, fuel-efficient transportation, etc.). In pursuit of having a reasonable and a competitive product persistently delivered to the consumer, the course of producing the product will have to be environmentally suitable. In case of returns after the useful life of the product, the supply chain would also have to secure that the process is capable of absorbing returns into manufacturing or production of new goods. The **sourcing and operations** factors drive businesses to connect in green sourcing practices, at times pushing suppliers to adopt processes which are more environment friendly. Companies like Subaru and Toyota declare to operate a zero-waste facility as a way of decreasing costs and supporting the environment. They

achieve zero wastes by ensuring that no by-product of their productions goes into a landfill. The **transport and logistics** factors guide companies to reflect on the economics of reverse logistics and closed loop supply chains and reuse, recycle and return programs. The **marketing and public relations** factors point out the contributions of companies to design a value proposition for the customers, particularly when the ‘‘environmental friendly’’ product is more expensive. Companies should also raise awareness of the practices which are responsible to make the product more environment friendly or more sustainable, e.g., use Carbonfund or Bullfrogpower as a means to indicate to the customers that the product is environmental friendly with the use of logos and co-branding. For instance, focal companies in the supply chain force their upstream suppliers to become more green and sustainable, companies should adopt measures to educate, persuade and encourage their customers to buy their green products. Pressure can be exerted externally, NGO’s can organize boycotts or aggressive publicity campaigns against the companies producing non environmental friendly products by jolting their conscience to produce more sustainable products. Lastly, the social issues factor lays focus on the prevailing behavior and practices of companies in relation to the handling of their labor force, procurement practices and environmental impact on their communities. Green, sustainable operations are more concerned with translating those aspirations into economically sustainable business practices (Wang & Lin, 2007).

2.5 Literature on framework for sustainable supply chain management metrics

Elkington (1997) states that due to the advancement of information technology companies can no longer keep their practices secret from stakeholders. They have to report on their sustainability practices to inform them and to serve as a benchmark against competitors. It is also pivotal that

measures or indicators be inclusive in these reports that hold the company's performance certifiable by external agencies and global standards. In order to attain transparency in reporting and measuring, Elkington has endorsed the importance of forming partnerships with supply chain partners and with government and NGOs. In this section, our observations will be reflected in the literature by outlining the key obstacles in developing sustainable supply chain metrics and suggest a viable framework in the given context.

2.5.1 Sustainable supply chain management metrics literature

Despite its importance, there is a scarcity of research on this subject. This is expected as the research on supply chain metrics in general is inadequate (Gunasekaran, Patel, & McGaughey, 2004). Even in the relevant supply chain metrics studies, one can feel the absence of the discussion of sustainability indicators. For example, in a latest review by Gunasekaran and Kobu (2007) Out of the 27 major performance measures that they have found out in the literature, there are no sustainability related measures. Hervani et al. (2005) suggest exercising ISO 14032 as a foundation for green supply chain performance management system (GSC/ PMS). Still, it is pertinent to stress here that the ISO guidelines are designed and developed for individual organizations. Though, Hervani et al. (2005) recorded some of the difficulties of designing a GSC/PMS, however, they do not give remedies to overcome them. Zhu & Sarkis (2004) observe the merits of employing green supply chain practices on economic and environmental performance in the Chinese manufacturing industry. Clemens (2006) explores a similar question meant for small firms. They find a productive relationship between financial and green performance. Apparently, this correlation is further reinforced in the presence of the incentives given by the government. Vachon & Klassen (2008) analyze how environmental collaboration affects manufacturing performance. They discover that while upstream collaboration has obvious

benefits, the case lacks clarity in customer based collaboration. Vachon and Mao (2008) connect supply chain strength, at a country level, with its social and environmental sustainability performances. Sarkis (2006) uncovers that early adoption of environmental and risk management practices might not reflect in a positive manner on a company's environmental performance. Searcy et al. (2007) illustrate a case study focusing on sustainable performance indicators for an electric utility company. Here they scrutinize environmental and social issues. It is important to note that no study has broadly covered the three dimensions of sustainability (economy, society and environment). It is imperative to note that the measures mentioned above have not been used or intended to be used in a supply chain context; the measures do not span across the various players active in the supply chain.

