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Enabling sustainable energy futures: factors influencing green supply chain collaboration

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ABSTRACT

To explore the relationship between sustainability strategies and future energy needs, supply chains need to reduce their CO2 emissions through developing their green credentials and improving performance. Knowledge management (KM) is an enabler to support collaboration efforts. The SCM and KM areas have largely focused on improving organisational performance. While the latter has yielded successful outcomes in different sectors, there is still a scarcity of research on identifying influential factors highlighting those aspects which may enable green supply chain collaboration (GrSCC), thus leading to sustainable energy futures and carbon-efficient production. This paper examines the role of KM in facilitating GrSCC. Through the identification of key factors extrapolated from the literature, a model for implementing GrSCC using a futures-based perspective is proposed. This paper inductively demonstrates the relationship between identified GrSCC factors through fuzzy cognitive mapping technique. Findings support a futures-based perspective that enhances understanding and refines forward-looking strategies for GrSCC.

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Green supply chain; supply chain collaboration; supply chain management; fuzzy cognitive mapping; CO_2 Emissions; energy futures

1. Introduction

It is important for firms to now consider and include so-called 'green' or environmental strategies' in order to retain competitive advantage by considering what Orsato (2006) either eco-efficiencies, compliance leadership, eco-branding or environmental cost leadership. Striving for the first of these, eco-efficiency, requires greater supply chain collaboration (SCC) with upstream and downstream partners within a supply chain and therefore should leverage the resources and knowledge of suppliers and valued customers as well, capitalising on prospects for learning and knowledge formation (Sancha, Gimenez, and Sierra 2016; Shaw, Yadava, and Thakur 2013). The current understanding of the impact across supply chains (SCs) – in terms of customers, manufacturers, suppliers, 3PL/4PL logistics firms, as well as reverse-chain agents – means that organisations need to plan and do much more in order to reduce their effect on the environment (Halldórsson, Kotzab, and Skjøtt-Larsen 2009). On the other hand, increasingly global competition has triggered organisations to reconsider the necessity for developing cooperative, communally beneficial supply chain partnerships (SCP) and the mutual enhancement of inter-organisational processes has become a high priority (Cheng et al. 2004; Flynn, Huo, and Zhao 2010; Zhao et al. 2008).

Supply chains though are fundamentally a source of competitive advantage, are intricate (Christopher and Towill 2002) and require the collaboration and synchronisation of many organisations operating in concert to pacify the twin objectives of effectively and efficiently satisfying customers' requirements (Mentzer 2004). The latter can be achieved through several approaches thereby achieving SC goals such as: collaboration (Schnetzler and Schönsleben 2007), information sharing (Malhotra, Gasain, and Sawy 2005), process integration (Wahab, Mamun, and Ongkunaruk 2011), aligning measures and rewards (Mentzer 2004) and standardisation (Defee and Stank 2005). On the other hand, global supply chains in developed regions include several affiliated organisations in the developing regions. As there is little awareness of the issues related with reducing carbon emissions in developing regions (e.g. Brazil, India), researchers highlight the growing need for investigating methods to reduce carbon emissions or to green SCs among these regions (Diabat and Simchi-Levi 2009).

In line with the Intergovernmental Panel on Climate Change (IPCC 2007) findings, decreasing and mitigating carbon emissions; the prime culprit of global warming and climate change, is a huge dilemma for both industry and government leaders. There is global agreement that greenhouse gas emissions have the largest negative impact on the environment (Diabat and Simchi-Levi 2009). Many government leaders are under increasing pressure to introduce legislation to curtail the emissions output (Benjaafar, Li, and Daskin 2013). Organisations globally are responding to the perils of such legislation or to apprehensions raised by their individual customers, as a result are embarking on initiatives to decrease their carbon footprint. For instance, the United Kingdom (U.K) government has set targets for organisations to decrease the carbon emissions by 60% from the levels of 1990 by 2050 (Carbon

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Trust 2006). As consumers and businesses are becoming more environmentally cognisant and governments are developing stringent environmental protocols, the manufacturing, production and services sector organisations are required to lessen the ecological effect of their SCs (Genovese et al. 2013). However, the implementation of these approaches across manifold SC members entails strong leadership (Mentzer 2004). A SC leader often becomes the motivating strength behind strategic SC decisions, e.g. the case of WalMart that stirred DELL Computers, Procter & Gamble and Zara to initiate collaboration and develop their SCs (Simatupang and Sridharan 2008). It is also suggested that as organisations develop, business and management leaders need to focus on avoiding disarray among SC members by taking a holistic approach and work collaboratively (McAdam and McCormack 2001).

In order to reduce carbon emissions, organisational leaders have focused on transforming their internal operating structures and business processes including their external SC relationships (Matopoulos et al. 2007). For instance, Hewlett Packard, Walmart, Samsung, UPS and Tesco all have considered green supply chain management (GrSCM) and thus have instigated in reducing the burden of their own SCs on the environment (Ji, Gunasekaran, and Yang 2014; Wahab, Mamun, and Ongkunaruk 2011). In particular, these organisations have designed and operated SCs in order to limit their carbon emissions since CO_2 is the dominant release due to fuel combustion. Researchers such as Fernie et al. (2003) and Chong et al. (2013) emphasise the significance of better coordination between SC partners including retailers, distributors, manufacturers, customers and intermediaries. Hongjuan and Jing (2011) state that the higher the degree of the consultation and collaborative relationship between SC partners, the higher the probability of enabling sustainable energy futures and carbon-efficient production within the SC. Thus, to achieve effective SC fusion, collective wisdom advocates the use of collaboration among SC partners that share knowledge, so as to rationalise core business processes and streamline cross-organisational operations (Chen and Chen 2005). Although some promoters in the SC area remain unconvinced vis-á-vis the pact between leadership and SCs (e.g. McAdam and McCormack 2001; Robinson and Malhotra 2005), nonetheless, Sharif and Irani (2012) argue that inter- and intra-organisational decision processes must take advantage of skilled leadership in the management of SCs.

Although collaboration has been an SC *mantra* for well over a decade, a number of organisations have yet to understand the prime factors that enable organisations to implement green SC collaborative ventures (Corso et al. 2010). In order to understand this, the authors attempt to connect the KM discipline with green supply chain collaboration (GrSCC). The combination of KM with SCM discipline is, therefore, seen by the authors as achieving the combined goals outlined above in terms of addressing the challenges posed by energy futures. Desouza, Chattaraj, and Kraft (2003) assert that from a technological perspective, KM and SCM disciplines correspond with each other in the rationale that external knowledge shared and synchronised between SC partners considerably benefits inter-organisational efficiency.

Noting that to increase inter-organisational synchronisation, organisations often call for supply chain partners to implement common business processes and sources of knowledge, this paper, therefore, aims to examine the role of KM in enabling GrSCC implementation through in-depth analysis of the extant literature and secondary research. By contributing to the research domain through examining the role of knowledge management in facilitating GrSCC the authors identify key factors extrapolated from the normative literature, developing a model for implementing GrSCC using a futures-based perspective. The presented research inductively demonstrates the relationship between identified GrSCC factors through the application of a fuzzy cognitive mapping (FCM) technique thus seeking to explore the granularity of GrSCC interrelationships to be explored and identified in the wider context of energy futures. These factors are also based upon current best practice as reported in the extant literature, i.e. based on those organisations that claim to be greener and stimulate GrSCC, e.g. M&S Group, BT Group (providing UK's power from renewable sources), Unilever (incorporates environmental sustainability into its overall business strategy) and Biffa (offers waste collection, handling and reprocessing and dumping services across the UK). The paper is structured as follows: Section 2 details the research design of the study, while Section 3 outlines the overlap between KM and SCM (as a pathway to GrSCC). Within this Section, 24 factors identified from the extant literature are surveyed, following which nine factors are prioritised for subsequent analysis through the FCM method. Section 4 details the process and findings of two scenarios which centre on collaborative efforts to adopt green initiatives; and subsequently what factors may influence the incentivisation of GrSCC schemes. Section 5 concludes the paper.

2. Research design

This paper aims to identify and examine major research studies on GrSCC research incorporating KM thinking into SCC and, thereafter, to classify them so as to identify factors that highlight how GrSCC can be enabled. A detailed analysis of the extant literature seems to be a valid approach (Ji, Gunasekaran, and Yang 2014), as it is an essential phase in forming a research area and forms a central component of any research undertaken (Easterby-Smith, Thorpe, and Lowe 2002). The latter argument is supported by Walsham (1995), who states that the strategic chore in developing a research structure and design is to describe the research method that the research team has adopted. Meredith (1993) argues that this supports researchers in ascertaining the theoretical content of the research discipline in context and leads towards theory development. Searcy and Mentzer (2003) assert that this may also be categorised as an archival research approach in the framework for undertaking and assessing existing study. Therefore, the authors constructed a vigorous research structure and design, which acted as a blueprint for the research process (as illustrated in Figure 1). Using this figure as a roadmap of the research process, the focus of this paper is to investigate and understand the factors that highlight the role of KM in enabling GrSCC. The process of analysis considered in this paper is based on the following three steps, in which each step acts as a basis for the next step.

- *Step 1* is about identifying and classifying influential factors that define KM in enabling GrSCC. This was achieved through analysing the extant literature on KM and SCM, GrSCM, and SCC. This research exercise (based on approximately

