Green supply chain performance measurement using fuzzy ANP-based balanced scorecard: a collaborative decision-making approach

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1. Introduction

Supply chain management (SCM) has strategic implications for businesses. SCM is one of the most effective operational strategies to enhance organisational competitiveness (Gunasekaran and Cheng 2008). Sustainability of a business in the context of a rapidly changing global economy requires identifying performance measures on most of the critical evaluating criteria of the supply chain (SC). Such a procedure considers critical evaluation of the dependent business strategies as an integral part of the business. The traditional SCM model defines the SC performance as the degree of fit between ideal profiles of knowledge elements (i.e. critical evaluating criteria) and business strategies (Hult et al. 2006). In recent times, manufacturing operations have been strongly influenced by changing environmental requirements (Beamon 1999). Therefore, adequate attention is required to incorporate green operational strategies in an SC. Effective and efficient green management strategies, when combined with manufacturing operational strategies, facilitate the business in evaluating, managing, enhancing and controlling the individual performances of the manufacturing operations.

Although a good number of studies have been reported in the literature, there is a lack of benchmarked knowledge on the measurement of green performance in SCs (Björklund, Martinsen, and Abrahamsson 2012). Existing performance measurement approaches disregard sustainable development elements, viz. social and green aspects (Cuthbertson and Piotrowicz 2008). Therefore, a thorough investigation into the links between green constructs and sub-constructs of SC is necessitated considering other contributing inter-organisational elements responsible for performance measurement.

In order to bridge the existing gap, a collaborative decision-making (CDM) approach has been adopted in this paper. This paper demonstrates how a green-balanced scorecard (GrBSc) method is developed and implemented for a UK-based carpet-manufacturing company in order to measure SC performance within a CDM environment. The company has systematic plan to reduce waste. Their workers are appropriately trained and educated to contribute in the waste reduction process. They have identified eight wastes in manufacturing and implemented methods to reduce those. Additionally, they have invested in training their human resources to implement an effective waste reduction process. The company is currently extending its quality management programmes to major critical suppliers.

The intra-organisational CDM supports an efficient information exchange among disparate stakeholders of the carpet-manufacturing firm. The firm’s stakeholders working together to create technological, managerial and procedural solutions in both the pre- and post-manufacturing processes share knowledge-base that contributes to efficient decision-making. A multi-criteria decision-making tool, fuzzy analytic network process (ANP) (Saaty 1996) assists in coordinating the various functionalities of the company required to arrive at timely collective decisions, enabling all relevant stakeholders to participate in the process for an effective decision-making process through the design and use of a GrBSc. A synergistic effect of three interdependent major functions is considered in this paper so as to enable effective green intra-company collaboration and networking thereby forming the basis of the CDM platform. These are: (i) discussion and overlay knowledge (both the subjective and objective); (ii) knowledge-sharing; and (iii) collective decision for the best course of action.

The paper is organised in the following manner. Section 2 illustrates a comprehensive background based on a systematic literature review. The next section elucidates the GrBSc framework. Section 4 delineates the implementation of GrBSc focusing on a case of a UK-based carpet-manufacturing company. Section 5 discusses observations from the implemented approach followed by a discussion. The last section concludes the paper indicating the scope for further research.

2 Background

A considerable number of performance measurement approaches exist in the literature (Alfaro, Ortiz, and Poler 2007; Bhagwat and Sharma 2009; Gunasekaran, Patel, and McGaughey 2004; Mettänen 2005). Key performance indicators (Camarinha-Matos and Abreu 2007) and their measures and metrics in SCM are reported in literature based on a survey and case studies (Gunasekaran and Kobu 2007). Yang (2012) reports a conceptual framework for evaluating the knowledge-sharing effect of SC capabilities on SC performance. It is observed that an effective performance measurement approach should consider managerial accounting along with operational strategies. Manufacturing synergy can be developed if a strong link is developed among strategies, operational actions and performance (Ketokivi and Heikkilä 2003). However, gaps between these two disciplines exist within SC research (Hofmann and Locker 2009). The scope of this paper is limited to green supply chain (GSC) performance using a Balanced scorecard (BSc)-based CDM approach. Therefore, a critique of the literature in the arena of GSC performance and BSc-based performance measurement frameworks is relevant.

2.1 Green SC performance

Significant awareness amongst manufacturers, increased level of societal awareness among consumers and regulatory pressures on businesses are steadily forcing SCs to meet consumer demand for 'greener' products (Hitchcock 2012). Therefore, it is envisaged that the organisation performance would take a different shape when green and societal aspects of SCs are considered. The literature on the GSC performance is wide-ranging (Dey and Cheffi 2012; Olugu, Wong, and Shaharoun 2010; Tsoulfas and Pappis 2008). A good level of recognition is found amongst practitioners on the necessity for more knowledge on environmental performance across different actors in an SC (Björklund, Martinsen, and Abrahamsson 2012). Modern SC performance measurement includes 'ecological sustainable performance measure' as a component (Bai et al. 2012). Taking into account present challenges and obstacles, a definition of green SCM is as follows: 'to maximise overall environmental profit by adopting a life cycle approach through product design, material selection, manufacturing, and sales and recovery, and therefore helps the firm to realise its sustainable development and improvement' (Shi et al. 2012). Therefore, in addition to economic performance measure (Rao and Holt 2005), it is essential to identify the SC constructs, ecological aspects of performance measures and causal relationships that form the building blocks of these GSC elements within an organisation.

2.2 BSc and its variants for performance measurement

The purpose of BSc is to keep the scores of a set of performance measures balanced. The measures comprise short- and long-term objectives, financial and non-financial measures, lagging and leading indicators, and internal and external performance perspectives (Kaplan and Norton 1992, 1996). Three most relevant ways have been elucidated for utilising a BSc framework in assessing performance (Malmi 2001): (i) to focus on management of the organisation by objectives; (ii) to use as an information system; and (iii) to visualise the cause and effect relationships between different measures. Customised forms of BSc have been adopted by many companies (Lee, Chen, and Chang 2008). Businesses are aligned to new strategies thereby opening growth opportunities based on more customised, value-added products and services (Martinsons, Davison, and Tse 1999). Empirical evidence from Dutch firms suggests that appropriate usage of BSc improves the performance of the company (Braam and Nijssen 2004). Examples of the application of BSc framework in various sectors for performance measurement are abundant (Mendes et al. 2012; Sawalqa, Holloway, and Alam 2011). However, the way of BSc implementation plays a crucial role for performance measurement (Braam and Nijssen 2004).

