Green supply chain performance measurement using the analytic hierarchy process: a comparative analysis of manufacturing organisations

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1. Introduction

Today's organisations face pressure to enhance sustainable behaviour from several sources, including regulations, consumers, customers, stakeholders, fund investors, environmental advocacy groups, employees and unions (Hall 2000). An organisation may pass these pressures on to its suppliers, thus sharing both risk and responsibility. Behind the pressures to green the supply chain and optimise the initial investments, there is a huge opportunity to reduce costs, simplify processes and improve performance across the supply chain (Angell and Klassen 1999, Sarkis 2003, Kleindorfer et al. 2005, Corbett and Klassen 2006, Vachon and Klassen 2008). Indeed, environmental operations management may improve operational performance (Gupta and Sharma 1996). The US Environmental Protection Agency (EPA) shows that proactive management of suppliers' environmental performance, as practised by Hewlett-Packard, can lead to product and process simplification, more efficient resource utilisation, product quality improvement, liability avoidance and an enhanced leadership image (EPA 2000). Sarkis (2003) says that private organisations such as Hewlett-Packard, IBM, Xerox and Digital Equipment Corporation have introduced some form of initiative for greening their supply chains, including the integration of suppliers, distributors and reclamation facilities. IBM has tried to propose a carbon heat map to optimise carbon impact across the supply chain components (Butner et al. 2008).

An extended view of environmental management in the supply chain is justifiable due to the transfer of environmental impacts within outsourcing practices as well as to the different legislation of different countries (Brown 2008). In connection with outsourcing trends, Child and Tsai (2004) explain that companies have to deal with different institutional constraints in different countries that could affect their strategy and the results of their behaviour (environmental proactive or reactive attitudes). Van Hoek (2002) highlights the need for environmental initiatives to comply with market requirements (upstream supply chain) as well as other regulations, and also uses Reinhardt's (2000) approach to discuss the possible advantages of economies of scope. For van Hoek (2002), an environmentally friendly supply chain would need to consider all activities within the chain: raw material acquisition, inbound logistics, transformation, outbound logistics, marketing and after-sales. Nevertheless, due to supply chain extension and complexity, a company would need to think strategically about the greening of its supply chain to increase the chances of effective implementation.

If on one hand, companies look to reduce risk and environmental impact and to enhance performance through green supply chains (GSCs), on the other hand, this increases the complexity of managerial decisions as well as performance measurement. It is stated increasingly often that performance measurement is a pillar of the effectiveness of supply chains (Bond 1999, Liang et al. 2006). For Hervani et al. (2005), the basic purposes of GSC performance measurement (GSCPM) are: external reporting (to justify charging or paying economic rent), internal control (to manage the business better) and internal analysis (to understand the business better and continuously improve). These are the fundamental motives that drive the development of frameworks for business performance measurement.

It is important to consider the scope (Agndal and Nilsson 2010) as well as the interrelationships of the various measures (Ittner et al. 1999, Hervani et al. 2005, Mahama 2006). In fact, measures for GSCs should include economic and environmental indicators. Zhu et al. (2007a) have looked at the Chinese automotive industry through a set of performance measures, which include traditional economic (e.g. cost and investment) and environmental measures (energy use, air emissions, water and solid waste, etc). Tsoulfas and Pappis (2006) have identified and integrated environmental principles for the design and operation of supply chains. In a further study, these authors (Tsoulfas and Pappis 2008) have listed a broader range of environmental performance indicators for supply chain management decisions, analysing the supply chain from product design to final disposal. These articles are in line with the recommendations of ISO 14031 (2002), which presents a useful guide for environmental performance indicators. We point out the need for a holistic view of performance, which looks both at internal factors of performance and at the external factors that affect the business. Indeed, authors like Zhu et al. (2007a) reveal that external relationships in GSC management may receive less attention than might be expected. Considering the complexity involved in making a supply chain leaner and greener, quantitative methods can be useful (Kainumaa and Tawarab 2006) in deciding what to do first (Kleindorfer et al. 2005, Orsato 2006) or in assessing the value of specific initiatives to the overall greenness of the supply chain (Zhu et al. 2007b). Handfield et al. (2002) use a multi-attribute utility theory method to assess the environmental practices of suppliers. A similar method is adopted by Kainumaa and Tawarab (2006), who attempt to appraise supply chains over a product's life cycle. Sarkis (2003) introduces an analytic network process-based approach. However, the main pitfall for present techniques is that they are too internally focused, as they measure the performance of individual organisations and do not assess the GSC performance of the entire supply network. So far, the literature shows there is a panoply of performance measures for GSCs (Zhu et al. 2007a, 2008a). Our literature review shows numerous types of measures – economic, social and environmental (Olugu et al. 2010). The profusion of performance measures in the literature hides a lack of integrated approaches for conducting performance measurement in the GSC (Zhu et al. 2008a). Hence, this article proposes an innovative framework for GSCPM across the upstream supply chain, internal operations and downstream customers. This framework also integrates organisational decision levels (strategic, tactical and operational) using the analytic hierarchy process (AHP). We field-test the framework on three selected organisations in the manufacturing industry. The GSC performance of each company is measured and benchmarked.

This article is organised as follows: Section 2 demonstrates the methodology. Section 3 introduces the relevant constructs for GSC performance measures using our literature review. Section 4 demonstrates the proposed framework for performance measurement. Section 5 shows how the framework applies in three different companies in the UK. Section 6 concludes this article.

2. Methodology

This research adopts both primary and secondary methods of data collection. First, we reviewed the literature to identify holistic constructs for GSC performance. Leading journals of operations management were searched using key words such as GSC performance, environmental performance and sustainability criteria, covering publications from mid-1990 till date (including articles in press). Second, the constructs were collated to form a logical structure. In this study, the constructs were organised across supplier relationship management, internal supply chain management and customer relationship management as well as across the strategic, tactical and operational decision levels. Third, we asked a few researchers in the GSCPM field to comment on the proposed hierarchical GSCPM framework. Their comments were incorporated through amendment in the structure of the framework. Fourth, three organisations were selected from the UK manufacturing industry to apply the proposed framework and demonstrate its effectiveness. This study adopts the AHP for measuring performance. Here we briefly explain the AHP.

The AHP, developed by Saaty (1980), provides a flexible and easily understood way of analysing complicated problems. It is a multiple-criteria decision-making technique that allows subjective as well as objective factors to be considered in decision making. The AHP allows the active participation of decision-makers in reaching agreement, and gives managers a rational basis on which to make decisions. AHP is based on the following three principles: decomposition, comparative judgement and synthesis of priorities.

As a theory of measurement for dealing with quantifiable and intangible criteria, AHP has been applied to numerous areas, such as decision theory and conflict resolution (Vargas 1990). AHP is a problem-solving framework and a systematic procedure for representing the elements of any problem (Saaty 1983). The detailed steps for the AHP application have been demonstrated elsewhere (Saaty 1980).

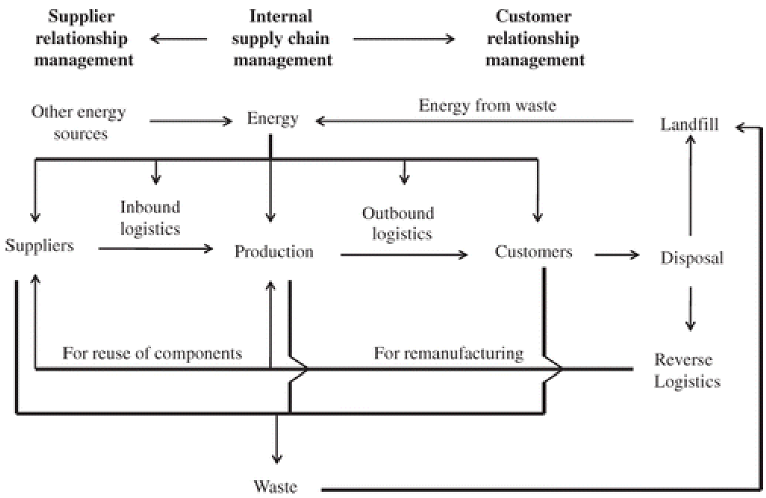
Performance measurement is usually a team effort. The AHP is one available method for forming a systematic framework for group interaction and group decision making (Saaty 1982). Dyer and Forman (1992) describe the advantages of AHP in a group setting as follows: (1) both tangibles and intangibles, individual values and shared values can be included in an AHP-based group decision process; (2) the discussion in a group can be focused on objectives rather than alternatives; (3) the discussion can be structured so that every factor relevant to the discussion is considered in turn and (4) in a structured analysis, the discussion continues until all relevant information from each individual member in a group has been considered and the decision is chosen by consensus. A detailed discussion on conducting AHP-based group decision-making sessions, including suggestions for assembling the group, constructing the hierarchy, getting the group to agree, coping with inequalities of power and concealed or distorted preferences, and implementing the results, can be found in Saaty (1982) and Golden et al. (1989).