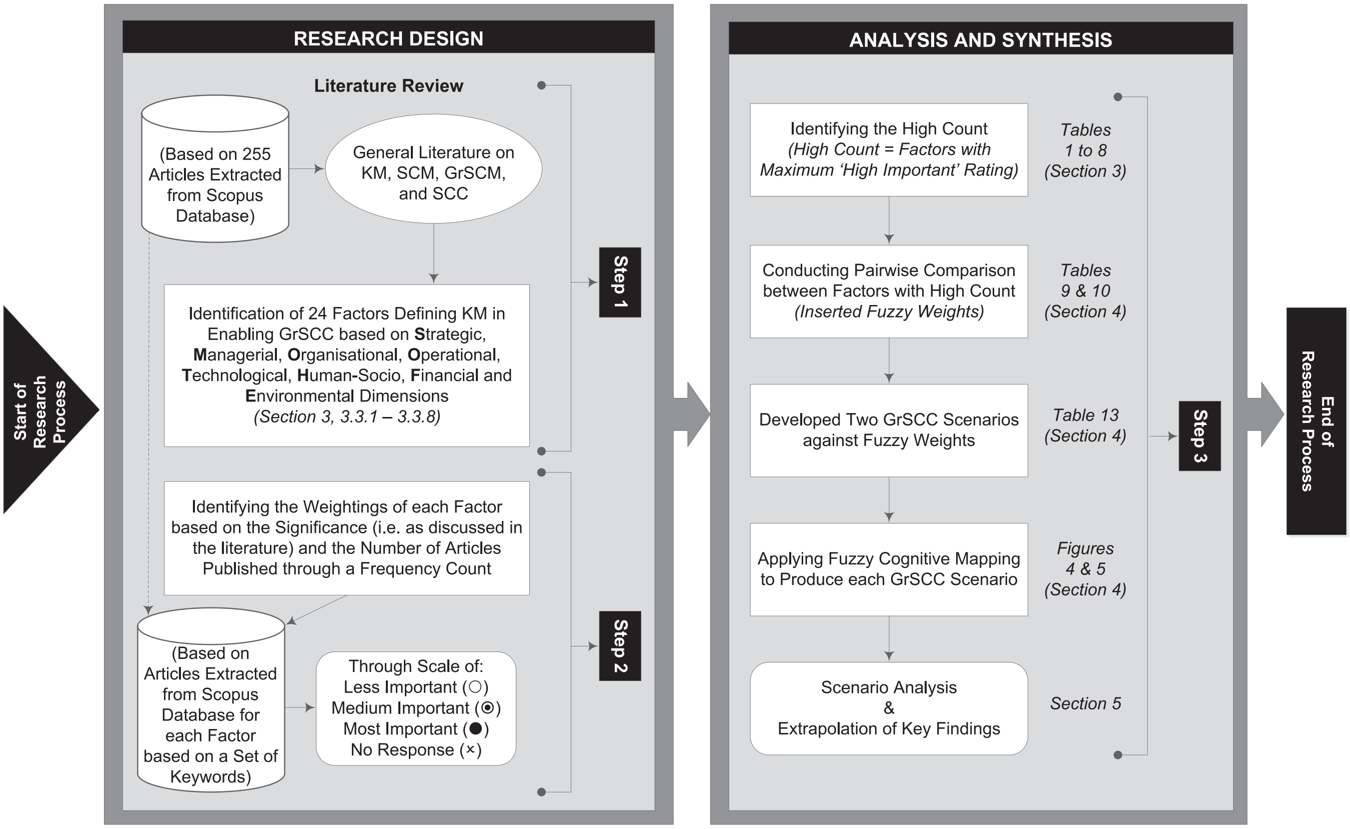

Figure 1. Research design.

255 articles extracted from the Scopus database) was conducted with the aim of identifying factors (and their justification) that may influence GrSCC implementation. The authors selected the Scopus database as it is a stockpile of more than 18,000 titles from over 5000 international publishers (including covering of 16,500 peer-reviewed journals spanning across different disciplines). Therefore, it is likely to search for and locate a significant proportion of the published material on SCM, GrSCC, and SCC using the general and advanced search facility. The literature used in this exercise can be classified on the basis of methodology and approach used into: normative works, frameworks, models and approaches, benchmarking, empirical studies (i.e. case research, field surveys and interviews, field and laboratory experiments and simulations), mathematical modelling approaches, and general literature review articles. Moreover, complementing the extant literature search and reports from industrial case studies were also used to support the findings and emergent factors.

- *Step 2* is about identifying the weightings of each factor based on the significance (i.e. either the factor is discussed within the article as a conceptual finding or has resulted from the empirical findings) and the number of articles published through a frequency count. To achieve this, the authors conducted profiling research through the Scopus Database to identify relevant articles around each of the factors (identified through Step 1) with a combination of different keywords (as presented in the Sections 3.2.1–3.2.8). Then each factor was assigned a weighting identified by a degree of shading in a circle, i.e. using Miles and Huberman's (1994) scale of less important (○), medium important (◉) and most important (●).

This scale represented the frequency of literature that suggested the coverage of each relevant factor. However, where the authors could not identify any denotation regarding any factor, '×' symbol was used to register a response. This search exercise is related to identifying the significance of each factor and is different to the one conducted in Step 1, where the authors only focused on identifying the factors.

Finally, the authors identified a range of GrSCC scenarios (i.e. supply chain events), two of which are listed in Table 13. The purpose behind defining these is to look at the causality of the factors that drive each event. Furthermore, the purpose of the scenarios are to explore and derive a contextual grounding for what might allow an organisation to define their own strategic perspective on green supply chain implementation (therefore allowing an insight into what green supply chain strategic planning elements might need to be considered based upon a list of causal relationships). In such a manner this also allows for any future identification of GrSCC strategies based upon calculated inter-relationships between fundamental supply chain factors.

The scenarios developed were based upon two contemporary green SC challenges, namely, collaborating to become greener (where SCC and design is a key driver); and incentive structures for green initiatives, noting the 'triple bottom line' of people, profit, (where supply chain sustainability is a key driver), see, for example, Elkington (1997). As such, the scenarios developed were extrapolated green challenges from the literature which were generated through expert opinions from the literature-derived factors and were then applied to the causal inter-relationships (i.e. pairwise comparisons).

Each scenario offers a contextual view (via a numerical vector representation) that identifies specific elements of a green supply chain event which is then applied to the matrix of pairwise comparisons (i.e. the subsequent fuzzy matrix) identified above. Upon calculation via Equation, a new fuzzy matrix (of inter-related green supply chain factors) is created – although this does not change the initial, starting set of causal relationships. These scenarios were then applied to the FCM simulation process and results obtained (with further details on this given in Section 4).

The GrSCC simulation process is as described by Kosko (1991), Sharif et al. (2012) and Irani et al. (2014). It is not the intention of this study to explore and interpret the dynamic interrelationships of these factors but rather to evaluate the *change* on GrSCC inter-relationships as represented through the FCM. As such, analysis of the initial and hence resulting FCMs are presented for each scenario before a description and conclusion is offered.

3. Knowledge management and GrSCC

Collaboration as a means by which manufacturer and supplier work closer together and towards a common purpose surfaced in the mid-1990s in the most recognisable form of collaborative planning forecasting and replenishment, (VICS 1998). This paved the foundation for modern day supply chain management principles that promote collaborative links. In recent years, the *green* aspect has become increasingly important with Yang et al. (2013, 56) describing green supply chain integration and collaboration as *a means to promote efficiency and synergy among business partners and an approach to strengthen corporations*. It is also (inbid) claimed *to help enhance environmental performance, minimise waste and save costs* (Cheng et al. 2004; Vachon and Klassen 2006; Zhu and Sarkis 2004). There is an ever-increasing need to integrate environmentally sound choices into supply chain management, with Srivastava (2007) proposing a problem-context classification around green supply chain management.

Organisations focusing on KM have identified that knowledge sharing within green SCs has been marked by increased productivity and sustained competitive advantage (Baresel-Bofinger et al. 2011; Chong et al. 2013; Liu et al. 2014). KM facilitates managers in obtaining, categorising and corresponding both tacit and explicit knowledge. Alavi, Kayworth, and Leidner (2005) advocate that by doing so, other employees of the organisation can utilise this knowledge to transform their effectiveness and productivity. Like other tangible resources in the organisation, managements consider knowledge analytically and explore KM to enhance and maintain their competitiveness in the marketplace. In a buyer/supplier relationship, suppliers who quantify and publish their individual carbon emissions are tactically more desirable than others as they support the buyers in managing their carbon emissions. Shaw et al. (2012) argue that very few SC members have broad knowledge about low-carbon material procurement for their SC.

In this context, Wang, Klein, and Jiang (2007) assert that organisations can effectively utilise knowledge management practices to enhance their SC competencies. Warkentin, Sugumaran, and Bapna (2001) report here that organisations that re-develop their in-house structure, revive their relationships with external SC partners and networks and create collaborative knowledge networks, and are better placed to facilitate share knowledge and increase harmonisation.

Gunasekaran and Ngai (2007) advocate that knowledge networks facilitate their collaborators to develop, share and effectively employ tactical knowledge in order to enhance an organisation's operations and functions. In line with this discussion, Yang et al. (2013) report that such green collaboration with SC partners implies mutual understanding of environmental perils and responsibilities. Moreover, steering shared decision-making to solving environmental glitches, sharing knowledge, resources and skills facilitates accomplishing sustainable environmental common goals mutually among SC partners. As a result, this enhances the quality of the decision-making process and planning in the organisation to adopt appropriate knowledge management systems (KMS) and support the greening of the whole SC collaborative venture (Autry 2011; Simatupang and Sridharan 2002). In response to the latter, Humphreys, McIvor, and Chan (2003) developed a model on knowledge-based system to assess suppliers' overall environmental performance. According to this model, green image, management competencies, green design, cost, environmental management systems and environmental capabilities were deemed as the assessment constructs.

3.1. Knowledge management within supply chains

The organisations' requirement to establish close connections with businesses and SC partners needs harmonisation, sharing knowledge and best practice (Corso et al. 2010). Knowledge is hard to handle as it is somewhat intangible, nevertheless, it is a vital source that distinguishes the 'best value supply chains' from the customary SCs. Its creation and transfer are particularly important for continuing affiliations. This is because KM just not only considers managing organisational knowledge assets, but managing the processes as well (e.g. creating, preserving, using and sharing knowledge) that act on these key resources. Therefore, KM becomes one of the main elements to facilitate collaborating organisations to supplement each other's strengths and shape their association and SC strategies (Mentzas et al. 2006). With active knowledge sharing and management, the strategic objective of SCC for a sustainable competitive advantage can be accomplished by linking the pertinent organisational resources and competences of all SC partners (Madhok and Tallman 1998). According to Cheng, Yeh, and Tu (2008), SCs are designed to accomplish a sustainable competitive advantage for all partners engaged. SC partners operating in a collaborative SCM environment accomplish collective goals by sharing thoughts, rewards, risks and knowledge on SC events (Chong et al. 2013). The latter two arguments are supported by Sodhi and Son (2009), who state that partnership within SCs does not simply impact on an organisation's operational performance but also significantly influences financial performance. Autry (2011) reports that despite the best efforts of SC managers, only some collaborative ventures among organisations end up working out for the members' mutual benefit.

Moreover, Voelpel, Dous, and Davenport (2005) argue that an imperative cause for the failure of KM systems to expedite knowledge sharing is a lack of consideration of how organisational and interpersonal contexts along with individual characteristics influence knowledge sharing. Therefore, it is vital to understand that SC collaborative ventures are predominantly reliant on:

- Managing and sharing knowledge between the workforce (Sodhi and Son 2009), individual skills of the SC partners (Fernie et al. 2003), leadership skills (Sharif and Irani 2012), trust among the SC partners (Cheng, Yeh, and Tu 2008) and internal champions to maximise their returns on the relationship (Autry 2011).
- Alliances between geographically separate organisations mostly take place virtually – in this context implementing a suitable technological collaboration tool is another key enabler for GrSCC. Zahay and Handfield (2004), in their case study research, indicate that organisations that have the capability to acquire knowledge and share information are the most likely to successfully automate their SC through advanced technological solutions.

In addition to these enablers, there are factors that inhibit the overall effectiveness of a strong inter-organisational collaboration arrangement. For instance:

- Lack of collaborative and strategic planning, limited interaction between the members of the SC including activities such as disloyalty, lack of trust and workforce related malpractices (deliberately or unconsciously undertaken), the need for large investment and lack of mutual targets, would clearly endanger an SCC venture (Hongjuan and Jing 2011).
- Resistance to change by some members of the SC partnership is another often cited cause for failing to implement collaborative SC ventures (Simatupang and Sridharan 2002).