A number of studies have paid special attention on the issue of performance measurement in supply chains. As discussed earlier, the major issues that have been investigated in this area comprise evaluating and monitoring progress, reporting of performance, identifying achievements, promoting improved process understanding, identifying critical issues, confirming priorities, and provision of guidance to draw future actions, amongst other topics (Akyunz & Erkan, 2010; Beamon, 1999; Cuthbertson & Piotrowicz, 2008; Gopal & Thakkar, 2012; Gunasekaran & Kobu, 2007; Gunasekaran, Patel, & McGaughey, 2004). Recommended metrics for measuring supply chain performance are also extensively available. There is dearth of research that focuses specially on measuring performance in green or sustainable supply chains; however, we can spot evidence of increasing interest in this area. For example, Hervani et al. (2005) offer a summary of the issues related to environmental (green) supply chain performance measurement. They advocate that the objective of a green supply chain is to get rid of the negative environmental impacts or to at least minimize the toxic aspects (air, water, and land

pollution) and waste of resources (energy, materials, products) from the removal or acquirement of raw materials till used and disposal. Hervani et al. (2005) suggested exercising ISO 14031 as a foundation for the performance management of Sustainable Supply Chain Management.

3 Research Methodology

A systematic literature review was carried out on the topic of Sustainable Supply Chain Management in an attempt to analyze the foundations of the concept, level of research conducted on it, the depth of fields covered and those left to be explored as yet. Systematic literature reviews have been used in the field of research as a basis for data collection and analysis since a long period of time. They provide a researcher with evidence based unbiased activities (Tranfield, Denyer, & Smart, 2003) by only reviewing the literature reviews, discussions, analysis and results from the published literature while ignoring the introduction, methodology and conclusions.

In an attempt to search for the relevant articles, Scopus database of articles and research papers was used. Research work was searched with typical key words such as 'Sustainable Supply Chain Management, 'Green Supply Chain Management', 'sustainability drivers', 'sustainability metrics' etc. The articles found by these key words were further filtered by screening out articles published in English language and those published in the last decade or fifteen years. Thus a total of over fifty articles were studied in order to get an insight on the subject.

In the process of carrying out a literature review, it was noticed that there is scarcity in the subject area research with reference to measurement of sustainability or identification of metrics used for evaluation of Sustainable Supply Chain Management. Therefore, the focus of the paper was shifted towards formulating a comprehensive framework to be used for identifying metrics for performance measurement of Sustainable Supply Chain Management. It is necessary to gauge the level of sustainability in today's firms so that they can know where exactly they stand on the frontier of sustainability and compare their performance with other firms. Therefore, the research articles searched were reviewed again, now with an aim to consolidate the research

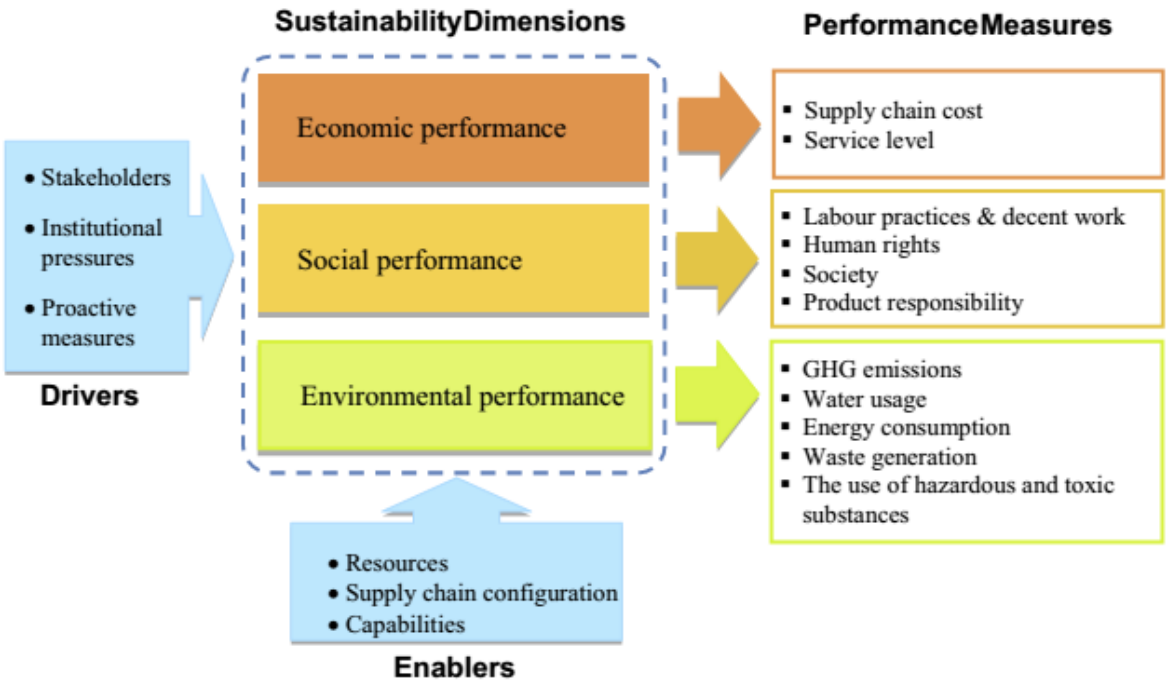
carried on sustainability measures and metrics and formulate a comprehensive frame work for metrics for Sustainable Supply Chain Management.