3. The relevant constructs for GSCPM

GSC management practices cover activities, such as assessing the environmental performance of suppliers, addressing packaging and waste issues, developing eco-friendly products and reducing greenhouse gas emissions. Various terminologies are used to define a GSC, such as 'sustainable supply chain' (Linton et al. 2007), 'socially responsible supply chain' (Salam 2009) and 'environmental supply chain' (van Hoek, 2002; Beamon 2005). Regardless of the terms used, the concept of GSCs brings environmental and sustainability issues within the buyer-supplier relationship. According to Gilbert (2001), greening the supply chain is the process of incorporating environmental criteria or concerns into organisational purchasing decisions and long-term relationships with suppliers. Geffen and Rothenberg (2000) discuss how suppliers can contribute in environmental innovation. This is because GSC practices include a range of initiatives across activities such as transportation, material handling, manufacturing, storage, distribution, packaging, purchasing and transfer of technologies to suppliers. Gilbert (2001) supports the idea of two types of initiatives to stimulate the greening supply chain. The first involves improving coordination with suppliers on environmental efforts to facilitate the development of greener products. The second type involves demanding improved environmental performance at a supplier's operating facilities, for example by requiring the supplier to obtain ISO 14000 certification or achieve a set of performance standards. Both types may affect the way the company selects and manages suppliers. The decision to buy a greener product from suppliers may affect the costs, quality or flexibility of supply chains. Building close relationships with good operational partners is crucial in implementing environmental initiatives (Nawrocka et al. 2009). Some authors also include reverse logistics as part of greening the supply chain (Sarkis 2003, Kleindorfer et al. 2005).

It becomes obvious that in today's organisations GSC performance depends on sustainable management of customer relationships, internal supply chains and supplier relationships, as increasingly organisations operate globally. Moreover, there is evidence that leading companies across the world outsource many business processes. While effective environmental management within a company's own organisation is important, the green operations of upstream suppliers and downstream customers are equally important in order to achieve sustainability in this turbulent and challenging economic environment. Figure 1 shows a typical manufacturing process, involving both upstream suppliers and downstream customers. It also depicts sustainable practices (e.g. reverse logistics, waste disposal, energy usage). Hence, the major constructs for GSC performance are associated with the environmental practices and performances of customers, suppliers and the company in question.

Figure 1. A typical closed loop supply chain of a manufacturing company.



In fact, arriving at possible sustainable solutions is a complex undertaking. One reason is that reducing environmental impacts at specific points in a supply chain, for example reducing energy consumption in the usage phase, may be worth little or nothing if other changes also occur, such as increasing energy consumption in manufacturing and recycling (Mildenberger and Khare 2000). Given this complexity, the question of how to integrate environmental issues in the company's activities needs continuous reflection. Ilgin and Gupta (2010) emphasise the importance of reviewing and discussing the development of environmentally conscious manufacturing and product recovery in the literature. Angell and Klassen (1999) say that when the literature on environmental management in operations is broadly examined and synthesised, two dominant perspectives emerge: the external constraint and the component perspectives. The first, which historically dominated much of the operations management literature, considers environmental performance requirements to be an externally imposed constraint on the operating system (i.e. ISO 14001). In contrast, the second perspective recognises environmental issues as legitimate operating factors, with implications for operations strategy. This article adopts the component perspective. It integrates the potential to use environmental issues to gain influence and competitive advantage both internally and externally (Angell and Klassen 1999).

Beyond recognising the significant impact of environmental regulation (Porter and van der Linde 1995, Smith and Crotty 2008), this article highlights the need for a holistic perspective on GSC management as well as a new way of thinking about environmental improvements (Beamon 2005, 2008, Haskins 2006, Orsato 2006, Iraldo et al. 2009). This is in line with the need for corporations to set holistic objectives in greening their supply chains. Indeed, companies green their supply chains to (1) control issues of risk and performance in supplier management, where they place emphasis on avoiding risk from suppliers that perform poorly against set environmental and social standards; and (2) proactively seek to source sustainable products from suppliers (Seuring and Müller 2008). Therefore, to measure GSC performance, organisations must review their overall environmental practices and sustainable performances (Hervani et al. 2005, Mentzer et al. 2007, Zhu et al. 2007a, Tsoulfas and Pappis 2008). The design of an appropriate performance measurement system provides vital support in strategy development, decision making and performance improvement (Chan and Qi 2003). Several companies have failed to integrate their supply chain because they have deployed inadequate measures and metrics (Mentzer et al. 2007). The appropriateness of these measures is crucial for achieving sustainable development (Wong and Wong 2008, van den Abbeele et al. 2009, Olugu et al. 2010). While environmental practices are leading (proactive) factors, which enable the organisation to perform better; sustainable performances are lagging (reactive) factors, which prove that the organisation's strategies have achieved and can continue to achieve success.

It is worth noting, with Sundarakani et al. (2010), that measuring GSC practices is a challenging task. These authors recognise that such practices take place at dislocated phases of the supply chain and have multi-dimensional consequences. Measuring the practices also requires the organisation to ensure that their customers (downstream companies) and suppliers (upstream companies) comply with environmental regulations and requirements through desired environmental practices and sustainable performances. Olugu et al. (2010) argue that performance measurement frameworks for GSCs should integrate forward and backward chains. Their article identifies a list of 16 measures across a ‘two-in-one chain’ and test its applicability by means of questionnaires distributed to academics and practitioners. Zhu et al. (2008a) provide a list of 21 measurement items, which emphasises cooperation with customers and green purchasing. The authors test the validity of their model on the basis of questionnaires sent to Chinese manufacturers.

Our study extends the work in the field of GSCPM. This particular field is in its early development phases both academically and practically (Zhu et al. 2008a). We contribute an innovative framework of GSC measurements across the upstream supply chain, internal operations and downstream customers. In addition, our holistic framework innovates by incorporating organisational decision levels (strategic, tactical and operational) using the AHP. In contrast to previous studies, the framework is applied by means of three case studies in the manufacturing industry, and benchmarking is performed. We consider environmental planning, environmental auditing and management commitment as strategic constructs/criteria under environmental practices; and environmental performance, economic performance and operational performance as strategic constructs under sustainable performance constructs/criteria. These six constructs/criteria form the strategic-level constructs for GSCPM.

In this article, environmental planning refers mostly to long-term objectives, and to the scope and level of importance that the management team assign to green issues. The environmental audit ensures the organisation embeds the policy into the system and monitors performance. This might require systematic, documented, periodic and objective auditing as recommended by certain academics and by regulations such as the European Union Eco-Management and Audit Scheme (2009). For example, while studying the role of ISO 14001 in environmental supply chain management in Swedish companies, Nawrocka et al. (2009) observe that audits are not commonly performed and monitoring methods require further development. The management commitment is in line with providing leadership and fostering a culture that is conducive to achieving overall good performance. Finally, sustainable performance may be achieved through environmental, economic and operational performances.

The various subcriteria to measure environmental planning, auditing, management commitment, environmental performance, economic performance and operational performance are depicted in Table 1. This table reviews several studies in the area of GSCPM (Beamon 1999, van Hoek 1999, Rao 2002, Hervani et al. 2005, Rao and Holt, 2005, Zhu et al. 2007a, b, 2008a, b, Tsoulfas and Pappis 2008, Olugu et al. 2010). The subcriteria are the tactical and operational level constructs for GSCPM. Similar analysis needs to be carried out for both the upstream and downstream sides of the supply chain. Table 2 shows the literature sources of each subcriterion.

Table 1 Criteria and subcriteria for GSC performance.