There are instances where multi-criteria methodologies are integrated with the BSc framework. For example, fuzzy analytic hierarchy process (AHP) (Saaty 1980) is integrated with the BSc approach (Lee, Chen, and Chang 2008). Use of AHP and its variants in the BSc framework provides a mechanism for calculating the relative weights for each performance measure (Wu, Tzeng, and Chen 2009). Data envelopment analysis, case-based reasoning (Yuan and Chiu 2009) and quality function deployment (Cohen 2011) are useful tools for performance measurement within the BSc framework (Banker et al. 2004). A hypothetical case study using the BSc framework for performance evaluation in the construction sector is reported using AHP and multi-attribute utility theory (Stwart and Mohamed 2001).

While AHP is used to structure the hierarchy and relative weightings of performance perspectives, and indicators and measures (Lee, Chen, and Chang 2008; Stwart and Mohamed 2001) within the BSc framework, it does not consider the interdependencies, using a network, of the causal relationship meant for GrBSc.

Another variant of BSc uses the ANP for performance evaluation (Ravi, Shankar, and Tiwari 2005). Both AHP and ANP are 'versatile multi-attribute decision methodologies' that can be adapted to facilitate the implementation of a wide range of BSc frameworks (Leung, Lam, and Cao 2006). Advantageously, ANP considers the interdependencies among criteria, sub-criteria and determinants. Fuzzy ANP-based BSc approaches are reported in Tseng (2010); Yüksel and Dağdeviren (2010). Interpretive structural modelling and ANP are used in the development of BSc (Thakkar et al. 2006). A sustainability BSc framework is reported using fuzzy Delphi method and ANP (Hsu et al. 2011).

BSc can be successfully used for managing environmental aspects of performance (Länsiluoto and Järvenpää 2010). Wynder (2010) opines that environmental performance can be recognised as a driver of financial performance. A BSc-based GSC performance measurement approach is reported in Cheffi and Dey (2012). Relationship between sustainable BSc and eco-efficiency analysis is found in Möller and Schaltegger (2005). Ways to incorporate sustainable practices into BSc are reported in Butler, Henderson, and Raiborn (2011). Instances prevail where environmental and social aspects are integrated with the organisational aspects of a company within a BSc framework (Figge et al. 2002).

The CDM approach framed in this paper to assess GSC performance of a UK-based manufacturing company seeks to answer the following research questions:

1. How are GSC constructs, sub-constructs and sub-sub constructs related according to strategic, tactical and operational levels of management and what are the implications of these for GSC decision-making?
2. What are the critical evaluating factors responsible for measuring GSC performance?
3. How do the constructs, sub-constructs and sub-sub-constructs of an SC form a green network?
4. How does a green causal relationship, comprising the green network, serve as a black-box for GSC performance measurement?
5. What are the elements that contribute to the GrBSc while measuring SC performance?
6. How are the collaborative opinions, in linguistic terms, of stakeholders of a manufacturing company considered in GrBSc?
7. How is qualitative and vague information, in linguistic terms, of the stakeholders tackled in the interdependent network for measuring GSC performance of the manufacturing firm?

This research extends the literature in the field of GSC by developing a novel GSC performance framework for a UK-based carpet-manufacturing firm by devising a novel GrBSc approach through integrating holistic GSC performance constructs and implementing a CDM approach.

3 GrBSc-based framework

The British carpet industry is striving to survive amidst several competitors in EU. One of the sustainable manufacturing goals in the British carpet sector is the inclusion of a green element in the production planning processes. The manufacturing company under consideration takes such 'green' elements and its environmental and social responsibilities seriously. The company is committed to the long-term aims of sustainable development in all business activities. GSC management is central to the entire business as the product is intrinsically 'green'. Carpets are manufactured from renewable resources, viz. wool from grass-fed sheep. The products have extended lifecycles. The manufacturing plants continually strive to reduce their environmental footprint through training of the employees in regard to environmental awareness in sustainable communities. Further, the GSC includes recycling process waste and finished carpet at the end of its life. The company contributes positively to the leadership in energy and environmental design building certification criteria as a part of the recognition of its sustainability credentials. The company meets the stringent standards of the Carpet and Rug Institute Green Label Plus programme thereby contributing to a healthy indoor environment.

The company utilises five constructs for their GrBSc-based SC framework. Three of these are leading and two are lagging. Organisational commitment, eco-design, and GSC processes are considered as leading constructs while social and sustainable performances are treated as lagging constructs. Considering these five constructs a green causal relationship is designed (Figure 1). These constructs contain sub-constructs and sub-sub-constructs as illustrated in Figures 234. The sub-constructs and sub-sub-constructs considered for the GSC performance measurement are collated from the reported studies (Cheffi and Dey 2012; Dey and Cheffi 2012; Hervani, Helms, and Sarkis 2005; Olugu, Wong, and Shaharoun 2010; Rao 2002; Rao and Holt 2005; Thipparat 2011; Tsoulfas and Pappis 2008; van Hoek 1999; Zhu, Sarkis, and Lai 2007a, 2007b,2008).

3.1 Five-step procedure

Both primary and secondary methods of data collection are administered in this research. Some of the holistic constructs, sub-constructs and sub-sub-constructs for the GSC performance approach are obtained from a detailed literature research. These constructs are collated to form a logical structure so as to develop a green causal relationship (Figure 1). A number of researchers in the arena of GSC performance measurement are asked to comment on the proposed GrBSc-based performance framework. Their opinions contribute to the CDM approach in building the GrBSc framework. A fuzzy ANP approach is considered and a five-step procedure (Figure 5) is followed to implement the GrBSc framework.

Figure 1 The green causal relationship.