4 Frameworks for Metrics Used to Measure Sustainable Supply Chain Management Performance

4.1 Basic Level Sustainable Supply Chain Management Framework

A basic level framework for evaluation of metrics used to measure the efficiency and affectivity of sustainable supply chain management would start over with the basics of sustainability. In accordance with Ellington (1999) triple bottom line concept; any wide ranging framework for analysis of sustainability would be incomplete without the deliberation of economic, environmental and social objectives and performance measures (Steger, Ionescu-Somers, & Salzmann, 2005; Schaaltegger, Lüdeke-Freund, & Hansen, 2011). A lot of research on the topic is of the view that it is better to develop a unified wide spectrum approach for gauging the impact of any specific supply chain dimension (environmental, social or economic) instead of formulating deep isolated approaches for each separate dimension (Matos & Hall, 2007). Therefore, a basic level framework for Sustainable Supply Chain Management can be formulated through sustainability measures on the triple bottom line factors in lieu with the existing literature on the topic and the widely accepted GRI sustainability guidelines (GRI, 2012).

Varsei et al. (2014) have formulated an ideal framework for sustainable supply chain management metrics at a basic level. As depicted in figure 4, a basic level framework would focus on the basis of sustainability dimensions; economic performance, social performance and environmental performance.



Source: Framing Sustainability Performance of Supply Chains (Varsei et al. 2014)

Figure 4 A Basic Framework for Sustainable Supply Chain Management Metrics

4.1.1 Performance Measures (Metrics)

Economic Performance Measures (Metrics)

Economic performance has been the prime aim of organizations since inception. The entire concept is based on the simple accomplishment of two pivotal concepts; cost minimization and service level maximization (Shapiro, 2007). Likewise, the framework presented for economic performance uses the fundamental metrics of supply chain costs and service level. Supply chain costs cater for all the costs incurred by the entire supply chain, starting from the procurement of raw materials to processing of these materials and transforming them into consumable goods or services to transporting them to the end consumers and having them recycled. Service level is the net worth of the end product or service provided to the end consumer, the higher the difference

between supply chain costs and the service level is, the more economically affective and efficient the sustainable supply chain is.

Social Performance Measures (Metrics)

Social performance measures are the most difficult to measure in the context of supply chains, mainly because they are qualitative and nature and hard to quantify (Seuring, 2013). In order to gauge the level of social performance, comparative and relative metrics have to be used to make a comparison of these qualitative measures. The entire spectrum of social dimensions of supply chain performance can be segregated into the four categories of labour practices and decent work conditions, human rights, society and product responsibility (GRI, 2012).