Sl. No.	Criteria		Subcriteria
1.	Environmental practices	Environmental planning	• Adopting robust environment policy (EP1) • Reviewing and updating environmental plan (EP2) • Considering environmental criteria for major decisions (EP3) • Green procurement policy (EP4) • Cooperation with customers for green initiative (EP5) • Cooperation with suppliers (EP6)
		Environmental auditing	• Adequate audit process in place (EA1) • Procedures of reduction of nonconformities (EA2) • Procedures of monitoring time for addressing nonconformities (EA3) • Adequate auditing cycle (EA4)
		Management commitment	• Motivating employees (MC1) • Sustainability mission (MC2) • Environmental reward system and evaluation schemes (MC3) • Number of initiatives (MC4) • Greenhouse gas offsetting activities (MC5)
2.	Sustainable performance	Environmental performance	• Reduction of emissions (Env P1) • Reduction of usage of harmful materials (Env P2) • Reduction of accidents and safety issues (Env P3) • Recycle of materials (Env P4) • State of art design of sustainable reverse logistics (Env P4)
		Economic performance	• Energy consumption cost Eco P1) • Cost of procurement (Eco P2) • Water usage cost (Eco P3) • Reduction of disposal cost (Eco P4) • Reduction of waste cost (Eco P5)
		Operational performance	• Optimum design (OP1) • Minimum inventory (OP2) • High capacity utilization (OP3) • Improved quality (OP4) • Effective reverse logistics (OP5) • Reduction of time for recycling (OP6)

Table 2 Definitions and literature sources of each subcriteria.

Subcriteria	Sources
Adopting robust environment policy	Zhu *et al.* (2008a, b)
Reviewing and updating environmental plan	Olugu *et al.* (2010)
Considering environmental criteria for major decisions	Beamon (1999), Zhu *et al.* (2008a, b)
Green procurement policy	Hervani *et al.* (2005), Tsoulfas and Pappis (2008)
Cooperation with customers for green initiative	Zhu *et al.* (2007a, 2008a, b), Olugu *et al.* (2010)
Cooperation with suppliers	Gilbert (2001), Rao (2002), Rao and Holt (2005), Zhu *et al.* (2007b, 2008a, b), Olugu *et al.* (2010), Yang *et al.* (2010)
Adequate auditing programmes in place	Tsoulfas and Pappis (2006), Zhu *et al.* (2008a, b), Iraldo *et al.* (2009), Nawrocka *et al.* (2009), Olugu *et al.* (2010)
Procedures of reduction of nonconformities	Tsoulfas and Pappis (2006)
Procedures of monitoring time for addressing nonconformities	Beamon (1999), Nawrocka *et al.* (2009)
Adequate auditing cycle	Nawrocka *et al.* (2009), Olugu *et al.* (2010)
Motivating employees	Hervani *et al.* (2005), Rao and Holt (2005), Zhu *et al.* (2007b, 2008a, b), Tsoulfas and Pappis (2008), Olugu *et al.* (2010)
Sustainability mission	Beamon (1999, 2005), Hervani *et al.* (2005), Tsoulfas and Pappis (2008), Zhu *et al.* (2008a, b)
Environmental reward system and evaluation schemes	Tsoulfas and Pappis (2006), Bhagwat and Sharma (2007), Olugu *et al.* (2010)
Number of initiatives	Rao (2002), Bhagwat and Sharma (2007), Olugu *et al.* (2010)
Greenhouse gas offsetting Activities	Butner *et al.* (2008), Sundarakani *et al.* (2010)
Reduction of emissions	Hervani *et al.* (2005), Rothenberg *et al.* (2005), Zhu *et al.* (2007a, b, 2008a, b), Tsoulfas and Pappis (2008), Olugu *et al.* (2010)
Reduction of usage of harmful materials	Veleva *et al.* (2001), Tsoulfas and Pappis (2006), Zhu *et al.* (2008a, b), Olugu *et al.* (2010)
Reduction of accidents and safety issues	Veleva *et al.* (2001), Tsoulfas *et al.* (2006), Zhu *et al.* (2008a, b)
Recycle of materials	Beamon (1999), Rao (2002), Rao and Holt (2005), Zhu *et al.* (2007a, b, 2008a, b), Tsoulfas and Pappis (2008)
State of art design of sustainable reverse logistics	Beamon (1999), Gunasekaran *et al.* (2001), Sarkis (2003), Kleindorfer *et al.* (2005), Presley *et al.* (2007)
Energy consumption cost	Zhu *et al.* (2008a, b), Olugu *et al.* (2010)
Cost of procurement	Gunasekaran *et al.* (2001), Hervani *et al.* (2005), Zhu *et al.* (2007a, b, 2008a, b), Tsoulfas and Pappis (2008), Olugu *et al.* (2010)
Water usage cost	Chan (2003), Rothenberg *et al.* (2005), Zhu *et al.* (2008a)
Reduction of disposal cost	Chan (2003), Chan and Qi (2003), Zhu *et al.* (2007a, b, 2008a, b), Tsoulfas and Pappis (2006, 2008)
Reduction of waste cost	Chan (2003), Rothenberg *et al.* (2005), Zhu *et al.* (2008a, b)
Optimum design	Chan (2003), Gunasekaran *et al.* (2001), Tsoulfas and Pappis (2006), Bhagwat and Sharma (2007), Linton *et al.* (2007), Smith and Crotty (2008)
Minimum inventory	Bhagwat and Sharma (2007), Zhu *et al.* (2008a), Olugu *et al.* (2010)
High capacity utilisation	Beamon (1999), Gunasekaran (2001), Bhagwat and Sharma (2007), Zhu *et al.* (2008a)
Improved quality	Beamon (1999), Gunasekaran (2001), Olugu *et al.* (2010)
Effective reverse logistics	Gunasekaran *et al.* (2001), Ilgin and Gupta (2010)
Reduction of time for recycling	Rothenberg *et al.* (2005), Tsoulfas *et al.* (2006), Zhu *et al.* (2008a)

Table 3.Scale of relative importance for pair-wise comparison (Saaty 1980).

Intensity	Definition	Explanation
1	Equal importance	Two activities contribute equally to the object
3	Moderate importance	Slightly favours one over another
5	Essential or strong importance	Strongly favours one over another
7	Demonstrated importance	Dominance of the demonstrated importance in practice
9	Extreme importance	Evidence favouring one over another of highest possible order of affirmation
2, 4, 6, 8	Intermediate values	When compromise is needed

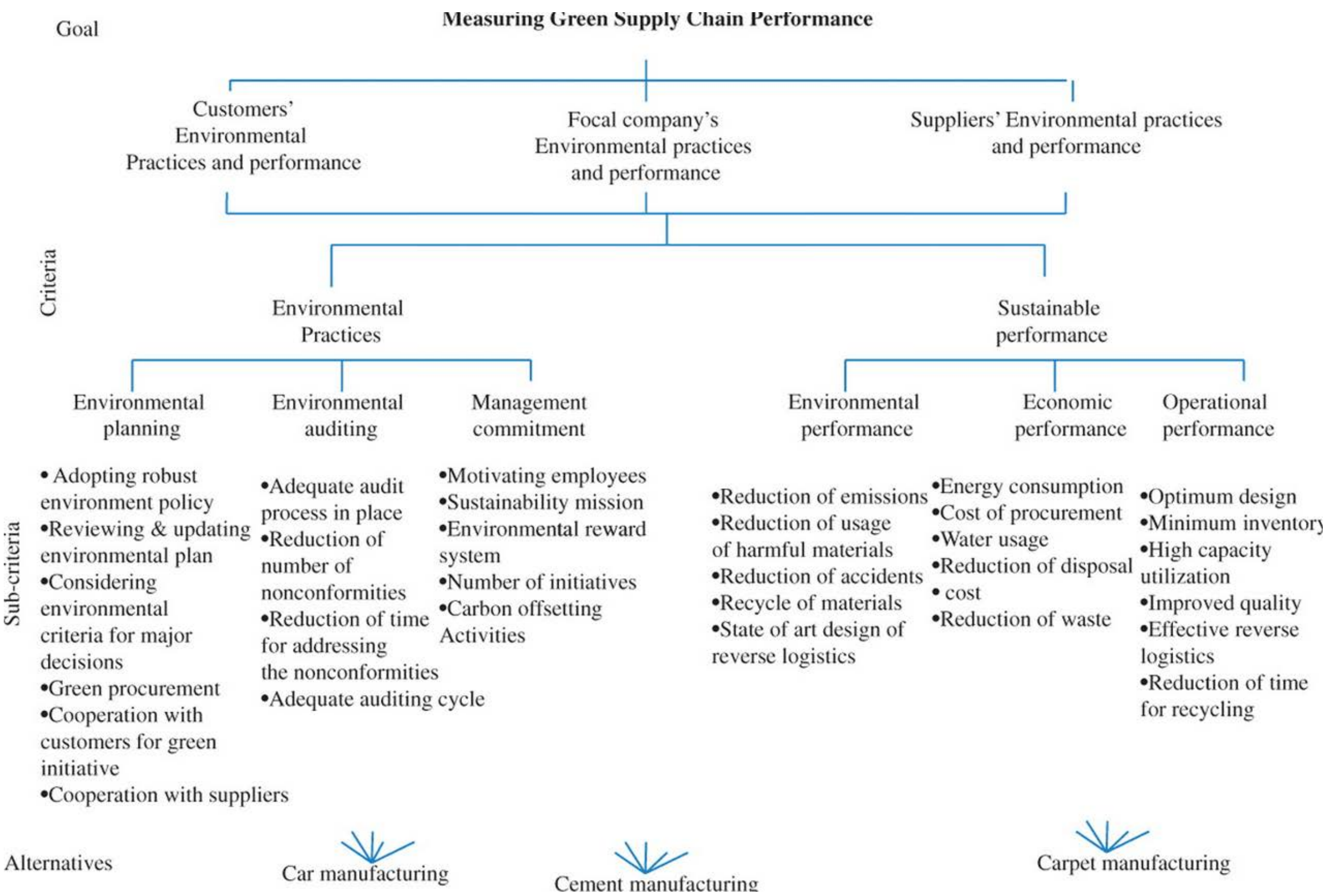
Hence, this study differs from the existing literature on GSCPM by adopting a balanced and integrative framework. This research develops an innovative GSC performance measurement framework by integrating supply chain processes (supplier relationship management, internal supply chain management and customer relationship management) with organisational decision levels (strategic, tactical and operational), using the AHP.