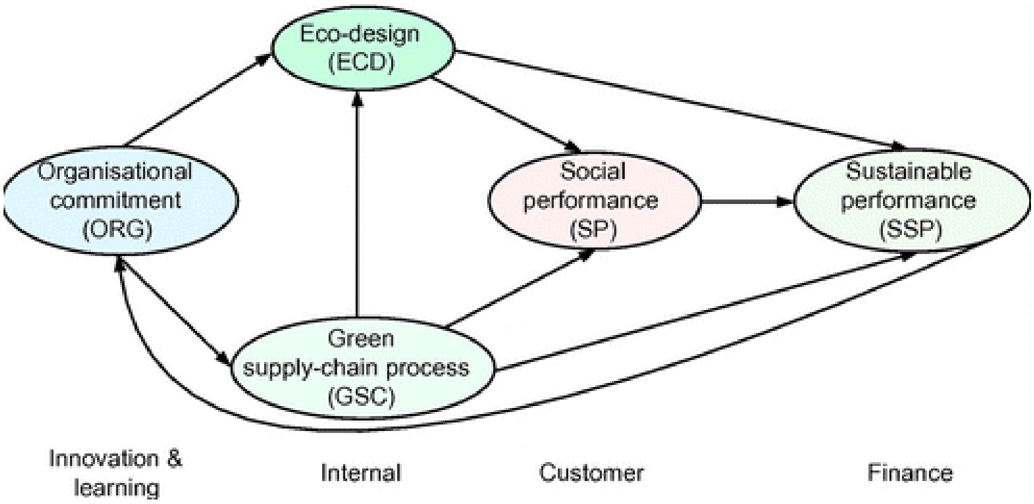


Figure 2 GSC constructs.

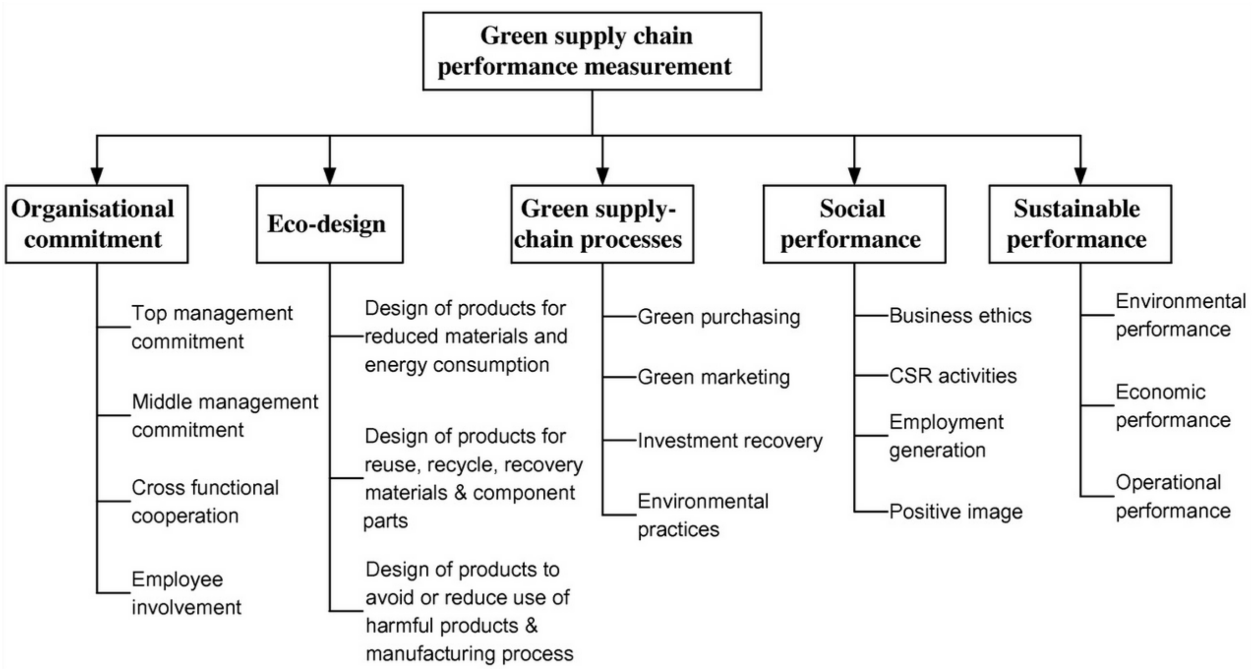


Figure 3 Sub-constructs for 'green supply chain processes'.

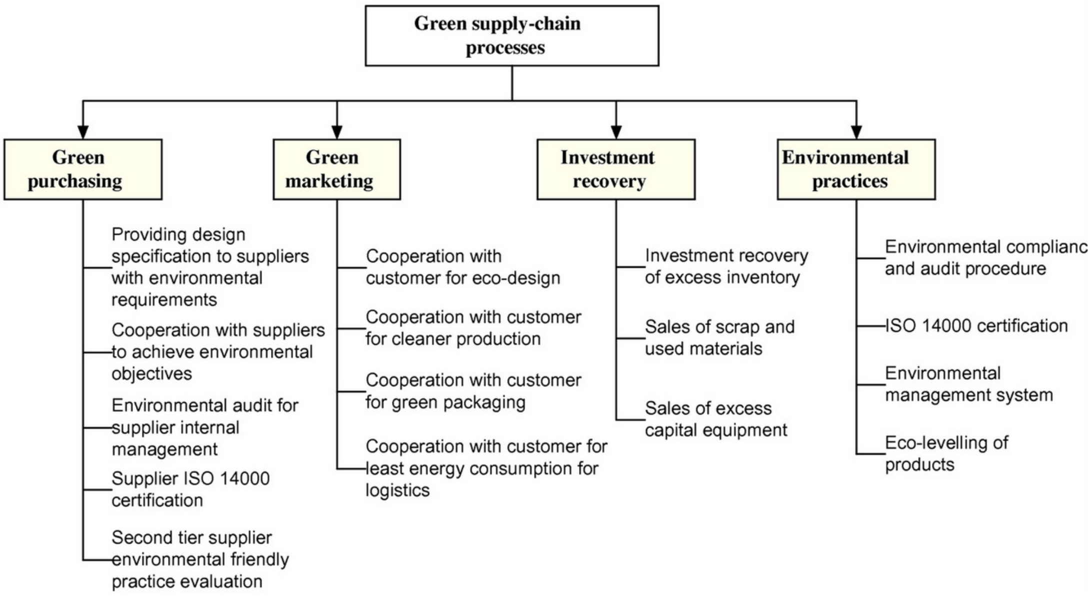


Figure 4 Sub-constructs for 'sustainable performance'.