Environmental Performance Measures (Metrics)

Environmental performance is the centre of attention for the concept of sustainability. There is a never ending list of factors or metrics used to evaluate the environmental impact or performance of any specific supply chain at various levels; such as analysis of localized, regional or global environment and at various environmental aspects such as air, water or solid waste (Varsei, Soosay, Fahimnia, & Sarkis, 2014). Some pertinent environmental metrics used in this framework are Green House Gases (GHG) emissions (Paksoy, Bektas, & Özceylan, 2011), waste generation (Tsai & Hung, 2009), energy consumption (Cholette & Venkat, 2009), water usage (Brent, 2005) and the use of hazardous and toxic substances in products (Hsu & Hu, 2009).

4.1.2 Sustainability Drivers

Stakeholders

Any business entity is obliged to cater for the needs and demands of their primary stakeholders in order to ensure the sustainability of their business operations. The concerns and demands of

stakeholders for greener and sustainable practices shall form the foundations for supply chain management in every sustainable organization (Golicic & Smith, 2013).

Institutional Pressures

Various institutions such as governments, media, pressure groups etc. can exert pressure on organizations to mould their decision making and operations. These pressures are categorized as coercive isomorphism, mimetic isomorphism and normative isomorphism. They can originate from monitoring organizations like NGOs, industrial and state regulations, trade associations, business publications and formal stakeholder engagement (Caprar & Neville, 2012).

Proactive Measures

Any organization is compelled to abide by the guidelines to achieve sustainable operations in today's world where awareness for environmental and social sustainability is at its historical peak and still growing. Any entity has to proactively pursue with the goals of green and sustainable supply chains to ensure its long term survival.

4.1.3 Enablers

Resources and Capabilities

The resources of any organization include all tangible and intangible assets such as capital, machinery, work force, technical capabilities, unique processes etc. These resources build the strength of any organization to be competitive by implementing strategies throughout the firm and supply chain. As advocated by the Resource Based Theory, the secret of any competitive advantage reaped through fine implementation of sustainable operations throughout the supply chain is effective utilization and sharing of capabilities and resources amongst the various supply chain entities (Priem & Swink, 2012).

Supply Chain Configuration

As stated before, a supply chain is comprised of various diverse and unique business activities working collectively for their individual interests. It can be seen as an interconnected social network of interrelated organizations working in harmony with each other. Integration of business processes and collaborative activities amongst the various supply chain players through effective and timely information exchange is pivotal to sustainable operations and practices of any supply chain.

4.2 Functional Sustainable Supply Chain Management Framework

Hassini et al. (2012) have illustrated the entire concept of Sustainable Supply Chain as a wheel comprising of six spokes. Every spoke is an individual unique function of the supply chain. By integrating all six of these functions we get a complete supply chain, a collaboration of all the parties involved in fulfilling a customer order. These six unique functions are sourcing, transformation, delivery, value proposition, customer and product use and recycling. Any single business entity acting as a part of the supply chain can either be performing any single of the above mentioned functions or may even be collectively performing all of them. However, it is assumed that each of these functions is performed by an independent supply chain player. The function of procurement is carried out by supplier, transformation by the focal firm, delivery by the distributor, value proposition by the retailer and the focal firm, customer and product use by the customer and recycling by the product end of life management (Ahi & Searcy, 2015). The functional framework for sustainable supply chain management (Figure 5) is built upon the roots of these unique supply chain functions; by assigning performance gauging metrics to the economic, environmental and societal aspects in the delivery of these functions.

Sustainability Metrics / SSCM Functions	Economic Metrics	Environmental Metrics	Societal Metrics
Sourcing (Suppliers)	Cost of procurement	Damage to environment GHG emissions Renewable sources	Fair trade practices
Transformation (Focal Firm)	Unit cost Value added to the inputs	Sustainability of processes GHG Emissions and toxic waste	Societal impacts of products produced Fair labour practices
Delivery (Distributor)	Costs of delivery Costs of inventory management system	GHG Emissions Mode of transport	Location of distribution facilities
Value Proposition (Retailor & Focal Firm)	Increase in price of products	Impact of marketing and PR on use of sustainable and green products	Societal impacts: customer demand for expensive green sustainable products
Customers and Product Use (Customer)	Efficient use of energy and scarce resources	Use of green energy GHG Emissions	Awareness and education for green and sustainable consumption practices
Recycling (Product End of Life Management)	Reuse of recycled products	Conservation of scarce resources by recycling	Awareness across the consumers with regard to the norms of recycling and a trend of returning goods to OEM for recycling once they have been used