4. The proposed GSCPM framework

The proposed framework has six levels (Figure 2). The first level is the goal (i.e. measurement of overall GSC performance); the second level consists of the axes of the overall supply chain (i.e. customers, focal company and suppliers); the third level is the environmental practices and sustainable performances; the fourth level is the criteria; the fifth level is the subcriteria and the last level is the alternative supply chains. The proposed framework could be applied using the following steps to measure GSC performance:

1. Step 1: Identify the supply chains for measuring GSC performance and benchmarking.
2. Step 2: Form a group of experts to pursue performance measurement by involving representatives of each participating organisation.
3. Step 3: Develop a framework for GSCPM.
4. Step 4: Measure performance using the AHP framework with the involvement of the stakeholders concerned.
5. Step 4 is undertaken first through pairwise comparison at criteria level, using the verbal scale as shown in Table 3 to assess the importance of the criteria. Subsequently, pairwise comparison is carried out at the subcriteria level to establish the importance of each subcriterion. Thirdly, each alternative supply chain is compared pairwise with respect to each subcriterion to determine the performance of each alternative supply chain. Lastly, the results are synthesised across the hierarchy to reveal the overall relative performance of each alternative supply chain.
6. Step 5: Suggest improvement measures in the light of the results.

Figure 2. Green supply chain performance measurement framework using the AHP.5. Application



5. Application

The proposed framework was applied to three different manufacturing organisations (automotive, cement and carpet) in the UK. The main reason for selecting these was the difference in the characteristics of their supply chains, revealing varied best practices. Additionally, they are very much frontier companies in the respective industries. The following paragraphs briefly describe their business and supply chain characteristics.

The automotive manufacturing company is a leading premier car manufacturer in the UK with world-wide markets. It has several manufacturing plants in the UK, with a research and development centre where it develops new products. It outsources materials from all over the world and has developed strategic relationships with their critical suppliers. It markets its products through dealers. It also provides after-sales services to the customers through its dealers. It practises advanced environmental planning, policy and auditing within its production facilities in terms of design, manufacturing, energy usage and waste management. However, the company does not try to manage the environmental practices of its suppliers and customers (dealers). Although it has numerous corporate social responsibility programmes, its carbon offsetting programmes need to be made more effective. It is investing over £800M to adopt environmentally friendly technology and is jointly planning environmentally friendly programmes with its suppliers and with universities. It was badly hit by the recent recession in the UK and Europe, but recovered very fast. It has achieved record sales in the current financial year.

The carpet manufacturing company has been a family-owned business in the UK since 1783. Its current turnover is slightly over £100M. It has manufacturing facilities in two places in the West Midlands, in Pune (India) and in Portugal, and is currently expanding its manufacturing in China. The company exports its products to most major markets across the world. Three-quarters of its products are custom made and the rest are sold through dealers. It is actively working to improve its environmental performance and reduce its impact on the environment through implementing a robust environmental policy, and is accredited to ISO14001:2004. The company takes environmental and social responsibilities very seriously and is committed to the long-term aims of sustainable development in all its business activities. It feels GSC management is central to the business, as the product is intrinsically 'green': carpets come from renewable resources – wool from grass-fed sheep – and have extended lifecycles, and manufacturing plants continually strive to reduce their environmental footprint by training environmentally aware employees in sustainable communities. It also extends the GSC theme by recycling process waste and finished carpet at the end of its life. In recognition of its sustainability credentials, this company contributes positively to the Leadership in Energy and Environmental Design building certification criteria. It also meets the stringent standards of the Carpet and Rug Institute Green Label Plus programme, contributing to a healthy indoor environment.

The cement manufacturing company is a global building solutions company and leading supplier of cement, ready-mixed concrete and aggregates. In the UK, the organisation also provides asphalt, roof tiles, concrete blocks and railway sleepers. The company generates over £1 billion in annual sales and has a UK supply network with over 500 locations to ensure that quality building materials are available to customers locally. The organisation is dedicated to building a better future and couples financial achievements with a firm commitment to sustainable development. The company recognises the need to proactively manage its business to contribute towards a more sustainable future, as part of a holistic approach within a rigorous governance structure and in line with the UK Government's wider social, environmental and economic objectives for sustainable communities. Every year the company invests more than £30 million in UK sustainability-related projects.

The following paragraphs explain each step of the application.

Step 1: Identify a supply network for measuring GSC performance and identify companies to benchmark.

As stated above, three totally different companies were identified to compare their GSC performance. The reason for selecting different companies was to understand different perspectives (drivers and motivations) for GSCPM.

1. Step 2: Form a group of experts to pursue the benchmarking exercise.

2. A group of five people (one representative from each company and two researchers) was formed to carry out the benchmarking exercise. Each member of the group had more than 15 years' experience of managing or researching supply chains.
3. Step 3: Develop a framework for GSCPM.
4. Figure 2 shows the GSC performance framework for the organisations concerned, as agreed by the participants. Table 2 describes each of the subcriteria and sources.
5. Step 4: Measure performance in the AHP framework, with the involvement of the stakeholders concerned.

GSC performance was measured by the following four sub-steps:

1.

    Pairwise comparison at criteria level: First, environmental practices and sustainable performances were compared pairwise, using a verbal scale as shown in Table 3. Next, three criteria for each environmental and sustainable performance were compared pairwise to determine the importance of the criteria. Table 4 shows the pairwise comparison matrices and normalised matrices.

Table 4. Pair wise comparison and normalized matrices in criteria level.[next page]

(a) Comparison among customer, focal company and supplier				
	CEPP	FCEPP	SEPP	
CEPP	1	0.333333	0.5	
FCEPP	3	1	2	
SEPP	2	0.5	1	
Column sum	6	1.833333	3.5	
Normalized matrix				
	CEPP	FCEPP	SEPP	Importance
CEPP	0.166667[a]	0.181818	0.142857	0.163781[b]
FCEPP	0.5	0.545455	0.571429	0.538961
SEPP	0.333333	0.272727	0.285714	0.297258
(b) Comparison between focal company's environmental practices and sustainable performance				
	Environmental practices	Sustainable performance		
Environmental practice	1	3		
Sustainable practices	0.333333	1		
Column sum	1.333333	4		
Normalized matrix				
	Environmental practices	Sustainable performance	Importance	
Environmental practice	0.75	0.75	0.75	
Sustainable practices	0.25	0.25	0.25	
(c) Comparison among the criteria under environmental practices				
	Environmental practices	Environmental audit	Management commitment	
Environmental practices	1	1	0.5	
Environmental audit	1	1	0.5	
Management commitment	2	2	1	
Column sum	4	4	2	
Normalized matrix				
	Environmental practices	Environmental audit	Management importance commitment	Importance
Environmental practices	0.25	0.25	0.25	0.25
Environmental audit	0.25	0.25	0.25	0.25
Management commitment	0.5	0.5	0.5	0.5
(d) Comparison among the criteria under sustainable performance				
	Environmental performance	Economic performance	Operational performance	
Environmental performance	1	1	1	
Economic performance	1	1	1	
Operational performance	1	1	1	
Column sum	3	3	3	
Normalized matrix				
	Environmental performance	Economic performance	Operational performance importance	Importance
Environmental performance	0.333333	0.333333	0.333333	0.333333
Economic performance	0.333333	0.333333	0.333333	0.333333
Operational performance	0.333333	0.333333	0.333333	0.333333
Notes: [a]Each cell divided by the column sum (i.e. 1/6 = 0.166667).				
[b]Average across row.				
CEPP: Customers' Environmental practices and performancel; FCEPP: Focal Company's Environmental practices and performance; SEPP: Supplier Environmental practices and performance.				