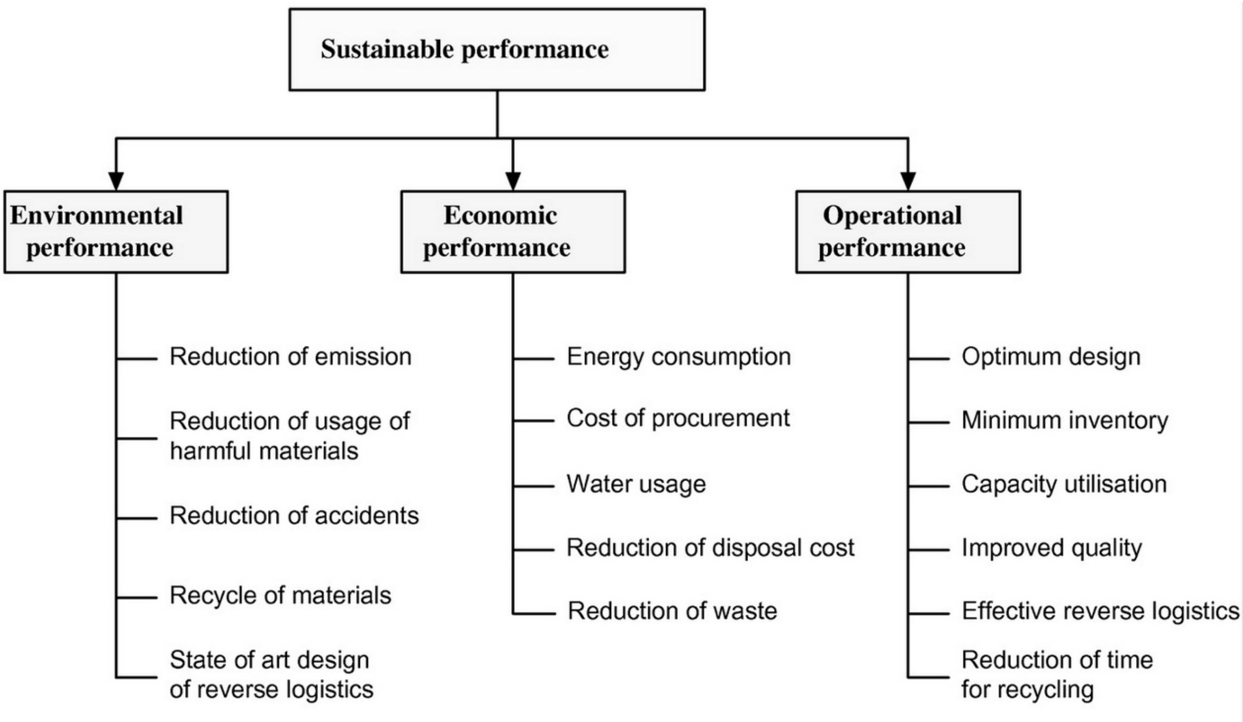


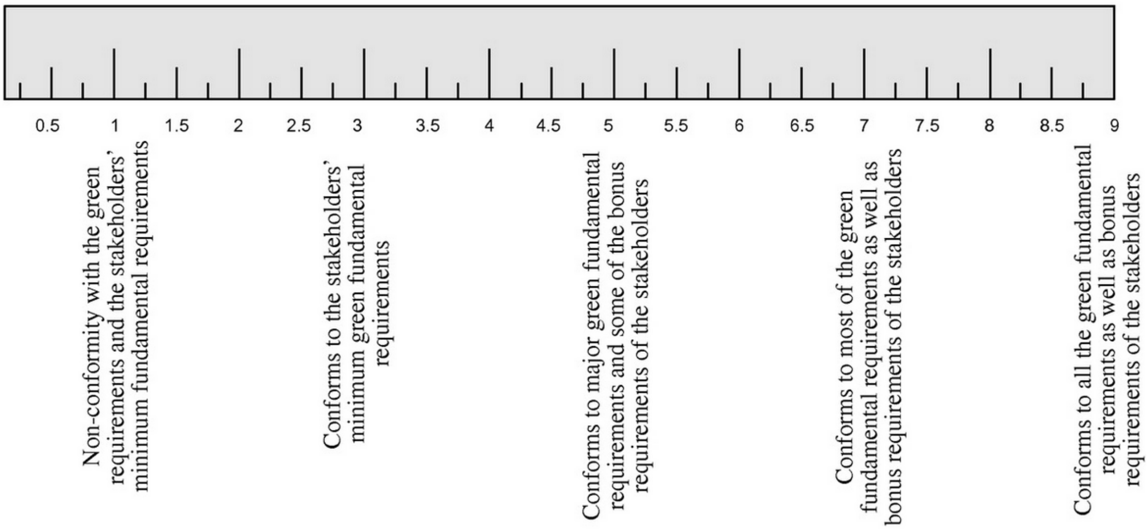
Figure 5 The five-step procedure for the implementation of GrBSc.

3.2 CDM through fuzzy ANP

ANP is a qualitative multi-attribute decision-making approach providing structured communication to address business problems. In this research, ANP is used within the GrBSc framework as it provides a collaborative trade-off under the complexity of multi-criteria environment. ANP is a comprehensive decision-making method that elucidates the interdependencies; reflects the dependencies as quantitative outcome; and simultaneously provides feedback within and between the clusters of elements (Ravi, Shankar, and Tiwari 2005). Therefore, ANP focuses dependency within a set of elements, i.e. inner dependence, and among different sets of elements, i.e. outer dependence (Saaty 1996). The methodology has a non-linear structure dealing with sources, cycles and sinks while having a hierarchy of linear form, like AHP (Ravi, Shankar, and Tiwari 2005). In this research, the CDM approach works in two linked segments. One segment influences the dependencies of constructs, sub-constructs and sub-sub-constructs through building network while the other segment generates a network having control over all the elements and clusters.

Qualitative feedback is received from the collaborative group of the manufacturing company in terms of linguistic preferences which are then converted into importance weights using the CDM scale based on Saaty (1980) (Figure 6). This feedback contains imprecise and vague information having conflicting-in-nature criteria with incommensurable units of measurement. Therefore, a structured way to process such imprecise and vague information is introduced using a triangular fuzzy membership function. Fuzzy sets are able to resemble human decisions. Further, fuzzy triangular numbers transform the qualitative linguistic preferences into quantitative forms.

Figure 6 CDM scale (adapted from Bhattacharya, Geraghty, and Young 2010).



