Stream 15 Technology, Innovation and Supply Chain Management
Interactive paper

A conceptual framework for the design and management of sustainable supply chains

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ABSTRACT: *Many organisations are realising the growing importance of sustainability in today's business lexicon and the need to incorporate a supply chain approach, since the implementation of sustainability extends beyond organisational boundaries and involves multiple parties and various considerations. Despite this need, the extant literature on sustainable supply chain management focuses predominantly on a single dimension in isolation and lacks practical integrated frameworks in which all three dimensions of sustainability (i.e. environmental, social and economic dimensions) can be discerned. To address this gap, we propose a more holistic framework which incorporates performance indicators for all three dimensions that can be used as a tool for the development and management of sustainable supply chains. This paper provides significant theoretical contribution and implications for supply chain management.*

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INTRODUCTION

Sustainability is a shared vision and a core business paradigm in the supply chain with extensive participation, coordination and commitment of all firms. A sustainable supply chain requires proactive management and the development of suitable strategies to remain environmentally, socially and economically sustainable. Various studies report the increasing number of organisations that have implemented sustainability documentation or voluntary codes of conduct within their supply chains for reporting purposes and performance measurement (Andersen & Skjoett-Larsen, 2009; Keating, Quazi, Kriz, & Coltman, 2008; Soosay, Fearne, & Dent, 2012; Vurro, Russo, & Perrini, 2009). This extends to the supply chain members that influence the extraction, transportation, production and consumption of materials and products (Gupta & Palsule-Desai, 2011). In this regard, focal organisations and their supply chain members are invoked by pressure for sustainable practices at both organisational and supply chain levels.

This pressure arises both internally and from external stakeholders, such as customers, shareholders, governments, non-governmental organisations (NGOs) and public authorities

(Moscardo, 2013; Wells, 2013). Freeman's (1984) development of the stakeholder theory provides significant contribution to the field through providing a theoretical ground wherein the new position of sustainability and sustainable business could be reinforced (Freeman, 1984; Lee, 2008; Moura-Leite & Padgett, 2011). He defines stakeholders as "groups and individuals who can affect or are affected by the achievement of an organization's mission" (Freeman, 1984, p. 52) and argues that a firm's stakeholders necessitate integration of business decisions and decisions related to social responsibility (Freeman, Harrison, & Wicks, 2008). Similarly, Carroll and Shabana (2010) posit that stakeholders can strongly influence businesses to be engaged with corporate social responsibility (CSR). It should be noted that the terms CSR and sustainability have been used interchangeably by scholars, mainly to address those business activities which consider economic, environmental and social aspects (Moscardo, 2013).

In addition to stakeholders' pressures, the pervading environmental issues, such as greenhouse gase (GHG) emissions, and social concerns, such as safety and the use of child labour, have forced many organisations to integrate a wider set of objectives than just reaching an acceptable level of economic performance. Additionally, the introduction of various environmental legislations and standards (e.g. ISO 14000), and also corporate social responsibility standards (e.g. SA8000 or GRI), would mean that firms must balance all three dimensions of social, environmental and economic sustainability (Matos & Hall, 2007; Zhu & Sarkis, 2004).

There are many challenges in developing and managing sustainable supply chains, which require the simultaneous incorporation of economic, environmental and social sustainability, based on the Triple Bottom Line approach (Andersen & Skjoett-Larsen, 2009; Elkington, 1999; Gimenez & Tachizawa, 2012). While there have been some efforts assessing environmental sustainability to date, there are still gaps in the current literature in terms of quantifying and measuring social sustainability and how it can be integrated into sustainability assessment models (Chaabane, Ramudhin, & Paquet, 2012; Seuring, 2013; Seuring & Müller, 2008; Winter & Knemeyer, 2013; Wu & Pagell, 2011). Various authors advocate the need for the development of decision-making frameworks and associated analytical models that can integrate multiple sustainability measures into supply chain

performance. To address this concern and to bridge the gap in the current literature, this paper presents a multi-dimensional assessment framework incorporating economic, environmental and social performance measures. The proposed framework will serve as a tool for the development and assessment of sustainable supply chains.