This study was undertaken from the perspective of the company in question. Hence, we focused mainly on the company's practices and performances. Among the suppliers' and customers' practices and performances, the supply side was given more weight than the customer side. Under 'environmental practices', the benchmarking group assigned highest importance to 'management commitment', as the other two criteria, namely 'environmental planning' and 'environmental audit', were fairly standardised within all the participating organisations. Under 'sustainable performance', all the criteria (environmental, economic and operational performance) received equal emphasis.

1. Pairwise comparison at subcriteria level: This was undertaken for the subcriteria under each criterion. Table 5 shows a sample pairwise comparison at subcriteria level along with a normalised matrix. The participants gave more importance to certain subcriteria under each criterion. Under 'environmental planning', they gave most weight to 'adopting a robust environmental policy' and 'green procurement'. Under 'environmental auditing', they picked out 'auditing practices', and 'adequate auditing cycle'. Under 'management commitment', they chose 'carbon offsetting activities' and 'number of initiatives for CSR'. Under 'environmental performance', the chief points were 'reduction of emission' and 'usage of harmful materials'. Under 'economic performance' they were 'cost of procurement' and 'reduction waste'; and under 'operational performance', the most important subcriteria were 'minimum inventory' and 'high capacity utilisation'.
2. Pairwise comparison at the alternative level: Subsequently, the organisations' alternative supply chains were compared pairwise with respect to each subcriterion to rank each alternative in order of preference. First, information against each subcriterion was gathered for the three participating organisations, and is given in Table 6. This helped participants to compare criteria pairwise in order to derive their relative performance. Table 7 shows a sample pairwise comparison matrix and normalised matrix at the alternative level.
3. Synthesising the results across the hierarchy: As the last stage, the results across the hierarchy were synthesised to derive the relative performance of alternative supply chains. Table 8 shows the results of the AHP analysis and relative performance of alternative supply chains. Figure 3 shows the relative GSC performance of participating organisations against each criterion. The results reveal that, overall, the GSC performance of the car manufacturing company is better than that of the other two organisations. However, the car manufacturer could further improve its performance by enhancing its environmental planning through adopting a more robust policy and green procurement. The cement manufacturing organisation, although good at environmental planning and policy (mainly because of regulatory pressure), has issues related to low commitment among its management and to the sustainability of its environmental, economic and operational performance. The carpet manufacturing organisation has recently taken very firm steps to improve its GSC performance, but still falls behind in quite a few areas, such as environmental planning and green procurement.

Step 5: Suggest improvement measures.

Figure 3. Relative green supply chain performance of each participating organizations.

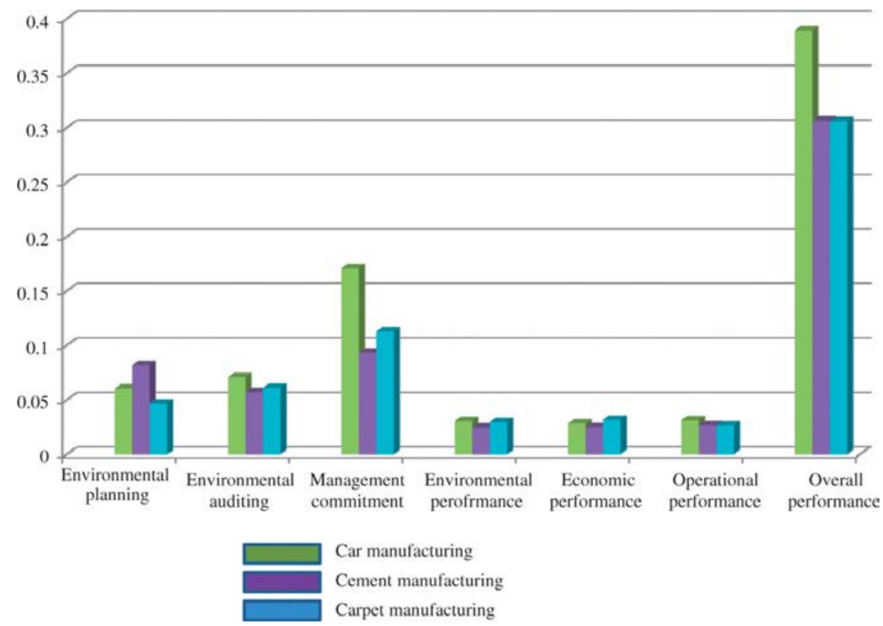


Table 5. Pairwise comparison and normalized matrix in subcriteria level (e.g. environmental planning).

	EP1	EP2	EP3	EP4	EP5	EP6	
EP1	1	3	2	1	4	3	
EP2	0.333333	1	0.5	0.333333	2	1	
EP3	0.5	2	1	0.5	2	2	
EP4	1	3	2	1	3	2	
EP5	0.25	0.5	0.5	0.333333	1	0.5	
EP6	0.333333	1	0.5	0.5	2	1	
Column sum	3.416667	10.5	6.5	3.666667	14	9.5	
Normalized matrix							
	EP1	EP2	EP3	EP4	EP5	EP6	Importance
EP1	0.293	0.286	0.308	0.273	0.286	0.316	0.293
EP2	0.098	0.095	0.077	0.091	0.143	0.105	0.101
EP3	0.146	0.190	0.154	0.136	0.143	0.211	0.163
EP4	0.293	0.286	0.308	0.273	0.214	0.211	0.264
EP5	0.073	0.048	0.077	0.091	0.071	0.053	0.069
EP6	0.098	0.095	0.077	0.136	0.143	0.105	0.109

Notes: EP1: Adopting robust environmental policy; EP2: Reviewing and updating environmental plan; EP3: Considering environmental criteria for major decisions; EP4: Green procurement; EP5: Cooperation with customers for green initiatives; EP6: Cooperation with suppliers.

Table 6. Comparative analysis of supply chains of participating organizations.

Subcriteria	Car manufacturing	Cement manufacturing	Carpet manufacturing
Adopting robust environment policy	Implemented ISO 14001, adopted environmental policy to transform the entire supply chain to green through greener products	Implemented ISO 14001, strong regulatory pressure from government and NGO lead to adopt stringent environment policy	Implemented ISO 14001, adopted green manufacturing policy
Reviewing and updating environmental plan	Less frequent, new products and facilities are designed with new targets for superior environmental performance	Frequent reviews due to regulatory pressure	Less frequent, the targets are closely monitored
Considering environmental criteria for major decisions	Environmental factors are considered along with economic, strategic and operational factors	Automatically covered because of regulatory pressure	Economic factors get more weight than environmental factors
Green procurement	Suppliers are not always involved in new product development from sufficiently early stage. Hence, it effects making green products	Cement is produced through continuous process and raw materials are sourced locally, source selection is pursued through adequate consideration of environmental factors, such as logistics, long-term environmental and social impact	Environmental and social factors are considered for sources selection. However, supplier environmental performances are rarely audited.
Cooperation with customers for green initiative	Dealer training programmes are in place. However, effectiveness is doubtful	Not yet been implemented	Adopted advanced programme in collaboration with the customers through after sales services
Cooperation with suppliers	Attempt to work in collaboration with suppliers to develop environment friendly products, but effectiveness is doubtful	Not yet been in place because of nature of business	Play advisory role to help suppliers to go green
Adequate auditing programmes in place	Environmental audit is undertaken as a part ISO 14001 accreditation	Environmental audit is undertaken as a part of environmental regulations	Environmental audit is undertaken as a part ISO 14001 accreditation
Procedures for reduction of number of nonconformities	Nonconformities that are related to ISO certification are addressed promptly. Other nonconformities are addressed as per its importance in relation to economic and operational needs	Nonconformities are addressed as soon as possible due to regulatory pressure	Nonconformities that are related to ISO certification are addressed promptly. Other nonconformities are addressed as per its importance in relation to economic and operational needs
Procedures of monitoring time for addressing nonconformities	Same as above	Same as above	Same as above
Adequate auditing cycle	Depends on regulations	Depends on regulations	Depends on regulations
Motivating employees	Organisation has adopted environmental leadership programme	Operators are trained to adopt sound environmental practices	Somewhat absent
Sustainability mission	Quite visible through product advertisement and business processes	More through regulation	More visibility is desired in products and processes
Environmental reward system and evaluation schemes	Recently implemented	Not in place	Not in place
Number of initiatives	In increasing trend but room for further improvement	Initiatives are limited by regulatory pressure	Constant