Figure 5: Functional Sustainable Supply Chain Management Framework

5.2.1 Sustainable Supply Chain Management Functions

Sourcing

Sourcing or procurement is the starting and detrimental phase in any supply chain. One of the most important characteristics of sustainable supply chain management is the implementation of green procurement practices (Varnas, Balfors, & Faith-Ell, 2009; Bala, Munoz, Rieradevall, & Ysern, 2008; Johnson, Lai, & Wortman, 2008; Dawson & Probert, 2007; Handfeild, Walton, Seegers, & Melnyk, 1997). The pressure exerted by the focal company to its upstream suppliers to implement green procurement practices acts as the point of inception for sustainable supply chain management. Various metrics can be applied to measure the sustainability of procurement practices with respect to the three fundamental pillars of sustainability. Economic metrics can measure the cost effectiveness of the procured materials, environmental metrics can access the adverse effects to the environment by factors such as renewability of resources, damage caused to the environment, Green House Gas emissions etc. and societal metrics can focus on the fairness of the trade practices employed to acquire these inputs.

It is noticed that the implementation of green procurement practices may push forward the prices of inputs and make their supply inelastic and unreliable (Beamon, 1999). The key here is to sell the green procurement practices in the value proposition and pass on these increased costs to the customers.

Transformation

Transformation is the most critical function of any supply chain. This is the part where most of the value is created or added for the customers. The function of transformation is carried out by the focal supply chain firm (the manufacturer in most of the cases). Numerous metrics can be used to evaluate the compliance of transformation activities to sustainability. Metrics used to measure the environmental impact of transformation could include sustainability of practices and processes used and GHG emissions and release of other toxic substances from the process etc. The economic impact can be measured through the unit cost of transformation in comparison to the value added to the raw inputs. The goal should be maximization of value added while minimizing the costs associated with the process. Societal metrics may include the implementation of fair labour practices and social impacts of the end product produced.

Delivery

The delivery function of Supply Chain deals with the transportation of the goods or services from the manufacturer to the end user. It may include many intermediaries involved in the process or might even be handled the manufacturer itself. This specific function gauges the sustainability of operations performed by the distributors of the Supply Chain. The environmental impacts from delivery of goods can be measured though the GHG emissions from the transportation process. Here there is a tradeoff between the cost associated with and the time it takes in transportation. High value and time sensitive items are transported via air or truck but

the emerging focus is shifting towards the trend of making less bulky goods in order to bring down the shipment costs (Dou & Sarkis, 2010; Triantafyllou & Cherrett, 2010). Likewise, the economic impact of delivery can be assessed by the cost of delivery in comparison to the time required for the delivery process. Moreover, the application of the appropriate inventory management system can also have a substantial effect on the costs. Social effects of delivery can be linked to the location of facilities used by the delivery process and the impact of these locations on the overall society.

Value Proposition

Production of sustainable or greed products or services is useless if the whole concept of environmental sustainability from the use of the good / service is not clearly communicated to the end user. Business entities that sell environmentally friendly green products incur higher costs of manufacturing and production. In order to pass on these costs to the end customer, a comprehensive and elaborate value proposition should be attached with the goods / services; not only quantifying the benefits of consuming these products but also convincing the customers that the value provided by them is far greater than the additional costs associated with its consumption. Many businesses have tried to sell remarkable green or sustainable products but have miserably failed due to their inability in reflecting the benefits of these products in their value propositions. Customers tend to ignore the marketing of green or sustainable products in the absence of objective and quantifiable environmental and personal gains associated with their use. Any value proposition that makes the use of saving the environment or being sustainable for charging more for the goods or services is referred to the execution of the Veblen's paradox (Zafirovski, 2003). Application of the right and appropriate value proposition to any product is the prime responsibility of the focal manufacturing company that markets the products. In

addition to that, it is also a partial responsibility of the retailer to communicate the appropriate value proposition to the customers. The customers should not be left ambiguous to the justification for passing on of the higher costs to them. Economic metrics for value proposition can measure the increase in selling price of the products resulting from the use of relevant and appropriate value proposition, environmental metrics would gauge the affects of marketing and PR efforts for selling these products spreading awareness regarding the use of sustainable and green products and the societal metrics would measure the impact of various marketing techniques such as snowballing that result in the sustainable uplifting of the society as a whole when customers alter their purchasing behaviors by demanding relatively expensive products that are environmentally friendly.