The fuzzy ANP method presented in this paper is an extension of the fuzzy AHP approach presented in Chan et al. (2008). This research adopts the process of obtaining the fuzzy numbers as elucidated in Chan et al. (2008). The identical notations are used as those of Chan et al. (2008) and these fuzzy numbers are infused into the ANP approach. A tilde '∼' on a letter is used to designate a fuzzy number. The triangular fuzzy number is represented by N = (n_{p1}, n_{p2}, n_{p3}), where n_{p1}, n_{p2} and n_{p3} refer to the smallest possible, the most promising and the largest possible preference weights for the 'p'th row of a decision-matrix, respectively.

The following fuzzy algebra has been adopted from Chan et al. (2008) in order to compute the triangular fuzzy numbers for the proposed fuzzy ANP method:

N^{J}_{oi}: The triangular fuzzy numbers (where i = 1, 2, …, n and j = 1, 2, …, m); and

W: A non-fuzzy number known as priority weight.

For N_1 = (n_{11}, n_{12}, n_{13}) and N_2 = (n_{21}, n_{22}, n_{23}), the ordinate of the intersecting point is calculated as

$$V(N_2 \geqslant N_1) = \frac{n_{11} - n_{23}}{(n_{22} - n_{23}) - (n_{12} - n_{11})} \quad (1)$$

In the matrix, a comparison between and is required to be made to justify the judgemental values. In order to do so, both the values of and are required to be computed.

Chan et al. (2008) defines the degree of possibility for a convex fuzzy number to be greater than 'k' convex fuzzy number N_i (where i = 1, 2, …, k) as:

$$\begin{aligned} V(\tilde{N} \geqslant N_1, N_2, \ldots, N_k) &= V[(N \geqslant N_1) \text{ and } (N \geqslant N_2) \text{and} \ldots \text{and } (N \geqslant N_k)] \\ &= \min V(N \geqslant N_1),\ i \\ &= 1, 2, \ldots, k \end{aligned} \quad (2)$$

Chan et al. (2008) further defines the weighted vector as:

$$W_P = (m(P_1), m(P_2), \ldots, m(P_n))^T \text{ where } P_i(i = 1,\ 2,\ 3, \ldots., n) \text{ are } n \text{ elements} \quad (3)$$

This relation W_p of holds for

$$m(P_i) = \min V(N_i \geq N_k) \text{ (where } k = 1,\ 2,\ \ldots, n \text{ and } k \neq i) \quad (4)$$

Normalisation of W_p generates normalised weight vectors:

$$W = (w(P_1), w(P_2), \ldots, w(P_n))^T \quad (5)$$

where W is a non-fuzzy number that provides priority weights of one alternative over other.

4 Case study of a manufacturing industry

The UK-based carpet-manufacturing company has a stringent environmental policy reviewed through external audit. The company under consideration achieves all emissions and energy consumption targets of the regulators. There is no reverse logistic system in place for their products. There is no environmental performance measurement framework in practice for measuring carbon footprint, carbon offsetting, etc. Further, the company does not use renewable energy.

The manufacturing company has a dedicated marketing team that remains in touch with its customers. Interviews revealed that there are several issues that need to be addressed in order to improve information integration with customers. These evolve mainly due to fast-changing customer requirements. In addition, customers often change their requirements even after placing the orders. Moreover, there is evidence of order cancellation and delay in processing during production because of communication gaps. Hence, there remains room for improvements in information integration that may result in improvement to the overall green performance of the SC.

The company's environmental policy allows purchasing materials only from reliable and recognised suppliers, who can conform to the company's stringent environmental requirements. They have more than 300 suppliers of which around 20 suppliers are strategic, i.e. with long-term relationship. The company's purchasing procedures are audited by the British Standard Institute as a part of the company's ISO 9002 certification process. All the chemicals used conform to COSHH regulations. The company has also initiated special agreements with suppliers to ensure that all containers and other materials brought on to the company's premises are either returned to the manufacturer for recycling or are disposed of by safe, secure and legal methods. The introduction of the ISO 14000 certification standard focuses attention on the environmental impact performance of the firm's processes. Purchase is one of the key processes, which is assessed in ISO 14000 because it is responsible for not only procurement of the materials but also their disposal at the end of their useful life.

4.1 Collaborative decision-making

Development of a set of green performance measurement constructs for GrBSc involves a complicated process and is challenging for businesses. Although in a typical firm a certain number of performance metrics are prevalent for assessing its financial performance, GSC-related performance metrics have not been widely adopted as businesses are typically uninformed of them. Firms often find that there is a lack of operational guidelines on how to develop performance measurement criteria and constructs (Lapide 2000). Therefore, a group decision-making process assists in developing GSC performance measurement metrics and criteria hierarchically across the cross-functional levels. Stakeholders of the carpet-manufacturing firm are selected from the following departments: marketing, production, purchasing, information, projects and human resources. Six key actors are selected from each stakeholder for their participation in the interviews. The interviewees from each stakeholder comprise one person from manager, deputy manager and assistant manager levels, and three key officers.

There are many decision points and variables within the company's decision-making processes. They are complex and need consideration of multiple factors and the involvement of various stakeholders. Although the decisions are currently being made with the involvement of concerned stakeholders, an appropriate collaborative decision-support system could help to standardise decision-making processes for making the right decision quickly. The company works closely in a coordinated manner with their strategic suppliers, viz. wool and jute manufacturers. They coordinate with their suppliers when making critical decisions with regard to materials specification, design option selection and production planning.

A focus group has been formed within the manufacturing company to consider decision-support aspects. This group comprises persons from each stakeholder, viz. marketing, production, purchasing, information, projects and human resources. All members of the group have more than 20 years of experience in manufacturing and have at least five years of experience with the company. They have been briefed on the objectives (GSC performance measurement). The GSC performance method is then explained to them including the rationale for each construct and their inter-relationships. The fuzzy ANP method is then elaborated in order to explain not only how the GSC performance method is to be undertaken but also to allow them to understand its rationale for selection. Next, the participants are asked to compare pairwise the high-level constructs for deriving their importance. Subsequently, they also compare sub-constructs pairwise. These comparisons are synthesised using the fuzzy ANP framework to determine the importance of all the bottom-level sub-constructs. Each functional manager is then asked to derive his/her GSC performance against each bottom-level sub-constructs.

The group forms a consensus decision in linguistic terms under the chairmanship of the operational director of the company. The process of decision-making is collaborative as flow and subsequent sharing of information is from one functional area to another. The procedures of performance measurement have been explained to the group within a workshop environment.