Green gas offsetting Activities	Recently incorporated number of programmes to improve product image	Somewhat limited to beginning of the project	Limited
Reduction of emissions	Reduced substantially both in products and processes through technological inventions	Regulated	Controlled
Reduction of usage of harmful materials	Improved	Improved	Improved
Reduction of accidents and safety issues	Improved	Improved	Improved
Recycle of materials	Somewhat constant but nature of the business is conducive to recycle	Somewhat constant	Substantially improved through collaborative programme with the customers
State of art design of sustainable reverse logistics	The industry is conducive for reverse logistics	Somewhat natural	closely monitored, improved substantially in recent years
Energy consumption cost	Energy intensive process but there are efforts to reduce energy consumption	Energy intensive process but little chance to reduce energy consumption once the project is implemented	Recently energy consumption has been reduced by replacing all legacy machineries by new technology
Cost of procurement	Cost of procurement is major concerned to the car manufacturing organisation. The company has more than 2000 suppliers and procures more than 60% of its turnover. Both the figures are in increasing trend.	Raw materials (lime stone) are locally sourced and own by the company. Hence, cost of procurement is always under control	Cost of raw materials (jute and wool) have been reduced substantially through strategic alliance with the suppliers in India, Bangladesh and New Zealand
Water usage cost	Normal	Substantial because of industry type	Normal
Reduction of disposal cost	Several initiatives were undertaken to reduce disposal cost	Closed-loop supply chain practice has been adopted	No effort on disposal cost
Reduction of waste cost	Organisation has adopted lean sigma approach	Waste is minimal because process industry	Organisation has recently adopted six sigma approach
Optimum design	Optimum design policy has been adopted	Process industry maintain optimum design policy	Design optimisation is difficult to achieve because of custom products
Minimum inventory	Minimum inventory policy is maintained	Minimum inventory policy is maintained in both raw material and finished products	Raw materials inventory is an issue as both wool and jute are imported from geographically different locations (India, Bangladesh and New Zealand)
High capacity utilisation	High capacity utilisation is maintained	High capacity utilisation is generally achieved	High capacity utilisation is hardly achieve as products are custom made.
Improved quality	Both product and process quality has improved	Specifications of the finished products are always achieved	Quality of carlet has been enhanced
Effective reverse logistics	Effective reverse logistics are in place	Not required	Organisation is currently implementing reverse logistics
Reduction of time for recycling	Effective recycling has been achieved	Achieved	Difficult to achieve 100% recycle

Table 7. Pairwise comparison in alternative level (e.g. for subcriteria 'Adopting robust environmental policy').

	Car	**Cement**	**Carpet**	
Car	1	3	2	
Cement	0.333333	1	1	
Carpet	0.5	1	1	
Column sum	1.833333	5	4	
Normalized matrix				
	Car	Cement	Carpet	Importance
Car	0.545	0.600	0.500	0.548
Cement	0.182	0.200	0.250	0.211
Carpet	0.273	0.200	0.250	0.241

Table 8. Synthesized AHP table showing relative performance of each supply chain.

					Subcriteria			SC1: Car manufacturing company		SC2: Cement manufacturing company		SC3: Carpet manufacturing company	
		Criteria	LP	GP		LP	GP	LP	GP	LP	GP	LP	GP
Environmental practices	0.75	Environmental planning	0.250	0.188[a]	EP1	0.293[b]	0.055[c]	0.297[d]	0.016[e]	0.539	0.030	0.164	0.009
					EP2	0.101	0.019	0.300	0.006	0.480	0.009	0.220	0.004
					EP3	0.163	0.031	0.380	0.012	0.340	0.010	0.280	0.009
					EP4	0.264	0.049	0.250	0.012	0.460	0.023	0.290	0.014
					EP5	0.069	0.013	0.360	0.005	0.210	0.003	0.430	0.006
					EP6	0.109	0.020	0.450	0.009	0.320	0.007	0.230	0.005
		Environmental auditing	0.250	0.188	EA1	0.384	0.072	0.460	0.033	0.220	0.016	0.320	0.023
					EA2	0.143	0.027	0.300	0.008	0.390	0.010	0.310	0.008
					EA3	0.088	0.016	0.300	0.005	0.390	0.006	0.310	0.005
					EA4	0.384	0.072	0.333	0.024	0.333	0.024	0.334	0.024
		Management commitment	0.500	0.375	MC1	0.091	0.034	0.430	0.015	0.310	0.011	0.260	0.009
					MC2	0.160	0.060	0.390	0.023	0.320	0.019	0.290	0.017
					MC3	0.105	0.040	0.480	0.019	0.260	0.010	0.260	0.010
					MC4	0.244	0.091	0.450	0.041	0.250	0.023	0.300	0.027
			1.000		MC5	0.400	0.150	0.480	0.072	0.200	0.030	0.320	0.048
Sustainable performance	0.25	Environmental performance	0.333	0.083	Env P1	0.416	0.035	0.410	0.014	0.260	0.009	0.330	0.011
					Env P2	0.262	0.022	0.350	0.008	0.320	0.007	0.330	0.007
					Env P3	0.161	0.013	0.340	0.005	0.330	0.004	0.330	0.004
					Env P4	0.099	0.008	0.240	0.002	0.340	0.003	0.420	0.003
					Env P5	0.062	0.005	0.320	0.002	0.190	0.001	0.490	0.003
		Economic performance	0.333	0.083	Eco P1	0.179	0.015	0.380	0.006	0.230	0.003	0.390	0.006
					Eco P2	0.314	0.026	0.230	0.006	0.340	0.009	0.430	0.011
					Eco P3	0.114	0.010	0.380	0.004	0.230	0.002	0.390	0.004
					Eco P4	0.091	0.008	0.350	0.003	0.410	0.003	0.240	0.002
					Eco P5	0.303	0.025	0.390	0.010	0.270	0.007	0.340	0.009
		Operational performance	0.333	0.083	OP1	0.136	0.011	0.420	0.005	0.240	0.003	0.340	0.004
					OP2	0.362	0.030	0.340	0.010	0.380	0.011	0.280	0.008
					OP3	0.230	0.019	0.350	0.007	0.350	0.007	0.300	0.006
					OP4	0.136	0.011	0.430	0.005	0.170	0.002	0.400	0.005
					OP5	0.081	0.007	0.360	0.002	0.260	0.002	0.380	0.003
					OP6	0.055	0.005	0.380	0.002	0.400	0.002	0.220	0.001
Overall performance	Σ								0.389		0.306		0.305

Notes: LP: Local percentage; GP: Global percentage.

Overall performance of each case study supply chain is derived by adding the global performance (GP) of each supply chain.

[a]Figures in column 5 (GP of criteria) are derived by multiplying the figures in column 2 (importance of high level criteria) and the figures in column 4 (importance (LP) of criteria).

[b]Figures in column 7 are the importance of subcriteria (refer Table 5).

[c]Figures in column 8 are derived by multiplying the GP of criteria (column 5) with LP of subcriteria (column 7).

[d]Figures in columns 9, 11 and 13 are derived from pair wise comparison of three case study supply chains with respect to each subcriteria (refer Table 7).

[e]Figures in columns 10, 12 and 14 are derived by multiplying the importance of each subcriteria (figures in column 8) with performance of each case study supply chain (figures in columns 9, 11 and 13, respectively).