As already mentioned, there is an increasing need for SCC and emphasising closer and long-standing operational affiliations and even partnerships with suppliers at various levels in the SC, as a way to construct ever more efficient SCs and deliver exceptional value to customers (Soosay and Hyland 2015). This indicates a growing trend towards greater green collaboration for a successful SC and optimal organisational performance, resulting in carbon-efficient production. For instance, Matopoulos et al. (2007, 177) argue that 'despite the barriers that potentially deteriorate collaboration among companies for many industries all over the world, collaboration is becoming more of a necessity than an option'. Barratt (2004) perceives that the failure of SCC is instigated by a lack of understanding of what collaboration actually signifies. As a result, vital factors such as developing a front-end agreement (Barratt 2004), top management commitment and support (Anbanandam, Banwet, and Shankar 2011), mutual trust (Matopoulos et al. 2007), and sharing knowledge (Sodhi and Son 2009) are crucial for successful GrSCC. Despite the fact that many recent studies have covered the two wide areas of KM and SCM (including SCC and GrSCM), research on the application of the two combined disciplines specifically focusing on the role of KM in enabling GrSCC (at the organisational level) is still in its early stages. With existing financial motivation, legislative pressures and the potential of developing a competitive edge, managers and practitioners have to move away from their current outmoded practices and determine new ways to green their supply chain operations leading to sustainable energy futures and carbon-efficient production. The authors thus argue that even though there are several studies in the literature about SCC and GrSCM, little is known about the factors (including their interrelationships) that clearly indicate the significance of KM in facilitating and implementing GrSCC in organisations.

3.2. Factors defining the role of KM in enabling GrSCC

As argued by Kostova and Roth (2002), a fundamental principle of the institutional perspective is that organisations sharing similar environment may also employ related SC practices and thus become 'isomorphic' with each other. Organisations are progressively being interlinked through intra- and inter-organisational SC – this transition from being homogenic to polygenic illustrates that individual businesses do not merely exist as exclusive self-governing entities that operate in isolation, but act as an interactive SC web (Sharif and Irani 2012; Stock, Boyer, and Harmon 2010). To understand this methodically, the authors assessed the existing literature on KM and SCM to investigate influential factors that define KM in enabling GrSCC. The authors classify these 24 factors based on the **s**trategic, *m*anagerial, *o*rganisational, *o*perational, *t*echnological, *h*uman-socio, *f*inancial and *e*nvironmental dimensions, with each dimension comprising three factors along with a description of each factor given below. This list of factors is not exhaustive; however, these factors and their description included in each dimension are identified and discussed based on the literature specifically focusing on KM, and SCM (including SCC, GrSCM, environmental sustainability and carbon-efficient production). With an overview of the key facets of KM, SCM, SCC and GrSCM and an understanding of the importance of green collaboration among the various parties in the SC to benefit the organisations, a proposed research model is proposed (see Figure 2). The significance and detailed relationships (through the use of FCM) of each factor are determined and presented later in this paper.

3.2.1. Strategic dimension

- *Strategic Impact (SI)*: Collaboration between strategic inter-organisational SC partners represents a vital investment option for managers in positively impacting business performance and competitiveness (Corso et al. 2010; Sodhi and Son 2009). Through their empirical findings, Cao et al. (2010) report that a major strategic impact of an SC collaborative venture is the accumulation of knowledge resources from all SC partners and utilising this knowledge for effective organisational performance.

As reported by Desouza, Chattaraj, and Kraft (2003), knowledge management clearly relates with the SCM discipline thereby sharing and synchronising external knowledge with SC partners and increasing inter-organisational efficiency. Malhotra, Gasain, and Sawy (2005) further highlight the significance of the two disciplines and state that collaboration between SC partners is not simply based on transactions; it influences information sharing and knowledge formation for sustainable environment and achieving competitive advantage. According to Esper et al. (2010), knowledge-based

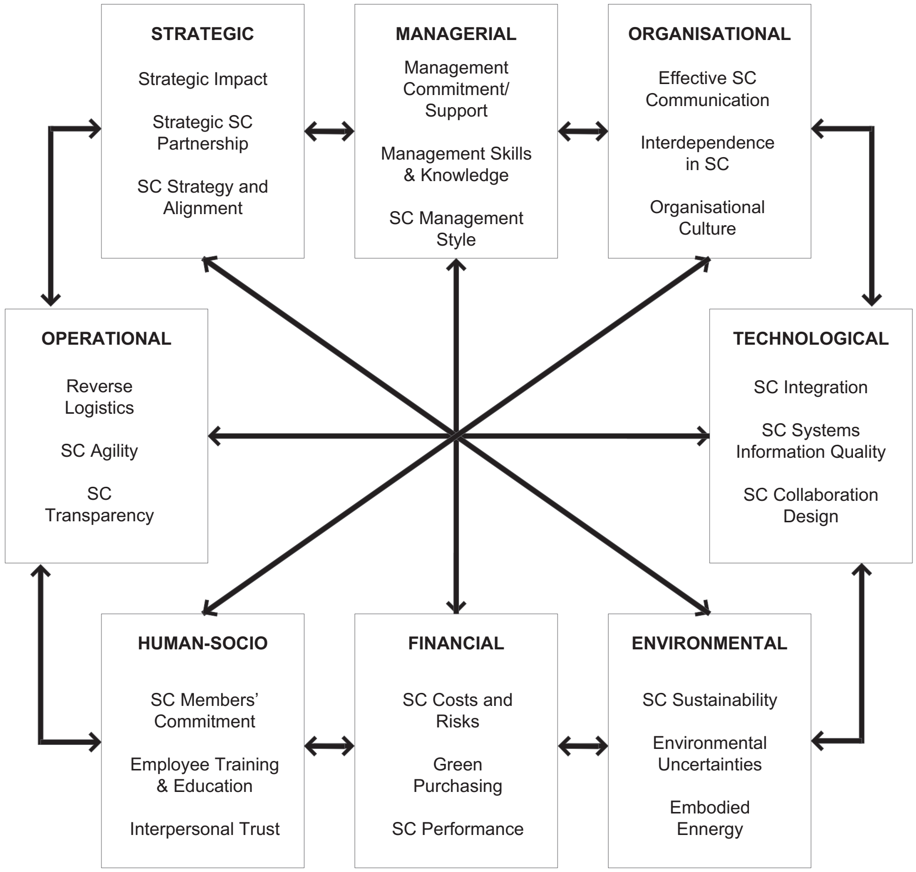

Figure 2. Factors defining knowledge management in enabling green supply chain collaboration.

theories of the firm highlight the strategic significance of leveraging knowledge, for instance, marketplace statistics and business intelligence to support and boost organisational performance.

- *Strategic Supply Chain Partnership (SSCP)*: Cooperative relationships among the SC partners (also referred to as partnering) is a vital element in enabling the integration of different actors' skills and knowledge and in efforts to mutually solve problems (Eriksson 2010). SCC is one such initiative that has encouraged many inter-organisational SC players for sharing knowledge and experiences to strengthen their partnerships (Ramanathan and Gunasekaran, 2014). In the words of He, Ghibadian, and Gallear (2013) SCP is most extensively implemented form of collaborative inter-organisational coalition that supports knowledge acquisition and sustainable organisational as well as environmental performance. For example, multinational organisations such as West-Marine, Procter & Gamble and Hewlett–Packard have developed successful SC partnerships and realised the benefits of SC collaborations such as reduced costs, enhanced sales, better forecast precision and eco-friendliness. In line with these collaborations, Toktay, Wein, and Zenios (2000) state that benefit sharing is the underlying constituent of such strategic SC partnerships. Thus, a mutual controlling mechanism between the partnering organisations also supports shared decision-making, reduced information irregularities and increased knowledge transfer.
- *Supply Chain Strategy and Alignment (SCSA)*: The misalignment of SC strategy with the business strategy can often lead to project failure (Braziotis and Tannock 2011). It is important for small enterprises and manufacturing businesses to evaluate their investments, and once aligned, it facilitates these organisations to perform better in terms of growth, efficiency and prosperity (Raymond and Bergeron 2008). Being integrated through shared knowledge and process alignment, SC partners function as if they were a component of a single organisation (Cao et al. 2010). In this context, Sakka, Millet, and Botta-Genoulaz (2011) recommend that to facilitate collective innovativeness, it is essential to align strategic vision and innovation objectives throughout the organisation, along with managing boundaries to enable collaboration across inter-organisational SCs. In terms of mutual financial outcomes, managements need to align their goals and outcomes with SC partners for developing collaborative advantage. Cao and Zhang (2011) maintain that such concerted gain directly surges the financial performance of each supply chain partner.

The above discussion clearly indicates the importance of the three strategic dimension factors. In order to identify the weightings of each factor (see Tables 1–8), the authors conducted a profiling research through the Scopus database.

3.2.2. Managerial dimension

- *Management Commitment and Support (MCS)*: The key to accomplishing an anticipated collaborative breakthrough is to establish strong management commitment towards SCM (Anbanandam, Banwet, and Shankar 2011). The significance of SC does not come from merely developing collaborative ventures; rather from mutually reforming (i.e. greening) both operational and management processes within the SC organisation (Diabat and Simchi-Levi 2009). In this context, the key responsibility of management is the provision of adequate monetary support, resources and their constant commitment (Min et al. 2005). The latter argument is supported by Fawcett et al. (2006), who state that commitment should come from all levels of the organisation and their SC partners. Only senior management can commit the resources and calibrate the incentives to develop factual cross-functional competences. Organisations are more likely to have proactive sustainable environmental strategies if there is high commitment by managers and they interpret environmental issues as opportunities (Sharma 2000).

Research on SCM and SCC has identified a positive connection amid top management's participation in continuing collaborative ventures. For instance, a high degree of management commitment and support in the collaboration venture is recognised as a predictor for successful inter-organisational relationships (Sheu, Yen, and Chae 2006).

- *Management Skills and Knowledge (MSK)*: The availability of personnel with ample capabilities and knowledge for generating original ideas and concepts is a vital factor for success in any business sector, logistics and to sustain the strategic importance of SCM (Thai 2012). Management capabilities include effective and efficient management of operations, synchronisation and communication with the workforce, project management and governance proficiencies. Such extensive experience and knowledge will facilitate the management of supplier–retailer networks to produce improved SCC and performance (Sheu, Yen, and Chae 2006). This indicates that by ensuring the availability of capable managers, an organisation can employ their services for support in developing both new and existing sets of business requirements. Other managerial competencies include management awareness of the benefits of the new SC systems that may result in high commitment towards successfully implementing SCC (Tsinopoulos and Bell 2010). In Eltantawy's (2008) words, SC managers must be capable and knowledgeable enough to determine and develop the fundamental skills that their departments require from them.
- *Supply Chain Management Style (SCMS)*: The type of management style can be effective for investing time and resources, evaluating and sustaining SCs, and managing SC performance (Robinson and Malhotra 2005). For example, Ou et al. (2010) emphasise that it is the leadership that pushes the overall SC system that results in enhanced financial outcomes and customer contentment. Ho and Lin (2004) argue here that if differences in opinions and management styles are not well understood and managed within the SC, they may potentially lead to project

Table 1. Conceptual weighting of strategic factors.