A questionnaire-based survey (Figure 7) is administered to the group. The responses are then collated and overall performance of the GSC is derived using the fuzzy ANP-based BSc approach. The CDM assists in obtaining a green causal relationship. The fuzzy ANP assists in capturing the level of vagueness of the information contained in the outcome of the consensus CDM process. BSc is tabulated to assess the development of the green performance and its dependent elements in the causal relationship.

4.1.1 Normalised weight for constructs and sub-constructs

The performances of the elements of the green causal relationship (Figure 1) are to be captured, viz. organisational commitment, ecological design, social performance, GSC processes and sustainable performance. Considering the causal relationship an ANP network is formed (Figure 8).

Figure 7 Sample questionnaire on green purchasing strategy of the company.

Q 1. What is your company environment policy? How do you ensure that your suppliers follow similar environment policy?

Q 2. How do you keep track if suppliers are following the designed environmental procedure?

Q 3. How do you ensure your supplier is following environmental friendly manufacturing process, in line with the national and international regulations?

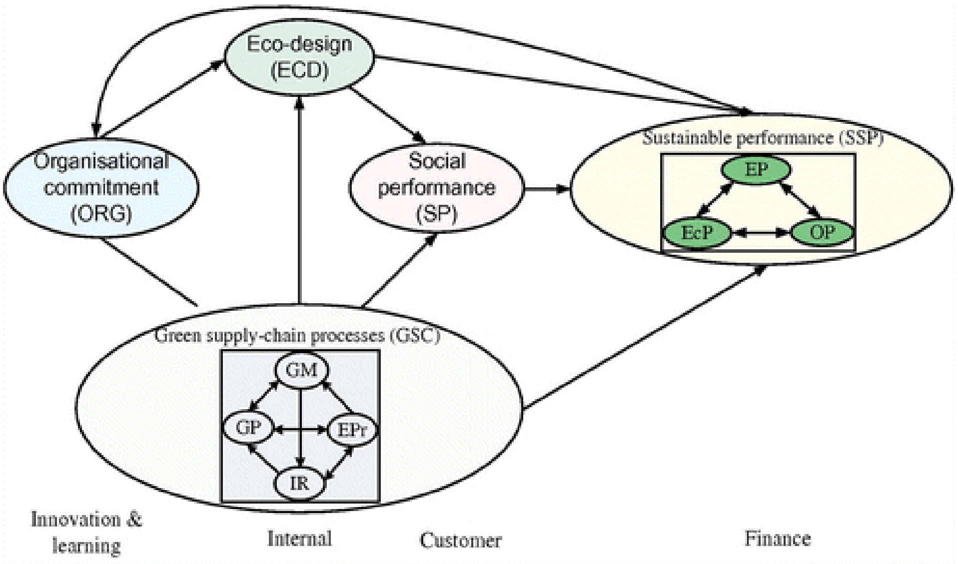
Q 4. Is there any third party accreditation exists?

Q 5. What arrangement do you have to take back your product for remanufacturing or disposal?

Q 6. How efficient is this process in 1 to 9 scale?

Q 7. What action do you take to ensure consideration of ethical issues during procurement?

Figure 8 Collaborative ANP network illustrating the causal relationship.



The linguistic preferences for the company are now obtained from the group and those qualitative preferences are translated into a quantitative meaning using fuzzy ANP involving Equations (1)–(5). Pairwise comparison matrices are formed (Figures A1 and A2 of Appendix) taking into consideration the sub-constructs embedded within each construct. Interdependencies of the constructs are established once the fuzzy quantitative measures for the linguistic preferences are obtained (Figure A3 of Appendix).

Super decision matrix (Table 1) using the ANP approach is constructed. It is to be noted that the decision-makers (i.e. the formed group in CDM phase) have provided their level of importance on the constructs ORG, ECD, GSC, SP and SSP. These are found to be 25, 17, 20, 13 and 25% respectively. The following realistic technique (Yüksel and Dağdeviren 2010) is considered to obtain the preference weights of the super decision matrix. This procedure is followed throughout this paper in order to compute the preference weights of the super decision matrices (Tables23).

$$\begin{bmatrix} 0 & 0.7719 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0.9124 & 0.4895 \\ 0 & 0.2281 & 0 & 0.0875 & 0.2106 \\ 0 & 0 & 0 & 0 & 0.2997 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix} \times \begin{bmatrix} 0.25 \\ 0.17 \\ 0.20 \\ 0.13 \\ 0.25 \end{bmatrix} = \begin{bmatrix} 0.331 \\ 0.241 \\ 0.103 \\ 0.075 \\ 0.250 \end{bmatrix}$$

Table 1.Super decision matrix.

	ORG	ECD	GSC	SP	SSP	Weight
ORG	0	0.7719	1	0	0	0.331
ECD	0	0	0	0.9124	0.4895	0.241
GSC	0	0.2281	0	0.0875	0.2106	0.102
SP	0	0	0	0	0.2997	0.075
SSP	1	0	0	0	0	0.250

The causal relationship among the elements of 'GSC processes' is shown in Figure 9. Four elements, viz. green purchasing, green marketing, environmental practices and investment recovery, are considered in order to build this relationship. A similar procedure is followed in order to obtain fuzzy decision matrices, interdependency matrices (Figure A4 of Appendix) and super decision matrix (Table 2).

Figure 9 Relationship within 'green supply chain process'.

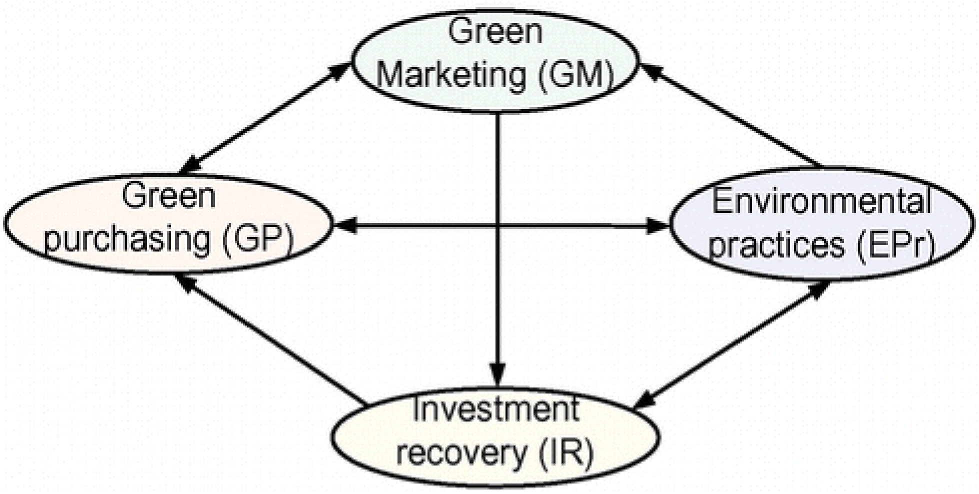


Table 2.Super decision matrix.