In line with the improvement measures suggested by the above analysis, the case-study organisations have taken several steps to improve their GSC performance. The car manufacturing organisation has recently implemented a green procurement policy with its major suppliers through incorporating environmental criteria in supplier selection and performance evaluation, and has started environmental auditing at regular intervals. The cement manufacturing organisation has recently enhanced its supplier auditing procedure. It has also introduced environmental leadership programmes for senior executives in order to improve management commitment to enhanced environmental performance. It has also strengthened its risk-based inspection and maintenance methods and updated equipment and machinery replacement policies to improve its overall environmental performance. The carpet manufacturing organisation adopted a holistic approach to improve its GSC performance by adopting a green procurement programme with its suppliers in Asia and New Zealand, and replacing old technology by new energy-efficient and environmentally friendly machinery. Additionally, it has implemented various environmental awareness programmes for its executives and workers.

After applying the proposed framework and revealing the results to the appropriate stakeholders of the participating organisations, we conducted a validation survey using a focus-group approach to consider the adoptability of the proposed GSCPM model. We asked the focus group a few unstructured questions about the benefits of using the proposed framework, its user friendliness, cost of application (capital and operating), sustainability etc. The representatives of the participating organisations were quite positive about the user friendliness of the framework, as they would be able to use Microsoft Office to analyse the data. However, they were concerned about data collection as the outcome would depend on the quality of the data used. They suggested that success would depend on the availability of high-quality data at the time of application. Hence, the success of the proposed GSCPM model would depend on creating a database system across the supply chain, exclusively for environmental data, and updating it regularly. The group also agreed that applying the GSCPM model need not involve a huge capital cost, compared to the benefit that could result from it. Adoption of the new performance measurement model may need a few changes in processes and in people's mind set.

6. Discussion and conclusion

6.1. Theoretical contributions

Dissatisfaction with mainstream perspectives on GSCPM arises partly because these perspectives are not in line with the specificities of organisational decision levels and also because the information they have produced is diffuse and nonintegrated. In addition, while many companies are adopting performance measurement systems to monitor their supply chain performance, much empirical evidence shows that these systems do not adapt easily to monitoring the sustainability of supply chains (Zhu et al. 2007a). Current GSCPM is insufficient because it considers only intra-organisational constructs, which mostly cover the environmental performance of production activities. This study proposes holistic constructs for GSCPM, covering the entire supply network (upstream and downstream companies along with the focal organisation). We also consider lagging (reactive) and leading (proactive) factors in performance measurement. The factors are both subjective and objective, and comprise environmental, economic and operational criteria. Further, we introduce an analytical framework to measure GSC performance at strategic, tactical and operational levels.

The literature review reveals a lack of field-based studies which test the applicability and validity of proposed measurement models. So far, to our knowledge, there is no comparative study on GSC performance in UK manufacturing industry. Several academics, such as Zhu et al. (2007b) and Linton et al. (2007), recommend the use of multiple case studies to look more closely at GSC management in different industrial contexts. Zhu et al. (2008b) point out that GSC practices are not considered equitably across diverse industries.

6.2. Managerial contributions

From a practical perspective, this article may help managers to make decisions and to analyse and benchmark their environmental initiatives across the whole supply chain dynamically. Our preliminary results, based upon three case studies in UK manufacturing industry, show that in some organisations internal operations are the most important factors in environmental performance, while in others it depends very much on suppliers or downstream activities. This is in line with Zhu et al. (2007b), who state that different industrial sectors implement GSC management at different levels, as well as achieving different performance outcomes. Also, we conclude that, depending on the level of integration in the supply chain and the outcome of environmental initiatives, managers may need to pay attention in varying degrees to audit and performance in order to improve overall GSC performance. Hence, this study considers the measurement of implementation practices in GSC management as well as the resulting performance outcomes. Zhu et al. (2008a) consider this a worthwhile undertaking.

Thus, the proposed GSCPM framework using the AHP helps organisations to make decisions dynamically on what they should do to improve performance and also involve relevant stakeholders. This provides an effective monitoring and control mechanism for all environmental, economic and operational variables. The proposed framework uses Expert Choice software to analyse performance. Additionally, the sensitivity utility of AHP provides an opportunity to observe the nature of the performance measurement model outcomes in alternative decision situations. It has the following advantages over contemporary approaches:

1.
AHP provides a flexible and easily understood way to analyse GSC performance.
2.
AHP calls for active involvement of the stakeholders concerned.
3.
Performance measurement using AHP integrates all stakeholders (upstream, downstream and client organisations). Hence, there is more chance of implementing all the improvement measures across the supply chain.
4.
AHP is a suitable approach for reaching a consensus in controversial decisions. Despite the existence of diverging interests, AHP can result in collective judgements based on a reasonable compromise or consensus.

6.3. Limitation

The proposed framework has two main shortcomings. The analysis is very tedious and time consuming. The accuracy of the results depends on the collective experience of the participants and the effectiveness of the facilitators. AHP has its own shortcomings, as indicated by various authors (Belton and Gear 1983, Finan and Hurley 2002). Nevertheless, on the whole, AHP has been a useful tool in dealing with multiple factors in different qualitative domains. The findings and recommendations vary across supply chains, perception of management, the organisation's objectives and policies, and its business environment.

6.4. Research perspectives

Consistent with our holistic framework and using the AHP method, further research avenues may be possible. While the proposed framework allows us to measure the performance of GSC and suggest improvement measures, it could be extended by examining in depth the reasons for the observed nature and degree of performance. In this article, benchmarking the supply networks among participating companies has revealed different levels of performance among these organisations. Future research may use a more proactive approach and focus on predicting the likely level of GSC performance for a given company, depending on managerial, organisational and environmental determinants. This is expected to help prevent failures at the early stages in the implementation of GSC management.

Another further research avenue could involve studying GSC performance measurement across different countries. This could provide additional insights, as the level of maturity of GSC management, the regulatory and market pressures, and the dissemination of innovative practices are likely to vary among countries (both developed and emerging). By adding additional observations to ours, it might be possible to develop a more comprehensive theory of GSCPM.

References

1. Agndal, H and Nilsson, U. 2010. Different open book accounting practices for different purchasing strategies. Management Accounting Research, 21: 147–166.
2. Angell, L-C and Klassen, RD. 1999. Integrating environmental issues into the mainstream: an agenda for research in operations management. Journal of Operations Management, 17(5): 575–598.
3. Beamon, B-M. 1999. Designing the green supply chain. Logistics Information Management, 12(4): 332–342.
4. Beamon, B-M. 2005. Environmental and sustainability ethics in supply chain management. Science and Engineering Ethics, 11: 221–234.