		References							
Dimension	Factors	Sakka, Millet, and Botta-Genoulaz (2011)	Esper et al. (2010)	Corso et al. (2010)	Cao et al. (2010)	Desouza, Chattaraj, and Kraft (2003)	Sambasivan et al. (2013)	Cao and Zhang (2011)	Braziotis and Tannock (2011)
Strategic	SI	○	●	●	●	●	●	●	⦿
	SSCP	●	⦿	●	●	●	●	●	●
	SCSA	●	●	×	●	⦿	⦿	●	●

Table 2. Conceptual weighting of managerial dimension factors.

		References							
Dimension	Factors	Eltantawy (2008)	Defee, Esper, and Mollenkopf (2009)	Tsinopoulos and Bell (2010)	Ou et al. (2010)	Sheu, Yen, and Chae (2006)	Robinson and Malhotra (2005)	Overstreet et al. (2013)	Sharma (2000)
Managerial	MCS	●	●	●	●	●	●	●	●
	MSK	●	⦿	●	○	●	⦿	⦿	●
	SCMS	○	●	○	●	⦿	⦿	●	⦿

Table 3. Conceptual weighting of organisational dimension factors.

		References							
Dimension	Factors	Cassivi (2006)	Sheu, Yen, and Chae (2006)	Machikita and Ueki (2013)	Bezuidenhout, Bodhanya, and Brenchley (2012)	Cao et al. (2010)	Robinson, Sahin, and Gao (2005)	Chae, Yen, and Sheu (2005)	Zhang and Huo (2013)
Organisational	ESCC	●	●	●	●	●	●	●	●
	ISC	○	●	⦿	○	⦿	○	●	●
	OC	○	⦿	×	●	○	●	⦿	○

Table 4. Conceptual weighting of operational dimension factors.

		References							
Dimension	Factors	Sharif et al. (2012)	Swafford, Ghosh, and Murthy (2006)	Liu et al. (2013)	Shao (2013)	Ramanathan (2012)	Hsu et al. (2009)	Bastian and Zentes (2013)	Pinna and Carrus (2012)
Operational	RL	●	○	○	○	○	○	○	●
	SCA	◉	●	●	●	◉	●	◉	○
	SCT	◉	◉	●	●	●	●	●	●

Table 5. Conceptual weighting of technological dimension factors.

		References							
Dimension	Factors	Farooq and O'Brien (2012)	Cassivi (2006)	Simatupang and Sridharan (2008)	Zhang and Huo (2013)	Li, Tarafdar, and Rao (2012)	London and Singh (2013)	Bhattacharjee and Mohanty (2012)	Azevedo, Carvalho, and Cruz Machado (2011)
Technological	SCI	●	●	◉	●	●	●	◉	●
	SCSIQ	●	◉	○	●	●	◉	◉	●
	SCCD	●	●	●	○	◉	●	●	●

Table 6. Conceptual weighting of human-socio dimension factors.

		References							
Dimension	Factors	He, Ghibadian, and Gallear (2013)	Matopoulos et al. (2007)	McCarter, Fawcett, and Magnan (2005)	Aitken and Harrison (2013)	Baresel-Bofinger et al. (2011)	Bhattacharjee and Mohanty (2012)	Ateş et al. (2012)	Sheu, Yen, and Chae (2006)
Human-Socio	SCMC	●	○	◉	◉	●	●	●	●
	ETE	○	○	●	◉	○	◉	◉	○
	IT	●	●	◉	●	●	●	○	●

Table 7. Conceptual weighting of financial dimension factors.

		References							
Dimension	Factors	Naspettia et al. (2011)	Eltayeb, Zailani, and Ramayah (2011)	Wuttke, Blome, and Henke (2013)	Walker, Di Sisto, and McBain (2008)	Tracey and Neuhaus (2013)	Hsu et al. (2013)	Wu, Ding, and Chen (2012)	Vlachos (2014)
Financial	SCCR	●	●	●	●	●	●	◉	●
	GP	○	●	○	○	◉	●	●	○
	SCP	●	●	●	●	●	●	●	●

Table 8. Conceptual weighting of environmental dimension factors.

		References							
Dimension	Factors	Wu and Hassis (2013)	Cervellon and Wernerfelt (2012)	Kudla and Klaas-Wissing (2012)	Chen, Preston, and Xia (2013)	Kara and Ibbotson (2011)	Iyer (2011)	Arıkan Fichtinger, and Ries (2014)	Winter and Knemeyer (2013)
Environmental	SCS	●	●	●	◉	◉	●	●	●
	EU	●	○	○	●	◉	●	●	○
	EE	○	◉	●	●	●	○	●	×

failures. Top management's role is to assess the main strategic partners, determining and sharing the vision, knowledge and SC strategy, organising collaboration seminars, scrutinising overall SC performance, and offering incentive structures to develop performance. McKinnon (2012) reports that the business mantra 'if you can't measure it, you can't manage it' relates as much to carbon emissions as to resources and costs. Thus, organisations subject to government control on carbon emissions are legitimately required to gauge their emissions precisely and consistently. van Hoek, Chatham, and Wilding (2002) report that effective leadership is an important stimulus for directing, managing and attaining impactful SCM performance. Certainly, management style seems to have a direct as well as indirect effect on inter-organisational SC success (Overstreet et al. 2013).

3.2.3. Organisational dimension

- *Effective Supply Chain Communication (ESCC)*: Researchers such as Bezuidenhout, Bodhanya, and Brenchley (2012) and Cao et al. (2010) assert that SC synchronisation and knowledge creation can only occur if there is a sufficient level of communication. According to Machikita and Ueki (2013), tangible knowledge embodied in capital goods can be simply relocated by way of simple inter-organisational SC transactions. Nevertheless, disembodied knowledge cannot be transmitted through direct communication between upstream and downstream SC partners. Paulraj, Lado, and Chen (2008) argue that miscommunication results in conflicts and misperceptions between SC partners and this jeopardises the whole collaborative venture. Thus, the formation and growth of SC partnerships can only flourish when instigated with effective communications between potential SC partners (Cassivi 2006). SC collaboration is not merely transaction-based; it influences sharing of information and knowledge creation for sustainable competitive advantage and environmental performance (Malhotra, Gasain, and Sawy 2005). Cristea (2011) argues that effective communication can facilitate the knowledge transfer process and support a decrease in international trading costs. Effective communication does not necessarily infer a greater level of communication frequency, but more bi-directionality and shared content (Bezuidenhout, Bodhanya, and Brenchley 2012).
- *Interdependence in Supply Chains (ISC)*: The collaborative paradigm in the SC discipline suggests that organisations function within a network of inter-dependent affiliations developed and nurtured through strategic integration (Stevens and Johnson 2016; Vachon and Klassen 2006). This paradigm is supported by Sheu, Yen, and Chae (2006) who state that mutual dependence or interdependence between SC partners is of high significance for inter-organisational affiliations. According to Heikkilä (2002), mutual dependence of an organisation on an SC partner signifies the organisation's necessity to sustain a connection with the other partners in the SC in order to accomplish its goals. On the other hand, Chae, Yen, and Sheu (2005) report that interdependence exists when one SC partner does not completely govern the whole SC operation. Interdependencies in business partnerships are not new as explained by Cook (1977), reliance in a business affiliation is developed between trading partners, and through such dependences the partners positive/negatively impact the business practices of their SC partners and eventually overall business performance. Retaining a social connection between interdependent SC partners may also support the development of trust-based relationships. Thus, it is this interdependence that inspires the readiness to share knowledge resources with other SC partners.
- *Organisational Culture (OC)*: Robinson, Sahin, and Gao (2005) perceive organisational culture as key to a sustainable competitive advantage in SCs. Zeleny (2005) argues that although information sharing is vital for an SC to sustain effective operations, it is the transforming of information into knowledge and sharing of (new) knowledge that allows organisations to remain competitive, and eventually the SC partnerships to remain competitive. If individual SC partners are not able to change information into knowledge and manage knowledge flow, then the SC partnership will not be able to produce the synergy essential to effectively compete against other SCs. Meng (2012) argues here that to have such a synergistic atmosphere, management needs to be in a position to closely work with and influence their workforce in order to transform the information into processes and knowledge that is shared among them. Transforming the culture is the key to leveraging organisational staff. In the absence of the right culture, the SC will fail to use their workforces effectively to transfer their urge into SC initiatives. Robinson, Sahin, and Gao (2005) however, argue that the organisations' cultural compatibility must be considered by the SC manager, so as to avoid the SC performance being directly and indirectly influenced by these chain cultures.

3.2.4 Operational dimension

- *Reverse Logistics (RL)*: Reverse logistics is a 'backwards' operating process, i.e. it consists of processes and functions related to the reuse of products (Amin and Zhang 2012). The extant body of literature highlights the significance of research conducted into RL systems, i.e. it offers pragmatic solutions for strategic business organisations in how to deal with the issues of implementing reverse flow. Advocates, such as Efendigil, Onut, and Kongar (2008) and Sharif et al. (2012), also highlight the significance of RL by stating that implementing an efficient RL structure can improve an organisation's return on investment and competitiveness in the marketplace. Multinational organisations such as Caterpillar have developed a whole new division based on the RL school of thought. RL is becoming a competitive necessity for many organisations (Jack, Powers, and Skinner 2010). The existence of an RL programme has provided organisations with direct monetary by decreasing the use of raw materials, by adding value with recovery, or by reducing disposal costs, thereby enabling sustainable environmental performance (De Brito 2003). Similar research indicates that organisations focusing on RL systems are redesigning their structures and relationships, creating a knowledge chain that facilitates and improves data, knowledge sharing and coordination, decision-making and planning (Sharif et al. 2012).
- *Supply Chain Agility (SCA)*: To be a global competitive entity, companies need to align with their suppliers and customers so as to restructure their functions and work collaboratively to achieve a level of agility (Shao 2013; Soni and Kodali 2012). Researchers, such as Swafford, Ghosh, and Murthy (2006) and Braunscheidel and Suresh (2009), describe SCA as a type of functional capability that refers to an organisation's capacity to perform operational activities together with SC partners so as to adjust or react to market fluctuations rapidly. According to Chopra and Sodhi (2004), agile organisations can reduce inventory risks by collaborating and functioning with highly responsive suppliers

and distributors, exchange essential knowledge with SC members, and can also reduce capacity risks by making existing capacity more flexible. For instance, Toyota reduces capacity risks by ensuring that each plant is flexible and has enough stock to be able to supply to more markets (Chopra and Sodhi 2004). Organisations need to collaborate with SC partners to perform linked activities (e.g. design, manufacture and delivery of products or services) more efficiently and mutually manage industry unpredictability to acquire competitive advantage (Liu et al. 2013). In this context, SCA, which is primarily about customer receptiveness, is vital in ensuring the organisation's competitiveness as it facilitates efficient responses to operational changes (e.g. procurement, manufacturing, delivery and market promotion).