LITERATURE REVIEW

Supply Chain Management and Sustainable Development

Supply chain management is the process of planning, executing and controlling the activities and operations of the supply chain efficiently to meet planned objectives (Melo, Nickel, & Saldanha-da-Gama, 2009). A typical supply chain consists of suppliers, manufacturers, distribution centres, retailers and customers (Snyder, 2011). Based upon the length of the time horizon, three planning levels in supply chain management are usually recognised: strategic, tactical and operational planning (Snyder, 2011). At the strategic planning level, with the longest planning horizon (typically between 5 to 10 years), one of the primary objectives is to establish the best possible configuration of the supply chain network (Melo et al., 2009). In other words, the supply chain network design is concerned with the long-term decisions related to the number, location and capacities of manufacturing plants and distribution centres, the flow of material through the supply chain, and the set of suppliers to select (Kaminsky, Simchi-Levi, & Simchi-Levi, 2004). At this level, supply chain managers select those chain members that are integral to fulfilling the long-term broad organisational objectives and in achieving superior sustainability performance.

Supply chain operations involve major business and industrial activities such as raw materials extraction, procurement, manufacturing, packaging, transportation and recycling, all of which can pose negative environmental and social impacts if not managed appropriately (Wisner, Tan, & Leong, 2008). The environmental impacts may include GHG emissions, hazardous materials, toxic chemicals and other pollutants as well as land use and resource depletion issues (Sanders, 2012). Governments are trying to mitigate these issues through enacting tighter environmental regulatory legislations. For

example, China has imposed restrictions on the import and manufacture of products containing cadmium or mercury (Wisner et al., 2008).

In addition to the environmental concerns, supply chains increasingly face issues related to their social performance (Dreyer, Hauschild, & Schierbeck, 2006) and commercial and reputational risks (Carter & Rogers, 2008). Not only can social issues threaten the company's brand image, but they also impact the economic viability of the entire supply chain. Several instances of this nature have been frequently reported in the past, jeopardising the reputation of large multinational corporations (Frost & Burnett, 2007) through the violation of union rights and the use of under-aged workers (Andersen & Skjoett-Larsen, 2009) or poor working conditions (Greenhouse, 2013). This indicates the significance of overseeing the performance of supply chain partners globally and in integrating economic, environmental and social sustainability objectives.

Sustainable Supply Chains

Sustainable supply chain management can be defined as "the strategic, transparent integration and achievement of an organisation's social, environmental and economic goals in the systemic coordination of key inter-organisational business processes for improving the long-term economic performance of the individual company and its supply chains" (Carter & Rogers, 2008; p.368). In a sustainable supply chain, the social and environmental harmful impacts need to be mitigated in various countries where upstream suppliers are located, while maintaining financial feasibility of the overall chain (Seuring & Müller, 2008). If a key supply chain player makes a long-term commitment to sustainable development and increases the pertinence of social and environmental objectives in its supply chain evaluation, then all downstream and upstream partners will need to comply with the rules of the new structure, as their economic viability is dependent on the focal company. This was the case when Wal-Mart discontinued collaborating with suppliers in Bangladesh in 2011 and Uzbekistan in 2008 due to serious misconducts related to sustainable practices (Walmart Global Responsibility Report, 2012).

Economic dimension

Economic sustainability in supply chain management has been largely researched in the past and is often the starting point in investigating sustainable supply chains (Seuring, 2013; Seuring & Müller, 2008). The elements of supply, operations, logistics and chain integration encompass important issues which impact economic sustainability of the chain (Wisner et al., 2008). These include supplier strategic alliances in the supply element, product design in the operations element, marketing issues and global network in the logistics element, and performance measurement in the integration element (Wisner et al., 2008). Supply chain management traditionally focused on economic based performance indicators with the main intention to minimise total costs in the supply chain while meeting market demands (Shapiro, 2007). This requires an optimised balance between both sub-objectives of costs and responsiveness (Chopra & Meindl, 2010). Supply chain costs, which can be classified as fixed and variable costs, cover raw material and other acquisition, production and facility investment costs as well as raw material, intermediate and finished product transportation within supply chain tiers, i.e. from suppliers to plants, from plants to distribution centres and finally to retailers (Chaabane et al., 2012; Pishvaee & Razmi, 2012; Pishvaee, Torabi, & Razmi, 2012). While it is believed that cost reduction may affect market responsiveness, there are other measures and strategies adopted in supply chain management which help overcome this paradox and enable long-term financial prosperity and overall economic sustainability. These include effective demand planning, inventory management, capacity management, lean approaches, facility location and supply chain network design (Boloori Arabani & Farahani, 2012; Melo et al., 2009; Ross, Parker, & Benavides, 2012; Shen, 2007).