5. Beamon, B-M. 2008. Sustainability and the future of supply chain management. Operations and Supply Chain Management, 1(1): 4–18.
6. Belton, V and Gear, T. 1983. On shortcomings of Saaty's method of analytical hierarchies. Omega, 11: 227–230.
7. Bhagwat, M and Sharma, MK. 2007. Performance measurement of supply chain management: a balanced scorecard approach. Computers and Industrial Engineering, 53: 43–62.
8. Bond, TC. 1999. The role of performance measurement in continuous improvement. International Journal of Operations and Production Management, 19(12): 1318–1334.
9. Brown, D. 2008. It is good to be green – environmentally friendly credentials are influencing business outsourcing decisions. Strategic Outsourcing: An International Journal, 1(1): 87–95.
10. Butner, K, Geuder, D and Hittner, J. 2008. Mastering carbon management: balancing trade-offs to optimize supply chain efficiencies, Somers, NY: IBM Global Business Services.
11. Chan, F.-T.-S. 2003. Performance measurement in a supply chain. International Journal of Advanced Manufacturing Technology, 21: 534–548.
12. Chan, F.-T.-S. and Qi, H-J. 2003. An innovative performance measurement method for supply chain management. Supply Chain Management: An International Journal, 8(4): 209–223.
13. Child, J and Tsai, T. 2004. The dynamic between firms' environmental strategies and institutional constraints in emerging economies: evidence from China and Taiwan. Journal of Management Studies, 42(1): 95–125.
14. Corbett, CJ and Klassen, RD. 2006. Extending the horizons: environmental excellence as key to improving operations. Manufacturing and Service Operations Management, 8(1): 5–22.
15. Dyer, RF and Forman, EH. 1992. Group decision support with the analytic hierarchy process. Decision Support Systems, 8: 99–124.
16. EPA. 2000. The Lean and Green Supply Chain: a practical guide for materials managers and supply chain managers to reduce costs and improve environmental performance, Washington, DC: United States Environmental Protection Agency.
17. European Union, Eco-Management and Audit Scheme, 2009. Regulation (EC) No 1221/2009 repealing Regulation (EC) No 761/2001 and Commission Decisions 2001/681/EC and 2006/193/EC
18. Finan, J-S and Hurley, W-J. 2002. The analytic hierarchy process: can wash criteria be ignored?. Computers and Operations Research, 29(8): 1025–1030.
19. Geffen, C-A and Rothenberg, S. 2000. Suppliers and environmental innovation: the automotive paint process. International Journal of Operations & Production Management, 20(2): 166–186.
20. Gilbert, S. 2001. Greening supply chain: enhancing competitiveness through green productivity, Tapei, Taiwan: Asian Productivity Association.
21. Golden, B-L, Wasli, E-A and Harker, P-T. 1989. The analytic hierarchy process: applications and studies, New York: Springer-Verlag.
22. Gunasekaran, A, Patel, C and Tirtiroglu, E. 2001. Performance measures and metrics in a supply chain. International Journal of Operations and Production Management, 21(1/2): 71–87.
23. Gupta, M and Sharma, K. 1996. Environmental operations management: an opportunity for improvement. Production and Inventory Management Journal, 37(3): 40–46.
24. Hall, J. 2000. Environmental supply chain dynamics. Journal of Cleaner Production, 8: 455–471.
25. Handfield, R, Walton, S and Sroufe, R. 2002. Applying environmental criteria to supplier assessment: a study of the application of the analytical hierarchy process. European Journal of Operational Research, 141: 70–87.
26. Haskins, C. 2006. Multidisciplinary investigation of eco-industrial parks. Systems Engineering, 9(4): 313–330.
27. Hervani, A-A, Helms, M-M and Sarkis, J. 2005. Performance measurement for green supply chain management. Benchmarking: An International Journal, 12(4): 330–353.
28. Ilgin, M-A and Gupta, M. 2010. Environmental conscious manufacturing and product recovery (ECMPRO): a review of the state of the art. Journal of Environmental Management, 91(3): 563–591.
29. Iraldo, F, Testa, F and Frey, M. 2009. Is an environmental management system able to influence environmental and competitive performance? The case of the eco-management and audit scheme (EMAS) in the European Union. Journal of Cleaner Production, 17(16): 1444–1452.
30. ISO 14031, 2002. International Organisation for Standardisation (2002). International Standard ISO 14031:2002. Environmental management – environmental performance evaluation – guidelines. Geneva, Switzerland
31. Ittner, C-D. 1999. Supplier selection, monitoring practices, and firm performance. Journal of Accounting and Public Policy, 18: 253–281.
32. Kainumaa, Y and Tawarab, N. 2006. A multiple attribute utility theory approach to lean and green supply chain management. International Journal of Production Economics, 101: 99–108.
33. Kleindorfer, P-R, Singhal, K and Wassenhove, L.-N.-V. 2005. Sustainable operations management. Production and Operations Management, 14(4): 482–492.
34. Liang, L. 2006. DEA models for supply chain efficiency evaluation. Annals of Operations Research, 145: 35–49.
35. Linton, J-D, Klassen, R and Jayaraman, V. 2007. Sustainable supply chains: an introduction. Journal of Operations Management, 25: 1075–1082.
36. Mahama, H. 2006. Management control systems, cooperation and performance in strategic supply relationships: a survey in the mines. Management Accounting Research, 17: 315–339.
37. Mentzer, J-T, Myers, M-B and Stank, T-P. 2007. Handbook of global supply chain management, California: Sage.
38. Mildenberger, U and Khare, A. 2000. Planning for an environment-friendly car. Technovation, 20: 205–214.

39. Nawrocka, D, Brorson, T and Lindhqvist, T. 2009. ISO 14001 in environmental supply chain practices. Journal of Cleaner Production, 17(16): 1435–1443.
40. Olugu, E.-U., Wong, K.-Y., and Shaharoun, A.-M., 2010. Development of key performance measures for the automobile green supply chain. Resources Conservation and Recycling, 65 (6), 567--579
41. Orsato, R-J. 2006. Competitive Environmental strategies: when does it pay to be green?. California Management Review, 48(2): 127–143.
42. Porter, M-E and van der Linde, C. 1995. Green and competitive. Harvard Business Review, 73(5): 120–134.
43. Presley, A, Meade, L and Sarkis, J. 2007. A strategic sustainability justification methodology for organizational decisions: a reverse logistics illustration. International Journal of Production Research, 45(18–19): 4595–4620.
44. Rao, P. 2002. Greening the supply chain: a new initiative in South East Asia. International Journal of Operations and Production Management, 22(6): 632–655.
45. Rao, P and Holt, D. 2005. Do green supply chains lead to competitiveness and economic performance?. International Journal of Operations and Production Management, 25(9): 898–916.
46. Reinhardt, FL. 2000. Down to earth, Boston: Harvard Business School Press.
47. Rothenberg, S, Schenck, B and Maxwell, J. 2005. Lessons from benchmarking environmental performance at automobile assembly plants. Benchmarking: An International Journal, 12(1): 5–15.
48. Saaty, T-L. 1980. The analytic hierarchy process, USA: McGraw-Hill.
49. Saaty, T-L. 1982. Decision making for leaders, New York: Lifetime Learning.
50. Saaty, T.-L., 1983. Priority setting in complex problems. IEEE Transactions on Engineering Management, EM-30, August, 140–155
51. Salam, M-A. 2009. Corporate social responsibility in purchasing and supply chain. Journal of Business Ethics, 85(2): 355–70.
52. Sarkis, J. 2003. A strategic decision framework for green supply chain management. Journal of Cleaner Production, 11(4): 397–409.
53. Seuring, S and Muller, M. 2008. From a literature review to a conceptual framework for sustainable supply chain management. Journal of Cleaner Production, 16: 1699–1710.
54. Smith, M and Crotty, J. 2008. Environmental regulation and innovation driving ecological design in the UK automotive industry. Business Strategy and Environment, 17: 341–349.
55. Sundarakani, B., et al., 2010. Modeling carbon footprints across the supply chain. International Journal of Production Economics, 128, 43--50
56. Tsoulfas, G and Pappis, C. 2006. Environmental principles applicable to supply chains design and operation. Journal of Cleaner Production, 14(18): 1593–1602.
57. Tsoulfas, G and Pappis, C. 2008. A model for supply chains environmental performance analysis and decision making. Journal of Cleaner Production, 16: 1647–1657.
58. Vachon, S and Klassen, R. 2008. Environmental management and manufacturing performance: the role of collaboration in the supply chain. International Journal of Production Economics, 111(2): 299–315.
59. van den Abbeele, A, Roodhoft, F and Warlop, L. 2009. The effect of cost information on buyer–supplier negotiations in different power settings. Accounting, Organizations and Society, 34: 245–266.
60. van Hoek, RI. 2002. Case studies of greening the automotive supply chain through technology and operations. International Journal of Technology Management, 23(1/2/3): 89–112.
61. Vargas, LG. 1990. An overview of the analytic hierarchy process and its applications. European Journal of Operation Research, 48(1): 2–8.
62. Veleva, V. 2001. Indicators of sustainable production. Journal of Cleaner Production, 9: 447–452.
63. Wong, W-P and Wong, K-Y. 2008. A review on benchmarking of supply chain performance measures. Benchmarking: An International Journal, 15(1): 25–51.
64. Yang, CL. 2010. Mediated effect of environmental management on manufacturing competitiveness: an empirical study. International Journal of Production Economics, 123: 210–220.
65. Zhu, Q, Sarkis, J and Lai, K-H. 2007a. Green supply chain management: pressures, practices and performance within the Chinese automobile industry. Journal of Cleaner Production, 15(11–12): 1041–1052.
66. Zhu, Q, Sarkis, J and Lai, K-H. 2007b. Initiatives and outcomes of green supply chain management implementation by Chinese manufacturers. Journal of Environmental Management, 85(1): 179–189.
67. Zhu, Q, Sarkis, J and Lai, K-H. 2008a. Confirmation of a measurement model for green supply chain management practices implementation. International Journal of Production Economics, 111: 261–273.
68. Zhu, Q, Sarkis, J and Lai, K-H. 2008b. Green supply chain management implications for "closing the loop". Transportation Research Part E, 44: 1–18.