- *Supply Chain Transparency (SCT)*: Beulens et al. (2005, 482) define SCT 'as the degree to which an SC player has access to relevant information about products, processes and flows of capital without loss, noise, delay and distortion'.

Transparent information and knowledge exchange in SC collaborative ventures is claimed to be a leading component behind all organisational successes (Ireland and Crum 2005). SCT is an indicator of the quality, availability, accuracy, accessibility and facts about SC data (Bastian and Zentes 2013). To accomplish enhancements in collaboration with SC partners, transparency beyond organisational boundaries is required (Shao 2013). According to Liu et al. (2013), the integrated and transparent flow of information facilitates organisations' acquisition of quality, rich and reliable content and real-time information across the SC to further enhance the SCT. SCT has two extents, i.e. horizontal (e.g. denotes situations, strategies and organisational business processes on specific SC tiers and information flows to key stakeholders) and vertical (i.e. covers knowledge about all companies and input and output flows in the SC) (Wognum et al. 2011). Thus, transparency plays a significant role in GrSCM and collaborative ventures and is a widely accepted phenomenon (Ramanathan 2012).

3.2.5. Technological dimension

- *Supply Chain Integration (SCI)*: Farooq and O'Brien (2012) report that, in realising global transformation and competitive business environments over the years, a number of manufacturing sector organisations have collaborated with their SC partners such as suppliers and customers in order to achieve seamless SC integration. In line with Cassivi's (2006) empirical research, the level of supply chain integration (internally) and virtual collaboration within the SC resulted in greater significance towards organisational performance. In the context of green SC practices, Azevedo, Carvalho, and Cruz Machado (2011) assert that for organisations implementing green SC collaboration practices, it is vital to assess their impact on overall SC performance. This is because it may enable management to understanding SC partners' integration better, while at the same time enlightening the effects of policies and likely prospects in SCM. Thus, integrating the SC facilitates streamlining the mutual (as well as individual) objectives of all the trading partners to achieve the common goal of enhancing productivity and environmental performance (Stevens and Johnson 2016). The latter concept is supported by Zhang and Huo (2013) who are convinced that SCI results in sharing knowledge, dilemmas and functioning collaboratively and this does not only benefit the customers but also benefits the whole SC in developing mutual understanding, interdependence and trust and eradication of a blame culture.
- *Supply Chain Systems Information Quality (SCSIQ)*: Collaborative knowledge management practices such as knowledge creation, storage, accessibility, diffusion and application of information drive better assimilation between SC partners, resulting in improved knowledge accessibility and information quality (Li, Tarafdar, and Rao 2012). To ensure that SC systems provide quality output and sustainable environmental performance, Patil et al. (2012) argue that organisations need to evaluate their information systems. Irani et al. (2014) report that this examination can be conducted in terms of performance and profitability, quality output and ease of customisation, implementation time, cost, customer satisfaction and overall greening of the SC. Many researchers have examined the role of SC information and information quality in improving SC performance. For example, Raymond, Croteau, and Bergeron (2011) identified that quality information outcome and performance from inter-organisational SC systems is viewed as a result of direct or proximal strategic alignment of IT. Forslund and Jonsson (2007) however, report that for upstream SC members (specifically the manufacture-to-order suppliers) forecast information quality may be mediocre; nevertheless, Ketzenberg et al. (2006) argue that managing the information efficiently will certainly improve the SC performance.
- *Supply Chain Collaboration Design (SCCD)*: A number of research studies provide extensive understanding into the operational and strategic aspects of SC design and management. For instance, SCC has often been associated with the design of inter-organisational process enhancements combined with information systems, which enable the SC members to efficiently deliver products and services to customers cost-effectively (Bhattacharjee and Mohanty 2012; Matopoulos et al. 2007). Advocates such as Simatupang and Sridharan (2008) emphasise that the SC processes and design should be flexible so as to respond to ever-increasing customer needs at the lowest cost regarding supply capability. Simchi-Levi, Kaminsky, and Simchi-Levi (2003) argue that to develop flexibility, the SC partners can restructure the SC design by streamlining the distribution system, product, production process and inventory management so as to capture knowledge and to be cost-effective and flexible enough to equal supply with varying customer demands. For instance, Dell, Zara and Toyota have reengineered their SC designs to achieve strategic objectives. In the case of Zara (an attire company), it capitalised on IT to capture knowledge on topical fashion developments and synchronise product delivery from manufacturers to retailers in a short span of 10 days. By redesigning SC structure, Zara managed to acquire a faster response, i.e. from fashion

draft to product delivery in stores that resulted in improved profits and reduced costs.

3.2.6. Human-Socio dimension

- *Supply Chain Members' Commitment (SCMC)*: Lack of commitment from business partners and their individual members is a major challenge to SC collaborative ventures (Walker, Di Sisto, and McBain 2008). According to Simatupang and Sridharan (2008), SCC suggests that two or more SC members develop commitment and support to sustain a long-term alliance. As such, effective knowledge transfer in an SC partnership is more dependent on the level of trust and commitment between partners (He, Ghibadian, and Galllear 2011). Bowersox, Closs, and Stank (2003) further support that these SC members utilise their core proficiencies and individual support to manage change taking place through SCC and deal with adaptive challenges that may come from forming an alliance.

  This process infers that the strategic objectives of the SC collaborative venture can be acquired from the mutuality of an association to develop and implement effective strategies of key components of collaboration (Simatupang and Sridharan 2008). A principle of trust and collaboration is that organisations and their SC trading partners have analogous aspirations and commitment to work together (Sheu, Yen, and Chae 2006). Thus, a high level of commitment towards cooperative functioning generates outcomes that stimulate effectiveness, productivity and efficiency. Moreover, it ensures that SC partnerships have less concern over unauthorised outflow of core knowledge as well as overflow at the knowledge acquisition stage (He, Ghibadian, and Galllear 2011).
- *Employee Training and Education (ETE)*: Researchers such as McCarter, Fawcett, and Magnan (2005); Ateş et al. (2012) and Bhattacharjee and Mohanty (2012) highlight the significance of employee training and education and state that organisations providing training and learning facilities to their employees may facilitate collaborative supply chain ventures. Gunasekaran and Ngai (2004) report that training and education are dynamic constituents of the continuing success of an organisation and in successfully transiting the change process. In the context of SC partnerships, the change process generates vital information and to convert such information to knowledge and further manage that knowledge efficiently and effectively, employee training and education becomes a strategic need (McCarter, Fawcett, and Magnan 2005). Moreover, for organisations to be successful, it is important that managers have the full support of their knowledgeable and experienced employees to ensure success in SCs (Irani et al. 2014). This indicates that SCC entails more than a change in attitude from antagonistic to collaborative green organisational interactivity where training and education provide employees with a vision and understanding to yield benefits. Senge (2000) describes such organisations as learning organisations – where the workforce is constantly acquiring knowledge and improving their competences to support their organisation in adapting to vibrant global environments and remain competitively superior.
- *Interpersonal Trust (IT)*: Trust in SC partnerships is conceivably one of the most frequently cited requisites and foundations of the SCM philosophy (e.g. Anbanandam, Banwet, and Shankar 2011; Bezuidenhout, Bodhanya, and Brenchley 2012; Chae, Yen, and Sheu 2005; Sheu, Yen, and Chae 2006). Wekselberg (1996) defines trust as 'beliefs that participants of an interaction share common goals and together pursue these goals'. In management and operation literature there has been an evident upsurge in the significance of trust in different forms of inter-organisational affiliations. For example, for some researchers, interpersonal trust nurtures greater teamwork and knowledge creation, decreases functional encounters and improves integration in addition to decision-making under ambiguity and uncertain conditions (Anbanandam, Banwet, and Shankar 2011), whereas, others cite that interpersonal trust is the binding force of any buyer–supplier relationship (Sheu, Yen, and Chae 2006). In the latter case, for instance, when the supply of a product is reduced, the farmer may demand higher rates. Similarly, when the supply of a product is augmented, the processor may demand a lower rate. In both these cases, the trust development process is affected as organisations start focusing on short-term benefits. The overall exercise of supply and demand places pressure on the partnership development process, further jeopardising the intensity of green alliance, and explicitly the depth of relationship from strategic to functional and tactical.

3.2.7. Financial dimension

- *Supply Chain Cost and Risks (SCCR)*: Organisations are depending more on external associates and partners to enable cost-effective value and service delivery to customers, as the pertinent knowledge is often found in other SC partners (Naspettia et al. 2011). Sodhi and Son (2009) and Bhattacharjee and Mohanty (2012) state that organisations practicing an SCC approach and knowledge and information sharing with their SC partners have realised significant cost reductions and increased revenues. Wuttke, Blome, and Henke (2013) specify that collaboration contributes to greater SC performance by reducing an organisation's logistical service-related costs and improving cash flow. However, as most collaborations take place virtually – in this case global SC can increase efficiency and effectiveness, but it can also result in increased risks. For example, the recent cases of the Japanese earthquake and tsunami and the volcano in Iceland – clearly indicate the how far the magnitude of such risks to the environment can spread. In the Japanese tremor case, for instance, the global SC electronics production line and dissemination was severely affected and this natural calamity led to prolonged business interruptions for the automotive businesses worldwide. The instability of global SC is associated with the evolving nature of risks; however, it is also linked to SC design strategies (Simatupang and Sridharan 2008). Integrating risk management with SCM has recently gained pace and many organisations have re-established the control between risk and cost emphasis while managing global SCs (Azevedo, Carvalho, and Cruz Machado 2011).

- *Green Purchasing (GP)*: The green purchasing concept is a green SC initiative, which is also referred to as 'Sustainable Procurement' or 'Green Procurement', includes classifying, opting and procuring products and services with considerably limited adversarial environmental impacts. Hsu et al. (2013) report that green purchasing focuses on developing external relationships with suppliers to ensure that they are committed towards rigorous ecological management practices, or design for the environment that focuses on internal and external collaboration on the design of both product and process (although still as part of a set of financial transactions). Through designing ecologically friendly products and services and focusing on reverse logistics, business organisations can create benefits for the environment, for example, through reduced wastage, better utilisation of resources and cost reductions to the organisations (Eltayeb, Zailani, and Ramayah 2011). From the GrSCM perspective, green purchasing is collaborative SC exercise that requires extensive and constant knowledge sharing. In this case, by accessing suppliers' ecological performance from upstream and collaborating with downstream customers, organisations can better implement GrSCM practices so as to accomplish energy and material usage reduction and green product reprocessing and remanufacturing (Vachon and Klassen 2006).
- *Supply Chain Performance (SCP)*: The motivation for GrSCC is to improve overall supply chain performance. In line with this, successful SCC implementation by Wal-Mart has stimulated many manufacturing organisations, such as DELL Computers, Procter & Gamble, Coca-Cola, Hewlett-Packard and Zara to initiate collaboration and enhance their SC and financial performance (Chae, Yen, and Sheu 2005; Simatupang and Sridharan 2008). In the literature, supply chain performance has been linked to sharing production information and knowledge (Baresel-Bofinger et al. 2011), generation of quality information (Li, Tarafdar, and Rao 2012), operational practices (Cassivi 2006), cost-effective financial outcomes (Wuttke, Blome, and Henke 2013), technological infrastructure practices (Vlachos 2014), etc. From an environmental perspective, Zhu and Sarkis (2004) have revealed how China endorsed strict environmental rules and procedures that surpassed national and international requirements and how this has motivated the manufacturing sector to implement GrSCC practices that eventually improve their overall business performance. Thus, effective collaborative strategy is anticipated (e.g. performance enhancement in the form of better information quality, reduced costs, improved responsiveness) to enhance SC performance by enabling a decision-making process that echoes an extensive insight of the SC (Gunasekaran, Subramanian, and Rahman 2015).