Customers and Product Use

The life cycle assessment of various consumer goods has showed that a significant part of any product's environmental impacts is associated with the customer's use of the product. Customers have an equally important role to play in the sustainable supply chain management. They have to be educated on how to use the products in order to minimize their environmental impacts and should follow these procedures. Environmental metrics in this context would include the extend of green energy used by customers or the total GHG emissions resulting from their consumption, economic metrics would include the efficient use or energy and/or other scarce resourced and societal metrics would include the overall level of societal awareness and education with regard to green and sustainable consumption practices. Without customer awareness on sustainability and green efforts, there would be no demand for sustainable and green products, wiping out the whole concept of sustainable supply chain management.

Recycling

Recycling is the most critical aspect for the sustainability of any supply chain. The concept of 3R (reuse, recycle and return) is reviewed thoroughly in the field of sustainability under the prominent topics of closed loop supply chains and reverse logistics (Hassini, Surti, & Searcy, 2012). Any supply chain cannot be truly sustainable if the products it produces are not recycled or reused. The basic thought is that any manufactured product shall end up being completely disassembled and its components and parts shall be either re-manufactured or recycled into basic raw materials. Any products End of Life Management is pertinent to the entire concept of recycling. Economic metrics for gauging recycling would include tools such as efficient recycling of products and the reuse of recycled products in different forms, environmental metrics would include the conservation of scarce natural resources by recycling used products and societal metrics would include the level of awareness across the consumers with regard to the norms of recycling and a trend of returning goods to OEM for recycling once they have been used.

4.3 Comprehensive Multi Tiered Framework for Sustainable Supply Chain Management

Finally, a comprehensive framework is developed that analyses the performance of any sustainable supply chain management at its three different tiers or levels. It is an adaption of the Conceptual Framework for Measuring Performance in SSCM provided by Ahi & Searcy (2015). There are various reasons that lead to the development of this multi tiered framework. First of all, there are no definite metrics used to cater for the wider sustainability context in which the entire supply chain functions. There is a deficiency of context based metrics focusing on the approximate level of environmental impact any specific supply chain can bear in order to be

sustainable in the long run (McElroy & van Engelen, 2012). Moreover, it has come to the surface that from the study numerous published metrics that all of these metrics do not unequivocally cater for the sustainability practices of all supply chain players (Ahi & Searcy, 2015). The metrics primarily focus on the focal manufacturing / producing firm with little or no emphasis on other important players of the supply chain. Lastly, there is dire need for a framework that encompasses the entire spectrum of sustainable supply chain management. In order to cover all aspects of Sustainable Supply Chain Management, it has been bifurcated into its thirteen key characteristics as identified by Ahi & Searcy (2013) by analyzing and combining the seven characteristics of Supply Chain Management with the seven characteristics of sustainability.

This comprehensive framework is comprised of three tiers. The first tier addresses metrics for the key functions of Sustainable Supply Chain Management and the key players associated with the fulfillment of these functions or duties. The second tier is used for the development of metrics that shall be devoted to the broader sustainability context of the Supply Chain. The third tier focuses on the thirteen key characteristics of Sustainable Supply Chain Management.