Social dimension

The ethical and social considerations in businesses today extend beyond the organisational boundary to implicate supply chain practices (Brammer, Hoejmose, & Millington, 2011; Dreyer et al., 2006). The social impacts of the supply chain must not only envisage legislative issues pertaining to human rights, working conditions or product safety, but also ascertain the impacts on communities and the larger society as a whole. The commercial and reputational risks (Carter & Rogers 2008)

which arise from social violations not only threaten product brand image, but also impact consumer confidence and loyalty. The publicised cases of Mattel, Nike, H&M and GAP (Frost & Burnett 2007) in their oversight of supply chain operations has sparked public concerns about ethical practices, union rights, and use of under-aged labour, particularly by upstream suppliers (Andersen & Skjoett-Larsen 2009). For example, the design flaws in Mattel's toys enabled small, high power magnets to loosen and pose risks to infants and children swallowing them. This had caused a worldwide product recall in 2007 which jeopardised its reputation (Lyles, Flynn, & Frohlich, 2008).

Environmental dimension

The environmental dimension of sustainability concerns impacts on living and non-living natural systems, including ecosystems, land, air, and water. Supply chain activities involve extracting and purchasing raw materials, manufacturing, packaging, transporting and recycling products; all of which present considerable threats to the environment (Gupta & Palsule-Desai, 2011). Some of the environmental issues addressed in the supply chain management literature include greenhouse gas emissions (Paksoy, Bektaş, & Özceylan, 2011), resource depletion (Yusuf et al., 2013), waste generation (Tsai & Hung, 2009), hazardous substances in products (Hsu & Hu, 2009), energy consumption (Cholette & Venkat, 2009) and water usage (Brent, 2005). Among these issues, greenhouse gas emissions in particular has been highlighted as the most important concern (Paksoy et al., 2011) and the main cause of global warming (Gupta & Palsule-Desai, 2011).

Taking environmental, social and economic aspects into account, it can be established that achieving a balance of all three dimensions of sustainability could often be challenging for decision makers in supply chains due to the complex trade-offs involved (Wu & Pagell, 2011). For instance, supplier selection might become a challenge for focal organisations since not all suppliers can satisfy the three requirements of reasonable operating costs as well as satisfactory social and environmental performance. Although some of the sustainability decisions can pay off in the long-term (e.g. through reverse logistics and recycling initiatives, or efficient water and energy usage), in many cases, the environmental and social objectives tend to be in conflict with economic goals (Ross et al., 2012). Despite this fact, many multinational organisations today are seeking to establish a fully sustainable

supply chain; as the United Nations Global Compact report cites that "93% of CEOs believe that sustainability issues will be critical to the future success of their business" (Lacy, Cooper, Hayward, & Neuberger, 2010). Bearing this in mind, small and medium enterprises who aim to set up new strategic alliances with their supply chain partners will require more sophisticated decision-making tools and techniques for sustainability assessment across their supply chains (Cousins, Lawson, & Squire, 2006).

Sustainable supply chain management is a new and rapidly evolving area for both research and practice (Ashby, Leat, & Hudson-Smith, 2012). Although the literature stresses that sustainable development at the supply chain level needs to embrace economic, environmental and social performance measures, most of the published works have primarily dealt with one or two dimensions only (Ashby et al., 2012; Seuring, 2013; Seuring, Sarkis, Müller, & Rao, 2008; Winter & Knemeyer, 2013). Green or environmental supply chain management has gained much more attention as compared to the social aspects (Carter & Easton, 2011; Miemczyk, Johnsen, & Macquet, 2012; Sarkis, 2012). In this paper, we address this important gap in the current literature and develop a framework for developing and managing sustainable supply chains incorporating economic, environmental and social aspects.