3.2.8. Environmental dimension

- *Supply Chain Sustainability (SCS)*: Organisations regard sustainability as a vital strategic goal and GrSCM is a key factor in stimulating inter-organisational SC sustainability (Hsu et al. 2013).

  The scale of this phenomenon is represented by the universal awareness and importance given to sustainability and also as manifested by the European Union (EU) which is an influential supporter of sustainability (Linton, Kalssen, and Jayaraman 2007). In the 1990s, the focus on the sustainability phenomenon shifted to 'green marketing' (Stone and Wakefield 2001), whereas in the twenty-first century researchers and SC practitioners started to investigate the lifecycle of goods during material collection (Vachon and Klassen 2006), the effect of green purchasing on SC partner selection (Hsu et al. 2013); managing wastage and packaging (Eltayeb, Zailani, and Ramayah 2011) and governing compliance. For instance, the Marks & Spencer Group is dedicated to taking the lead in the use of sustainable raw materials for its products, e.g. sustainable agricultural sourcing, setting standards and a pledge to retail certified organic goods. However, the research community stresses the need to educate and train organisational workforces to a better understanding of the benefits and tactics used towards implementing GrSCM as an innovative approach for sustainable environmental outcomes (Iyer 2011; Winter and Knemeyer 2013).
- *Environmental Uncertainties (EU)*: Uncertainty is one of the main impediments to the decision-making process in business organisations. In the SCC context, environmental uncertainty is an integral condition of cross-organisational communication as the stream of goods, information and knowledge includes numerous interaction modes and activities across SC partners, making it challenging to anticipate the underlying relationships of events (Wu and Hassis 2013). In such unexpected environments, organisations and their SC partners are required to develop appropriate strategies and capabilities, and share core knowledge in order to understand and adapt to ecological changes (Iyer 2011). The external factors related to SC environmental uncertainty are strategic in nature, e.g. modifications in product, service or process technology, opponent performance in the market and changes in customer demands. As a result, environmental uncertainty can cause substantial interruptions along the SC, compromising an organisation's capacity to continue functioning. Similarly, these disruptions and volatile market conditions could possibly effect the focal organisations in developing their competitive and SC strategies, as well as in realising the benefits of supply chain collaborative ventures. However, the empirical findings shown by Merschmann and Thonemann (2011) specify that fitting SC flexibility to environmental uncertainty may enhance overall business performance.
- *Embodied Energy (EE)*: The focus of sustainable SCs has been to incorporate environmental necessities into product manufacturing as a result of growing ecological needs from customers, SC partners and government regulations. Over the years, academics and practitioners have witnessed the need to include environmental considerations in inter-organisational SC operations, particularly for emission-intensive activities such as universal transportation and shipping of products (Arıkan, Fichtinger, and Ries, 2014; Cervellon and Wernerfelt 2012). For instance, the energy required while constructing buildings or highways starts

amassing long before the buildings or highways construction resources are on-site. The energy essential to extract, produce, and transport construction resources is equal to the sum total known as embodied energy (Chen, Preston, and Xia, 2013; Kudla and Klaas-Wissing 2012). Embodied energy is thus simply understood as the whole energy utilised during the product development life cycle, i.e. from material extraction to the product being consumed until exhausted. Manufacturing organisations can thus scrutinise and enhance the environmental performance of their energy products by evaluating environmental effects throughout the product development life cycle. However, the intricacy of such an examination process can be an arduous activity as it requires time, expert knowledge and huge investment.

The above-mentioned conceptual findings on the dimensions and the individual factors seem to apply well to the context of GrSCC. All these factors could significantly enhance the understanding towards implementing green supply chain collaborative ventures.

4. Visualisation and analysis

As described in Section 3, the authors constructed a matrix of the consolidated factors from the review of extant literature on knowledge management, SCC and green supply chain management, where keywords were chosen from the factors as shown in Table 9.

A range of causal fuzzy weights, as shown in Table 10, were then applied to the pairwise comparisons between each factor (hence fuzzy node) in the matrix, in a row and column fashion. The final pairwise comparison was a result of multiple iterations in order to ensure a stable and rational set of causal relationship could be interpreted within the context of the research. Applying the weightings to each of the pairwise relationships subsequently led to the generation of the fuzzy weight matrix shown in Table 11.

The pairwise combinations and relationships were systematically assessed and grounded through expert responses and further grounded by the researchers. The initial FCM matrix therefore describes all of the causal interrelationships between the consolidated factors identified from the literature. In assigning the fuzzy weightings the authors took the following factors into account as a basis for evaluating what the weights may be: loss of competitive advantage, commercial confidentiality and intellectual property rights (for example, sharing all information and being totally transparent within and across supply chain tiers may be of detriment to some or all partners as competitive edge may be lost as a result of loss of purchasing power, etc.); dimensions of integration from process throughout the supply chain (for example, increased integration may not necessarily imply increased efficiency or effectiveness due to the scale and constraint effects of enabling resources, processes and/or technology); affiliation/trust (for example, while close working relationships may benefit supply chain collaborators, there may be little or no additional improvement to process, intra-chain or extra-chain benefits – rather, ongoing effort would need to be maintained possibly at the expense of chain-wide relationships,

Table 9. Pairwise combinations of GrSCC factors based n keywords.

Dimension	Code	Description	SSCP	MCS	ESCC	SCT	SCI	SCCD	IT	SCP	SCS
STRAT	SSCP	Strategic SC partnership	–	Partnership – Mgmt. Commitment	Partnership – Comms	Partnership – Transparency	Partnership – Integration	Partnership – Collaboration	Partnership – Trust	Partnership – SC Performance	Partnership – Sustainability
MAN	MCS	Mgmt. commitment and support		–	Mgmt. Commitment – Comms	Mgmt. Commitment – Transparency	Mgmt. Commitment – Integration	Mgmt. Commitment – Collaboration	Commitment – Trust	Commitment – SC Performance	Commitment – Sustainability
ORG	ESCC	Effective SC comms			–	Effective Comms – Transparency	Effective Comms – Integration	Effective Comms – Collaboration	Effective Comms – Trust	Effective Comms – Performance	Effective Comms – Sustainability
OP	SCT	SC transparency				–	SC Transparency – Integration	SC Transparency – Collaboration	SC Transparency – Trust	SC Transparency – Performance	SC Transparency – Sustainability
TECH	SCI	Supply chain integration					–	SC Integration – Collaboration	SC Integration – Trust	SC Integration – SC Performance	SC Integration – Sustainability
TECH	SCCD	Supply chain collaboration design						–	SC Collab Design – Trust	SC Collab Design – Performance	SC Collab Design – Sustainability
HUMSOC	IT	Interpersonal trust							–	Interpersonal Trust – Performance	Interpersonal Trust – Sustainability
FIN	SCP	Supply chain performance								–	SC Performance – Sustainability
ENV	SCS	Supply chain sustainability									–

Table 10. Fuzzy causal weights.

Causal weight	Sign	Value
Never	−−−	−1.00
Not as much	−−	−0.67
Often	−	−0.33
Neutral		0
Sometimes	+	0.33
Very much	++	0.67
Always	+++	1.00

to keep 'local' affiliations well supported); product life cycle management factors (for example, dealing with built-in obsolescence and/or waste disposal costs and processes may incur a range of benefits and hindrances to supply chain participants depending on where in the chain they may be placed – and potentially, what level of influence they may have on wider supply chain decision-making).

Analysing the representation of these interrelationships further, Table 11 shows the adjacency values (A) for the FCM based upon the ordinal row and column sums.

Noting principles of matrix cardinality and rank, the locally influential nodes of the initial FCM (based upon the ranking of the rows of the FCM) are IT ≥ MCS ≥ SCP ≥ SSCP ≥ SCCD ≥ ESCC ≥ SCI ≥ SCS ≥ SCT (thus 6.334 ≥ 5 ≥ 5 ≥ 4.334 ≥ 4.333 ≥ 4.001 ≥ 2.667 ≥ 2 ≥ 1.334). Hence, these are the locally influential nodes. Similarly, the globally influential nodes of the FCM (based upon the ranking of the columns of the FCM) are IT ≥ SCCD ≥ SCI ≥ SCT ≥ MCS ≥ SCP ≥ SSCP ≥ SCS ≥ ESCC (thus 6 ≥ 5.334 ≥ 4.334 ≥ 4.334 ≥ 4 ≥ 3.333 ≥ 2.668 ≥ 2.666 ≥ 2.334). Moreover, the reachability matrix, R, can also be calculated from the initial FCM matrix. This matrix reflects the existence of indirect or deductive relationships, characterised by equation, $R = A + A^2 + A^3$ where the matrix A is based upon Table 11 (as defined by Nozicka, Bonham, and Shapiro 1976). Reachability in terms of graph theory can, therefore, be defined as the total number of possible paths from any one node (or point) to any other within a (directed) digraph. This identifies the total number of linkages from each node to all others – and therefore ultimately suggests the strength or *interconnectedness* of any single node with any other node (hence the interconnectedness from one factor to all other GrSCC factors, if they are connected). The reachability, R, is then computed as shown in Table 12.

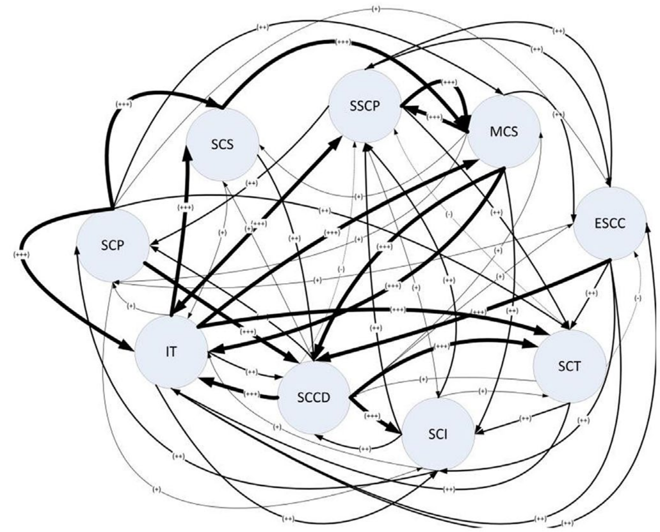

Figure 3. FCM diagram (from Initial Matrix).