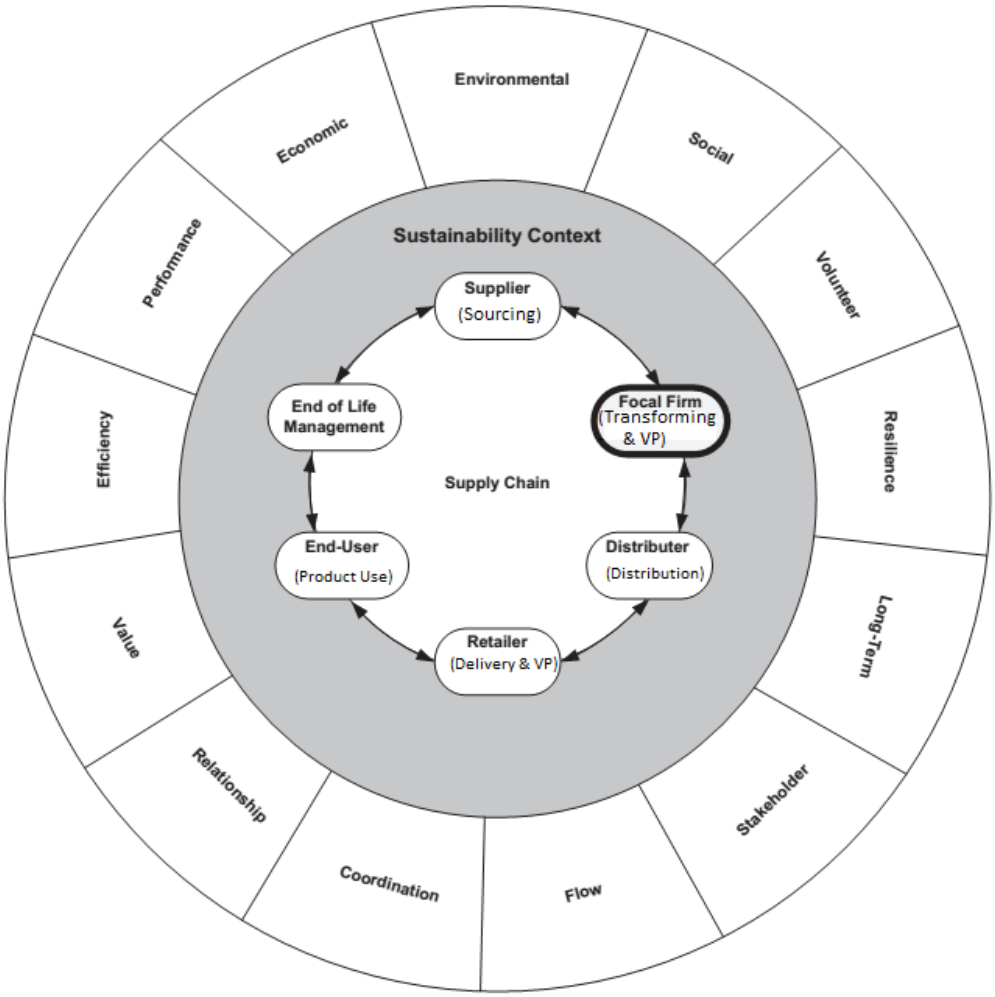


Figure 6: Three Tiered Framework for Sustainable Supply Chain Management

4.3.1 Tier 1

The first tier of the framework places the six key players of Sustainable Supply Chain Management under the spot light, combining them with the functions they have to usually perform in the supply chain. This tier focuses on the very same six functions and six players highlighted in the earlier discussed functional framework for sustainable supply chain management. These six players are supplier (sourcing), focal firm (transforming and value proposition), distributor (storage and delivery), retailer (value proposition and delivery), end user (customer and product use) and end of life management (recyclers, re-users and disposers). A great amount of importance is placed on the vitality of the focal firm in the supply chain. This is

due to the fact that in the essence of Sustainable Supply Chain Management, any metrics used should be orchestrated around the needs and goals of the focal firm. Moreover, there has to be a two way flow of information throughout the supply chain in order to ensure integration on unity of goals across the whole supply chain.

4.3.2 Tier 2

The second tier of the framework focuses on the wider sustainability context supply chains operate or function in. It depicts that all players in the supply chain are deep rooted in the wider sustainability context. Thus, any supply chain should be shaped in a way that it can gauge and register the economic, social and environmental impacts it leaves on the local, regional and global environment it operates in (Ahi & Searcy, 2015). In addition to that, this tier of the framework stresses on the fact that any attempt for evaluating performance in a sustainable supply chain should consider the broader sustainability context as well. The broader sustainability context has been neglected in most of the literatures published on metrics for sustainable supply chain management. Ahi & Searcy (2015) are the pioneers in considering the broader sustainability context in the framework for developing and evaluating metrics for sustainable supply chain management.