A FRAMEWORK TO ASSESS SUSTAINABLE SUPPLY CHAINS

A framework for comprehensive sustainability management and assessment requires the consideration of economic, environmental and social objectives and performance measures. However, given the complexity of a supply chain involving a number of participating firms, it may be impractical to take into account every single aspect of sustainability when developing an assessment framework. Therefore, every sustainability assessment framework will have its limitations to some extent. The framework that we present aims to incorporate the primary aspects of supply chain sustainability in line with the Triple Bottom Line concept (Elkington, 1999). The sustainability measures presented in our framework are based on the existing literature on sustainable supply chain management as well as universally accepted guidelines such as the Global Reporting Initiative (GRI, 2013).

Various studies employing supply chain modelling approaches have traditionally focused on the economic aspects of the network with cost minimisation and profit maximisation being the most predominant objectives (Fahimnia, Luong, & Marian, 2012; Shapiro, 2007). We follow the same line of thinking and incorporate supply chain cost as the economic performance measure in our framework. Supply chain costs may include the cost of raw material procurement, production, opening and operating facilities as well as transportation and storage costs (Chaabane et al., 2012).

For the environmental dimension, GHG emissions are considered as the primary performance measure. According to Global Reporting Initiative (GRI, 2013), there are several concerns in the environmental aspect of sustainability with GHG emissions being the main contributor to the climate change. There are six types of GHGs: primary ones are carbon dioxide, methane and nitrous oxide (IPCC, 2007), that are considered the main contributors to a rise in global temperature, threatening the balance in the ecosystem and damaging the stability of environment (Gupta & Palsule-Desai, 2011). Additionally, due to the carbon pricing or trading legislation in many regions, GHG emissions (also referred to as carbon-equivalent emissions) can pose financial concerns for many companies. We propose assessing the environmental aspect using tons of carbon dioxide equivalent (tCO2-e) emitted in procurement, manufacturing, in-bound and out-bound transport, and storage operations (Pishvaee et al., 2012; Ramudhin, Chaabane, & Paquet, 2010). The amount of tCO2-e emission can be calculated using the Emission Factor Data Base (EFDB, 2012) developed by Intergovernmental Panel on Climate Change (IPCC).

To the best of our knowledge, practical modelling efforts incorporating social sustainability measures are virtually non-existent. There is also no published sustainability framework that provides a useful guideline for the quantitative assessment of social performance in the supply chain (Seuring, 2013). It is argued that social performance measures are difficult to quantify and hence impossible to be embedded in supply chain assessment models (Chaabane et al., 2012). Conversely, to embed social performance in our framework, we introduce a unique assessment tool to quantify and score the social performance of supply chain members. We adopt a weighted approach to score the supply chain performance in four primary areas introduced by Global Reporting Initiative. These include labour

practices and decent work, human rights, society, and product responsibility (GRI, 2013). The four categories are also congruent with the guidelines of Social Accountability 8000 (SAI, 2008), Universal Declaration of Human Rights (UNHCHR, 1997), International Labour Organisation (ILO) and the social life cycle assessment (Dreyer, Hauschild, & Schierbeck, 2010; Hauschild, Dreyer, & Jørgensen, 2008).

In this weighted approach, a score is assigned to each supply chain member based on its performance against the available codes of conducts in four primary social areas. For this, we adopt a pairwise comparison scale that was first introduced by Thomas L. Saaty (1990) who used analytic hierarchy process (AHP) for complex decision makings. We propose a simplified version of this approach, a nine-scale comparison model that is designed for the assessment of supply chain social performance (Table 1). The unit difference between successive scales in Table 1 is based on the well-known psychological theory presented by Miller (1956). The total number of scales is determined noting that most individuals cannot make a comparison among more than seven objects (plus/minus two) simultaneously (Saaty & Ozdemir, 2003; Wang, 2011).

Insert Table 1 here

For this assessment, a score of 1 to 9 is assigned to each supply chain member reflecting its performance against the social guidelines established by the focal company. The larger the score, the higher the deviation from the established standards and hence the worse the social performance is. Once all scores are assigned, the summation of the four scores for each supply chain member determines the overall violation of that member against the social guidelines. Obviously, the highest and lowest scores represent the worst and the best performing members respectively in terms of social performance. The overall assessment framework is illustrated in Figure 1 summarising the above-mentioned economic, social and environmental performance measures.