The row sum of R for each row in Table 12 specifies the total interval of membership degrees of concepts reachable from a given node (i.e. local reachability via a given fuzzy node); while the column sum for a given column gives the total interval of membership degrees of concepts from which any node can be reached (i.e. global reachability via a given fuzzy node). Hence,

Table 11. Initial FCM matrix and related adjacency values.

	SSCP	MCS	ESCC	SCT	SCI	SCCD	IT	SCP	SCS	Σ
SSCP	0	1	0.667	0.667	0.333	0	1	0.667	0	4.334
MCS	1	0	0.667	0	0.667	1	1	0.333	0.333	5.000
ESCC	0.667	0	0	0.667	0.667	1	0.667	0.333	0	4.001
SCT	−0.333	0	−0.333	0	0.667	0.333	0.667	0.333	0	1.334
SCI	0.667	0	0	0.333	0	0.667	0.333	0.667	0	2.667
SCCD	−0.333	0.333	0.333	1	1	0	1	0.667	0.333	4.333
IT	1	1	0.667	1	0.667	0.667	0	0.333	1	6.334
SCP	0	0.667	0.333	0.667	0.333	1	1	0	1	5.000
SCS	0	1	0	0	0	0.667	0.333	0	0	2.000
Σ	2.668	4.000	2.334	4.334	4.334	5.334	6.000	3.333	2.666	

Table 12. Initial FCM and reachability values for GrSCC factors from the literature.

	SSCP	MCS	ESCC	SCT	SCI	SCCD	IT	SCP	SCS	Σ
SSCP	0.000	3.000	1.409	1.409	0.481	0.000	3.000	1.409	0.000	10.71
MCS	3.000	0.000	1.409	0.000	1.409	3.000	3.000	0.481	0.481	12.78
ESCC	1.409	0.000	0.000	1.409	1.409	3.000	1.409	0.481	0.000	9.12
SCT	−0.259	0.000	−0.259	0.000	1.409	0.481	1.409	0.481	0.000	3.26
SCI	1.409	0.000	0.000	0.481	0.000	1.409	0.481	1.409	0.000	5.19
SCCD	−0.259	0.481	0.481	3.000	3.000	0.000	3.000	1.409	0.481	11.59
IT	3.000	3.000	1.409	3.000	1.409	1.409	0.000	0.481	3.000	16.71
SCP	0.000	1.409	0.481	1.409	0.481	3.000	3.000	0.000	3.000	12.78
SCS	0.000	3.000	0.000	0.000	0.000	1.409	0.481	0.000	0.000	4.89
Σ	8.30	10.89	4.93	10.71	9.60	13.71	15.78	6.15	6.96	

Table 13. Scenarios used for the FCM of GrSCC factors.

Scenario	SSCP	MCS	ESCC	SCT	SCI	SCCD	IT	SCP	SCS
1	−0.167	0.667	0.667	0.667	0.834	0.000	0.834	0.834	0.500
2	0.000	0.667	0.000	0.000	0.000	0.500	0.667	0.500	0.000

Table 14. Comparison of adjacency and reachability values for GrSCC factors across all FCMs.

	Local influence (East–West, FCM matrix row, cardinality)			Global influence (North–South, FCM matrix column, cardinality)		
	Initial FCM[a]	Scenario 1[b]	Scenario 2[c]	Initial FCM[d]	Scenario 1[e]	Scenario 2[f]
GrSCC Factors (Fuzzy Nodes)	*R*	*R*	*R*	*R*	*R*	*R*
SSCP	10.71	−8.00	23.79	8.3	8.00	1.15
MCS	12.78	24.00	−6.74	10.89	4.00	5.48
ESCC	9.12	−8.00	−6.2	4.93	8.00	6.08
SCT	3.26	−8.00	23.97	10.71	8.00	1.09
SCI	5.19	24.00	12.89	9.6	4.00	3.03
SCCD	11.59	24.00	−7.99	13.71	4.00	4.26
IT	16.71	−8.00	2.37	15.78	8.00	3.54
SCP	12.78	−8.00	0.45	6.15	8.00	4.57
SCS	4.89	24.00	−7.8	6.96	4.00	5.52
$\bar{x}$	9.67	6.22	3.86	9.67	6.22	3.86
$\sigma(x)$	4.19	15.90	12.41	3.34	1.99	1.72

[a]IT ≥ SCP ≥ MCS ≥ SCCD ≥ SSCP ≥ ESCC ≥ SCI ≥ SCS ≥ SCT.
[b]SCCD ≥ SCS ≥ SCI ≥ MCS ≥ SCP ≥ IT ≥ ESCC ≥ SSCP ≥ SCT.
[c]SCT ≥ SSCP ≥ SCI ≥ IT ≥ SCP ≥ ESCC ≥ MCS ≥ SCS ≥ SCCD.
[d]IT ≥ SCCD ≥ MCS ≥ SCT ≥ SCI ≥ SSCP ≥ SCS ≥ SCP ≥ ESCC.
[e]SSCP ≥ ESCC ≥ SCT ≥ IT ≥ SCP ≥ SCI ≥ MCS ≥ SCS ≥ SCCD.
[f]ESCC ≥ SCS ≥ MCS ≥ SCP ≥ SCCD ≥ IT ≥ SCI ≥ SSCP ≥ SCT.

Table 15. Resulting FCM matrix – Scenario 1.

	SSCP	MCS	ESCC	SCT	SCI	SCCD	IT	SCP	SCS
SSCP	0.000	−1.000	−1.000	−1.000	−1.000	−1.000	−1.000	−1.000	−1.000
MCS	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
ESCC	−1.000	−1.000	0.000	−1.000	−1.000	−1.000	−1.000	−1.000	−1.000
SCT	−1.000	−1.000	−1.000	0.000	−1.000	−1.000	−1.000	−1.000	−1.000
SCI	1.000	1.000	1.000	1.000	0.000	1.000	1.000	1.000	1.000
SCCD	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000	1.000
IT	−1.000	−1.000	−1.000	−1.000	−1.000	−1.000	0.000	−1.000	−1.000
SCP	−0.999	−1.000	−1.000	−1.000	−1.000	−1.000	−1.000	0.000	−1.000
SCS	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000

the table indicates the rank for centrality for dependency from any given node is IT ≥ SCP ≥ MCS ≥ SCCD ≥ SSCP ≥ ESCC ≥ SCI ≥ SCS ≥ SCT (hence, 16.71 ≥ 12.78 ≥ 12.78 ≥ 11.59 ≥ 10.71 ≥ 5.19 ≥ 4.89 ≥ 3.26); and for dependency across the whole FCM is IT ≥ SCCD ≥ MCS ≥ SCT ≥ SCI ≥ SSCP ≥ SCS ≥ SCP ≥ ESCC (hence, 15.78 ≥ 13.71 ≥ 10.89 ≥ 10.71 ≥ 9.60 ≥ 8.30 ≥ 6.96 ≥ 6.15 ≥ 4.93).

Thus, clearly IT (supply chain interpersonal trust) has a local as well as global tendency to affect interaction with other nodes adjacent to it; closely followed by SCP locally, and SCCD globally within the FCM. The overall FCM that describes the relationships between the GrSCC factors can therefore be constructed from Table 11 and is shown in Figure 3. Subsequently, the FCM in this figure shows the causal relationship between each GrSCC factor (hence fuzzy node) where the strength of the relationship is determined by the thickness of the line connecting each factor. A thicker line/thinner line means strong and weak causal relationships, and a value of 0 or no line indicates no relationship.

This shows the range of complex inter-connections and identified relationships as identified and demonstrated from the literature by the authors as thus far described. Moreover, this directed graph visually shows the strength of interconnections between the various GrSCC concepts, wherein particularly strong causal relationships can be seen to be directed towards or from technological (SCCD), human-sociological (interpersonal trust, IT) and environmental (SCS) dimensions of the literature.

The only negative causal relationships exist between SCT and SSCP; SCT and ESCC; and SCCD and SSCP. Hence, overall, this FCM representation along with the analysis of the strength and directionality of the relationships through the assessment of reachability of nodes, begins to provide an insight into the implicit drivers of green supply chain management as derived from the literature which, the authors wish to note, are of interest as they are not necessarily those factors which are automatically viewed of as being core to green and carbon neutral supply chains.

As noted, two scenarios (in this case, being representative green supply chain events) were then applied to this FCM (as the source input vector, C_i^t) to explore what and how these factors may change. Hence, Table 13 denotes the respective scenarios that are now explored in more detail, while Table 14 shows the computed adjacency and reachability values for GrSCC factors

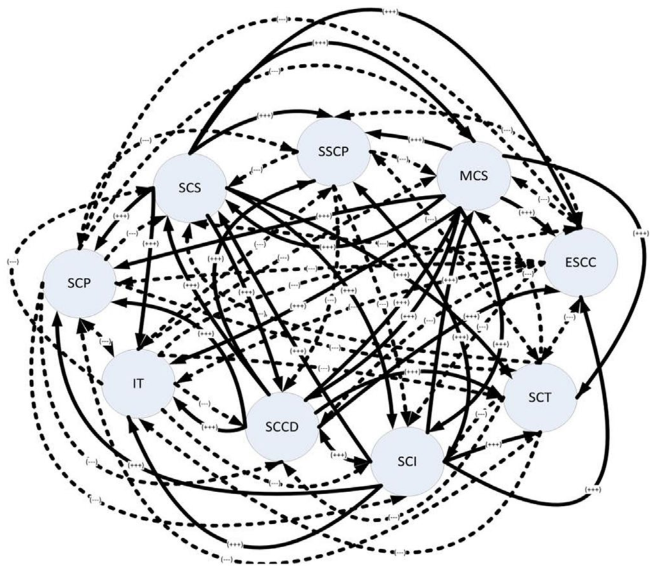

Figure 4. FCM diagram of Scenario 1.

across all FCMs created by the authors. Both these tables will now be referred to in the following sub-sections.

For each scenario, the key factors shown were identified from the FCM matrix in Table 11 on a row and column-averaged basis. Each scenario (starting vector) was 'fed' into the FCM simulation as a scenario to see how the FCM – hence inter – relationships – would change, given a different starting set of priorities.

4.1. Scenario 1: collaborating to become greener

The authors chose to interpret this scenario, in terms of viewing the manner in which collaborative design and associated source, make, deliver decisions may be perceived within a supply chain attempting to adopt 'green' SCC practices. Hence, for the purposes of this scenario, the authors chose the SCCD elements from the FCM matrix developed earlier. The values for this scenario were therefore calculated as an average of the SCCD row and column values from Table 11.