4.3.3 Tier 3

The third tier of the framework is built up on the key characteristics of Sustainable Supply Chain Management. As mentioned earlier, these 13 key characteristics of Sustainable Supply Chain Management have been developed after a thorough review of research conducted on sustainability and supply chain management. The seven key characteristics of business sustainability are economic, environmental, social, stakeholder, volunteer, resilience and long term focus and the seven key characteristics of Supply Chain Management are flow,

coordination, stakeholder, relationship, value, efficiency and performance focus (Ahi & Searcy, 2013). Incorporating these characteristics in the framework emphasizes on the fact that the metrics used to gauge sustainable supply chain management should be unequivocally based on the definition of sustainable supply chain management.

5 Analysis of metrics published in the literature for Sustainable Supply Chain Management

Ahli & Searcy (2015) carried out a comprehensive research with the aim of academic publications published on the topic of Sustainable Supply Chain Management. They reviewed almost four hundred and fifty articles with the aim of identifying the various different metrics used for evaluating the performance of any Sustainable Supply Chain. They were able to identify over twenty five hundred distinctive metrics from the articles reviewed. The broad spectrum of metrics recognized varied in their nature of performance evaluation. A little more than two thirds of the metrics were quantitative whereas less than one third constituted of qualitative measures. Moreover, a remarkable majority (80 percent) of these metrics used absolute measure while the rest used relative measures. None of the identified metrics could be identified as a context based metric. It has been pointed out by various researchers that there is an abundance of relative or absolute performance measurement metrics; however metrics relating Sustainable Supply Chain Management to the wider environment (Rockstorm, Steffen, Noone, Persson, & Chaplin III, 2009) or the social context (McElroy, Jorna, & van Engelen, Social quotients and the social footprint, 2008) are nonexistent.

Table 1 depicts a comprehensive analysis on the identifies metrics by assignment them to the thirteen characteristics of Sustainable Supply Chain Management as stated in the third tier of the Comprehensive Framework for Sustainable Supply Chain Management described earlier. Singular metrics were analyzed to gauge the performance of various multiple characteristics at the same time. Moreover, it was concluded that a vast majority of the metrics (over 60 percent)

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."

Source: An analysis of metrics use d to measure performance in green and sustainable supply chains, Ahi P. & Searcy C. (2015)

Table 1: Distribution of SSCM key characteristics addressed by the identified metrics

have been focused on any single characteristic of the Supply Chain. It can be concluded from these results that a vast majority of the metrics has focused on environmental and economic characteristics. On the other end, there is a strong need to develop reliable metrics used to measure the velocity of volunteer focus, resilience focus, flow focus, coordination focus, relationship focus and performance focus.

6 Conclusion

The paper has reviewed substantial research carried out on the topic of Sustainable Supply Chain Management, primarily from the last decade. After considerate research on studies published on the topic, there was a lapse identified in the subject research in the form of absence of a comprehensive framework for assessing Sustainable Supply Chain Management. The literature was again scrutinized for screening out published materials on frameworks for development of SSCM. Research reviewed was compiled to form a comprehensive framework covering a wide spectrum of sustainability metrics, explained in section 5.3 of the paper. Thereafter, an extensive analysis was made on metrics published in SSCM and GSCM literature. These identified metrics were assigned to thirteen essential functions of Sustainable Supply Chain Management in section 6 of the paper. It was noticed that the metrics identified from the past research do not cover all characteristics of Sustainable Supply Chain Management and have a great focus on the characteristics of economic, environmental and social focus as compared to the others. This has given birth to a new field of research on the topic. Future research on the subject shall identify and establish metrics for the other ignored characteristics of Sustainable Supply Chain Management. Moreover, it was noted that the already established metrics are qualitative and quantitative in nature, but there are no concrete context based metrics relating Sustainable Supply Chain Management to the wider environment or social context. Furthermore, it was noted that this generic framework for metrics and the metrics identified with its aid cannot be applied to all industries or sectors. Therefore, there is a need for industry or sector specific studies on the topic of Sustainable Supply Chain Management, identified industry specific metrics and setting the norms and benchmarks for sustainability in various industries.

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