	GP	GM	IR	EPr	Weight
GP	0.000	0.244	0.000	0.641	0.2882
GM	0.715	0.000	0.500	0.000	0.2930
IR	0.195	0.000	0.000	0.359	0.1962
EPr	0.090	0.756	0.500	0.000	0.2226

The causal relationship for a 'sustainable performance' construct is built (Figure 10). The sub-constructs 'environmental performance', 'economic performance' and 'operational performance' interact with each other and bind the relationship. Similar procedure is followed to obtain fuzzy decision matrices, interdependency matrices (Figure A5 of Appendix) and super decision matrix (Table 3).

Figure 10 Relationship within sustainable performance.

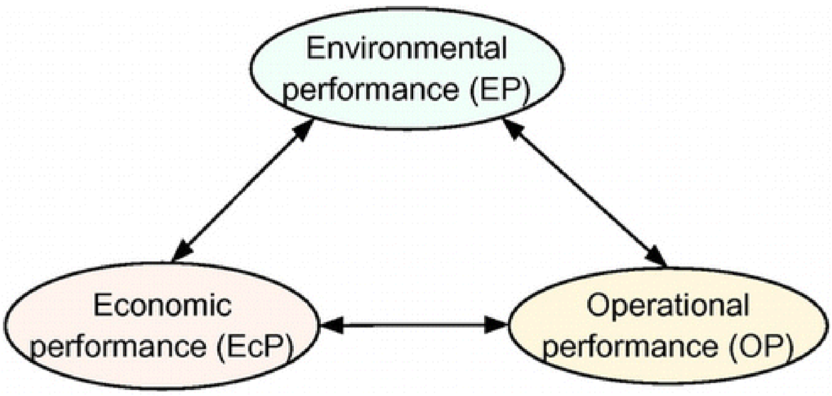


Table 3 Super decision matrix.

	EP	EcP	OP	Weight
EP	0.000	0.359	0.595	0.351
EcP	0.756	0.000	0.405	0.330
OP	0.244	0.641	0.000	0.319

5 Results and discussion

The preference weights obtained from the super decision matrices are processed so as to have global priority (GP) values. GPs are the performance measures for the SC constructs, sub-constructs and sub-sub-constructs of the carpet-manufacturing company. GPs are calculated by multiplying the normalised weight of constructs, sub-constructs and sub-sub-constructs. An example of the computational process is elucidated below (for 'organisation commitment' construct),

Similarly, the remaining GPs are calculated and these are reflected in the green BSc (Figure 11). From Figure 11, the percentage contribution of the construct, sub-construct and sub-sub-construct responsible for evaluating the performance of the GSC is apparent.

Figure 11 Green balanced scorecard.

$$\begin{aligned}\mathrm{GP} &= \text{Weight of constructs } (ORG) \\ &\times \text{ Sub-constructs } (\textit{top management commitment}) \\ &= 0.331 \times 0.1667 = 0.055.\end{aligned}$$

Organisational commitment contributes 33.1% in the performance evaluation while eco-design, GSC processes, sustainable performance and social performance contribute 24.1, 10.3, 25 and 7.5% respectively. This is illustrated in Figure 12. Contributions of the sub-constructs and sub-sub-constructs play a pivotal role in coming up with corrective measures for performance improvement. Figures1314 elucidate contribution of sub-constructs embedded within GSC processes and sustainable performance.

Figure 12 Contribution of the SC-constructs.

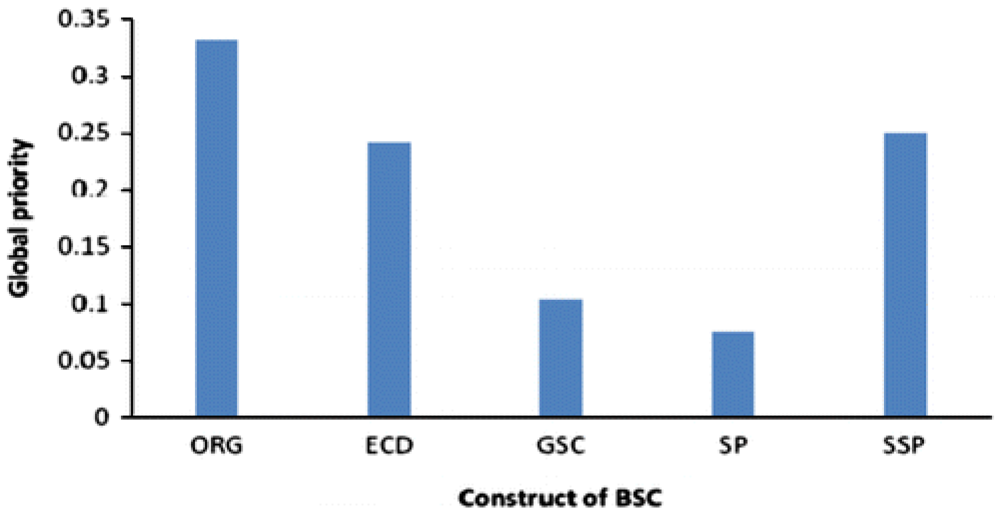


Figure 13 Contribution of the sub-constructs within GSC processes.