Insert Figure 1 here

For data collection, the cost-based economic assessment is carried out using documented financial reports and price/cost analysis for each supply chain member. The fixed and variable costs of a typical supply chain may include the costs incurred in opening and operating manufacturing plants and distribution centres, raw material acquisition, manufacturing and outsourcing, transportation, and storage (Fahimnia et al., 2012; Pishvaee et al., 2012). The environmental aspect will be assessed in terms of tCO2-e emissions by all supplier, manufacturers, distribution centres and logistics providers and retail stores. To measure tCO2-e emissions, various parameters of the supply chain will be obtained from the Emission Factor Data Base (EFDB, 2012), established by the United Nations Environment Program (UNEP). This involves determining the amount of tCO2-e emitted in various supply chain processes per unit of product delivered to the customer (Ramudhin et al., 2010). Data collection for social assessment can be through visits to supply chain members' facilities, interviewing relevant personnel using semi-structured interviews and by investigating the guidelines and related company reports (Dreyer et al., 2010).

DISCUSSION AND CONCLUSION

Sustainable supply chain management is an emerging area for both research and industry practice. The established notion of the Triple Bottom Line in enabling economic benefits through improving social standards and preserving the environment for future generations is well accepted and gradually pervading the business arena. Traditionally, researchers and industry practitioners have measured the performance and success of supply chains in terms of economic indicators (cost minimisation objectives). The challenge of global warming and climate change, emergent environmental regulations, rising consumer awareness of green operations, and the financial reporting requirements indicate that supply chain management has to integrate a wider set of objectives than just reaching an acceptable level of economic performance. Furthermore, the growing interest in sustainable supply chain operations would mean using suitable methods and systems for assessing and communicating sustainability to all stakeholders. We acknowledge that while there are various assessment models available, these do not always address all aspects of sustainability, pose methodological issues or are developed at the organisational level only. In hindsight, this paper offers

a relatively simple yet encompassing approach to sustainability for supply chains and offers several contributions to both theory and practice. Through a review of the literature and the integration of concepts from various studies in sustainable supply chains, we establish that it is essential for supply chains to consider who their stakeholders are and the interrelationships between supply chain members, resources, activities and interfaces comprising coordination, interaction, cooperation and competition. These may include internal stakeholders such as shareholders, employees and trade unions and external stakeholders such as customers, suppliers and other partners, competitors, government and regulators, non-governmental organisations and interest groups, and local and international communities (Bendell, 2003).

The proposed framework and performance assessment methodology can assist supply chain management and decision-making at various levels. The strategic and long-term objective of any sustainable supply chain would be optimising the best possible network design and configuration of suppliers, manufacturers, distribution centres and logistics providers. Our framework enables the multi-criteria assessment of supply chain members based upon the simultaneous consideration of economic, environmental and social goals. Decisions can be made about (1) number, location and capacities of manufacturing plants and distribution centres, (2) the strategic suppliers to select for the acquisition of raw materials and components, and (3) the optimal flow of material from suppliers to the demand points. At the tactical level, the multi-dimensional assessment framework serves as an intermediate tool in determining where interventions are mandated in the chain since the assessment entails economic, social and environmental performance of every supply chain member. This approach assists supply chain managers identify whether partners are interpreting and pursuing commercial opportunities beyond economic objectives or reducing the chain's long-term exposure to risk. At the operational level, managers can fully comprehend and identify with increasing stakeholder demands for sustainable practices. The assessment methodology can identify opportunities for resource allocation and improvements in various supply chain partners. This can help achieve more sustainable operations in the areas of inventory management, procurement, manufacturing, distribution and retailing; where investments can be made to enhance systems and processes as well as the competencies and knowledge of human resources. We acknowledge that while this framework is a

tool for developing and managing sustainable supply chains, the onus subsequently lies with supply chain managers and decision makers to identify with the sustainability agenda, where the constraints or weaknesses are within organisations, and undertake appropriate measures to achieve a balance between economic, environmental and social objectives for the supply chain.

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TABLES AND FIGURES

Table 1: The Proposed Pairwise Comparison Scale

Score	**Degree of conformance** (variation between social guidelines and the actual performance)
1	No variation
3	Weak variations
5	Essential or strong variations
7	Demonstrated variations
9	Absolute variations
2, 4, 6, 8	Intermediate values between two scores

Figure 1: The Proposed Assessment Framework