The resulting FCM matrix based on FCM calculation is shown in Table 15 with the FCM in Figure 4.This shows a much changed set of interrelationships between the given GrSCC factors. As can be seen from Table 15, the proximity of relationships locally and globally varies between extremely positive causal links and extremely negative causal links. Between nodes in the FCM, the results of the reachability analysis in Table 14 (i.e. a computation of matrix R for each FCM) show that SCS is more closely related to SCCD than SSCP and SCT.

This is as signified by the superscript 'b' in the table (hence the reachability path, SCCD ≥ SCS ≥ SCI ≥ MCS ≥ SCP ≥ IT ≥ ESCC ≥ S SCP ≥ SCT). Likewise, within the entire FCM for Scenario 1, SSCP is more closely related to ESCC and SCT than SCS and SCCD – signified by the superscript 'e' in the table (hence the reachability path, SSCP ≥ ESCC ≥ SCT ≥ IT ≥ SCP ≥ SCI ≥ MCS ≥ SCS ≥ SCCD).

Furthermore, in comparing the resulting FCM of this scenario with the initial FCM, nine positive causal relationships have emerged as new relationships as a result of running this scenario which were not in existence before. These are: two strategic dimension factors (SSCP-SCCD and SSCP-SCS); two human-sociological dimension factors (ESCC–MCS and ESCC-SCS); two operational dimension factors (SCT-MCS and SCT-SCS); two technological dimension factors (SCI-ESCC and SCI-SCS); and one financial dimension factor (SCP-SSCP). In contrast, seven negative causal relationships also emerged as new relationships: two operational dimension factors (SCT-SSCP and SCT-ESCC) and five environmental dimension factors (SCS-ESCC, SCS-SSCP, SCS-SCT, SCS-SCI and SCS-SCP). This presents the fact that although SCT and partnerships and risks identified with SCS may be concerns that hinder GrSCC collaborative efforts, a strong combination of strategic, human–sociological, technology, operations and financial dimensions may contribute positively to such initiatives instead. Primarily, strategic partnerships, collaboration and transparency (as identified through the reachability matrix analysis above) – are closely underpinned by effective communication and integration strategies. This, therefore, supports the emergent literature in the field which suggests that a combination of approaches to adopting green/carbon neutral strategies within the field, may have a higher chance of success than solely environmental or sustainability-driven arguments.

4.2. Scenario 2: incentive structures for green initiatives

As in Scenario 1, the authors chose a given factor from the FCM matrix in Table 11 – in this case this was chosen to be SCS. As in Scenario 1, the authors generated the input vector to the FCM from an average of row and column values of SCS derived from Table 11 (this is also as shown in Table 13). The resulting FCM matrix is shown in Table 16 with the FCM as shown in Figure 5.

Once again a perusal of the reachability components in Table 14 show that SCT is more closely related to SCCP than to SCS and SCCD. This is as signified by the superscript 'c' in the table (hence the reachability path, Local SCT ≥ SSCP ≥ SCI ≥ IT ≥ SCP ≥ ESCC ≥ MCS ≥ SCS ≥ SCCD). Across the entirety of the FCM in this case, ESCC is more closely related to SCS than to SCCP and SCT.

This is as signified by the superscript 'f' in the table (hence the reachability path, ESCC ≥ SCS ≥ MCS ≥ SCP ≥ SCCD ≥ IT ≥ SC I ≥ SSCP ≥ SCT). Furthermore, in comparing the resulting FCM of this scenario with the initial FCM, eight positive causal relationships have emerged as new relationships which are: two strategic dimension factors (SSCP-SCCD and SSCP-SCS); two operational dimension factors (SCT-MCS and SCT-SCS); three technological dimension factors (SCI-MCS, SCI-ESCC and SCI-SCS); and one financial dimension factor (SCP-SSCP).

Similar to Scenario 1, eight negative causal relationships have also emerged: one management dimension factor (MCS-SCT); two organisational dimension factors (ESCC-MCS and ESCC-SCS); and five environmental dimension factors (SCS-ESCC, SCS-SSCP, SCS-SCT, SCS-SCI and SCS-SCP). Here, the interpretation that can be presented is that, once again, a range of strategic, operational, (largely) technological and financial dimensions can provide positive causal support for incentive structures for green SCM initiatives. This is as opposed to the range of purely management, organisational and environmental dimension arguments which may have a negative causal influence on incentive structure uptake.

As in Scenario 1, if we now continue to combine the scenario interpretation with the analysis of the reachability from Table 14, this suggests that in this scenario, SCT and ESCC are dominant

Table 16. Resulting FCM matrix – Scenario 2.

	SSCP	MCS	ESCC	SCT	SCI	SCCD	IT	SCP	SCS
SSCP	0.000	0.991	0.996	0.996	0.998	0.999	0.991	0.996	0.999
MCS	−0.965	0.000	−0.934	−0.770	−0.934	−0.965	−0.965	−0.875	−0.875
ESCC	−0.918	−0.720	0.000	−0.918	−0.918	−0.957	−0.918	−0.846	−0.720
SCT	1.000	1.000	1.000	0.000	0.999	0.999	0.999	0.999	1.000
SCI	0.538	0.853	0.853	0.733	0.000	0.538	0.733	0.538	0.853
SCCD	−0.997	−0.999	−0.999	−1.000	−1.000	0.000	−1.000	−1.000	−0.999
IT	−0.011	−0.011	0.311	−0.011	0.311	0.311	0.000	0.575	−0.011
SCP	0.518	−0.093	0.236	−0.093	0.236	−0.402	−0.402	0.000	−0.402
SCS	−0.983	−0.998	−0.983	−0.983	−0.983	−0.995	−0.991	−0.983	0.000

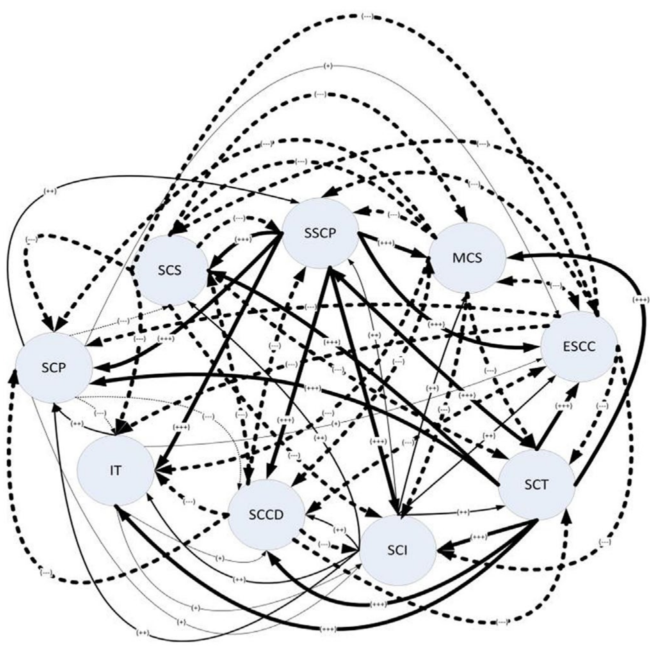

Figure 5. FCM diagram of Scenario 2.

factors. In this sense, dominant is defined as having the most number of available paths or connections to other GrSCC concepts. Furthermore, incentives for such GrSCC initiatives may be further supported through SCCP and SCS drivers as well. Once again, however, this can also be interpreted in terms of the furthest reachability factors (from cases c and f in Table 14) – which highlight factors of management commitment/support and supply chain integration, which may not be as causally strong to support the incentivisation of green initiatives alone. This supports the view of contemporary social psychologists such as Pink (2011), who suggests that direct motives to influence people to achieve shared organisational goals (such as direct and indirect financial incentives) have an overall negative effect on how those goals are achieved. For these reasons, incentivising supply chain members to be greener may not necessarily be driven by the financial (dis) benefits of engaging in green policies – rather by understanding the benefits of increased transparency and the integration through adoption of greener supply chain practices, which may be a greater influencing factor than other factors alone.

5. Conclusions

The contribution of this paper is the identification of the factors (i.e. proposed in Figure 2) enabling GrSCC. This research has identified and established the interrelationships between these factors associated with creating GrSCC. In light of the observations and analyses of the literature (as reported in Section 3), the authors were able to identify and then classify 24 factors based on strategic, managerial, organisational, operational, technological, human-sociological, financial and environmental dimensions. In doing so, the authors have been able to provide a descriptive classification that will allow others to distinguish aspects associated with GrSCC. This created the need to then understand the interrelationships between the identified factors. In addressing this research challenge, the authors then applied weighted relationships to each factor in turn, in order to allow a matrix of interrelationships to be visually developed, by way of the FCM technique.

The findings and analysis have shown that the FCM technique can be a useful tool to explore the inherent interrelationships between competing but mutually related concepts. As such, two scenarios were developed by the authors. These encompassed approaches to collaborating to become greener; and also the development of incentive structures for green initiatives, respectively. In both scenarios, the resulting, and hence, new matrix of inter-relationships were generated and the updated FCM diagram produced. The resulting cognitive mappings showed a granularity in positive as well as negative causal relationships between the key GrSCC factors. In the context of the research presented, the authors (through the analysis undertaken) were able to identify the following prioritised order of GrSCC factors as:

- Technological,
- Strategic,
- Operational,
- Organisational and
- Financial factors.

The resulting managerial implications are that the approach utilised in this paper highlights a technique for management to explore and then to prioritise and assess the scope and impact of GrSCC strategies (as is based upon the review and extraction of key factors from the literature). As a result, new strategies underpinned by knowledge management will give supply chain partners the confidence that every effort is being adopted to reduce dependencies on carbon producing supply chain components, thus promoting sustainable energy futures and carbon-efficient production. The identification of those factors that promote GrSCC through this paper now provides companies with the means by which they can seek a market position that offers them differentiation against a backdrop of efficient and effective sustainable operations management.

5.1. Limitations of the current research

Much care and attention has been taken by the authors of this paper to ensure that the research findings have sufficient content, context and contribution to both the academic and practitioner communities. While the literature review was underpinned through a rigorous selection of 255 contextual papers on SCC there remains scope to broaden this further to include further paper from the 18,000 articles available through the SCOPUS database. While the authors remain confident around the assumptions and causal weights described in Table 10 and then applied in Table 11, there is always the potential of data bias that if significant enough, might impact the causal relationships presented in Figure 4 and Figure 5.

5.2. Future research directions

During the development of any research design process, there is always opportunity to enhance the veracity of data collection and therefore conclusions through enhanced iterative evaluation. While the authors regard this as a further enhancement, it is more to mitigate any minimal bias that may be present than to question the results of the research presented. Such approaches could include the using a Delphi technique to allow cross-checking of the fuzzy weights used to construct the pear wise comparison. There is also an opportunity to extend the research domain itself, through including aspects such as food waste management within the supply chain (Irani and Sharif 2016; Sharif and Irani 2016) or Humanitarian logistics (Heaslip, Sharif, and Althonayan 2012).

Disclosure statement

No potential conflict of interest was reported by the authors.

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