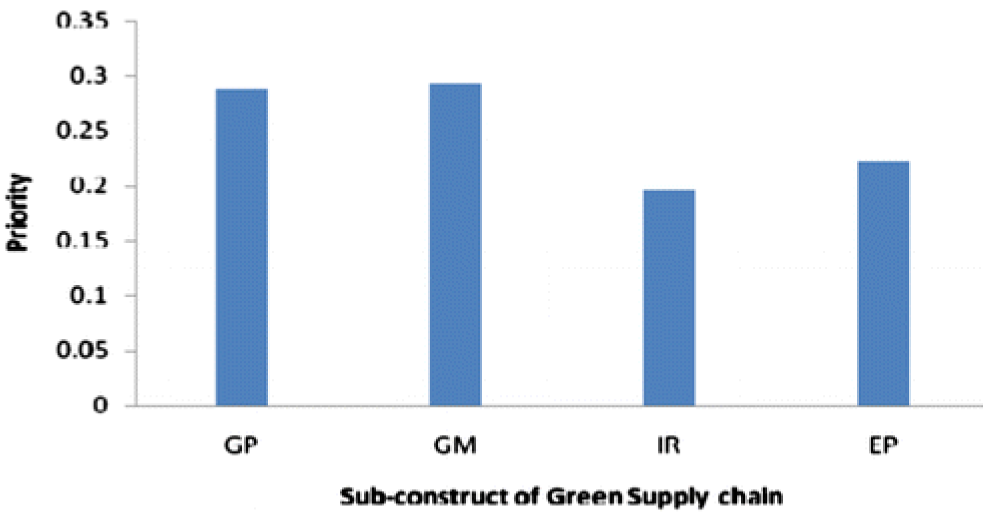
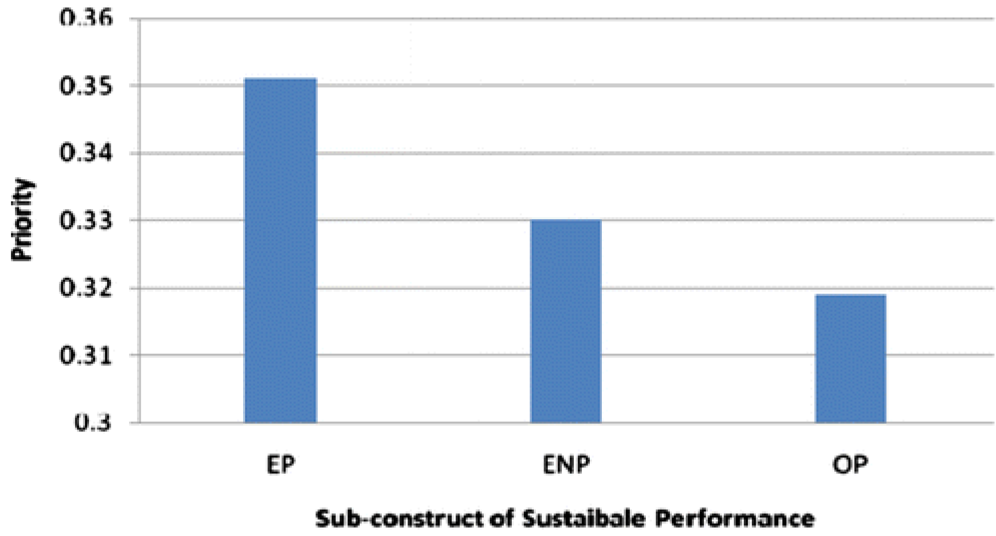


Figure 14 Contribution of sub-constructs within sustainable performance.



The group formed within the carpet-manufacturing company has thoroughly reviewed the entire data and its analysis in order to validate the CDM approach. They are satisfied with the outcomes as they are able to measure GSC performance of the organisation concerned and its SC. The performance evaluation has suggested possible improvement measures that would improve the sustainability of the entire SC.

6 Conclusions

A GSC performance measurement framework for a UK-based carpet-manufacturing firm has been elucidated using an intra-organisational CDM approach through a fuzzy ANP-based GrBSC framework. A green causal network is established involving organisational commitment, eco-design, GSC process, social performance and sustainable performance constructs. Sub-constructs and sub-sub-constructs are identified and linked to the causal relationship. The performance measurement approach aids in making decisions of the manufacturing firm in regard to the overall organisational goals. The implemented approach assists the firm in identifying if it requires further collaborative data across the supply chain. CDM plays a pivotal role in understanding the critical evaluating elements of performance measurement (Alfalla-Luque, Medina-Lopez, and Dey 2012; MacCarthy and Jayarathne 2012; Ulbrich et al. 2011; Verdecho, Alfaro, and Rodriguez-Rodriguez 2009). The CDM-based GrBSC approach assists managers in deciding if the suppliers' performances meet the industry and environment standards and the human resource is effective. The GSC performance measurement metrics and criteria are identified and developed using the group decision-making process across the cross-functional decision-making levels. The process of decision-making is collaborative as flow and subsequent sharing of information is from one functional area to another.

Holistic constructs of the firm are presented that cover the entire SC network, i.e. upstream and downstream companies along with the focal organisation. Wynder (2010), while reporting a BSc framework with an emphasis on the relationships between leading and lagging performance measures, considers the impact of environmental performance by integrating environmental measures into the organisational strategy map. Thus, reactive and proactive subjective factors are considered in performance evaluation. The factors cover environmental, social, economic and operational aspects of the SC. An analytical framework is adapted to measure GSC performance involving all concerned stakeholders thereby aiding in decision-making in strategic, tactical and operational levels.

The practical implication of this research is diverse. Managers of organisations would benefit in terms of decision-making performance and better managerial decision-making should result in improved company performance. Scope to analyse and benchmark an organisation's environmental initiatives across the entire SC is indicated in this research. The empirical investigation into the UK-based carpet-manufacturing company shows that internal operations play a pivotal role in assessing environmental performance. It has also been revealed that internal operations are dependent on suppliers' activities. The outcome of environmental initiatives and the level of integration of the SC may encourage managers to pay more attention to audit and performance thereby improving overall GSC performance.

This empirical investigation into GSC performance measurement determines the scope for further improvement between the company and suppliers in regard to collaborative information sharing, communication, eco-design and sustainable SC performance. Further, the outcome of the investigation generates room for improvement in regard to supplier–customer–company relationship and various other improvement initiatives to achieve better green supply chain performance of the company. The limitation of the study lies in the unscrupulous use of Saaty's nine-point scale in arriving at a predetermined consensus opinion during the CDM process.

Although the company has stringent purchasing procedures, there is no evidence that their suppliers have green environmental practices embedded in their manufacturing processes. Therefore, more emphasis should be placed on environmental issues by identifying and implementing key environmental indicators, viz. biodegradable product, environment friendly packaging, and recycling. Further, the purchasing managers of the company feel that there is room for improvement in providing more technical support to suppliers. Future research could include implementation of the case with a more efficient CDM approach such as integrated fuzzy multi-criteria planning tool combining quality function deployment and ANP.

[Appendixes unavailable in this version]

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