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Sustainable supply chain management: A closed-loop network hierarchical approach

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Abstract

Purpose – Assessing a measure of sustainable supply chain management (SSCM) performance is currently a key challenge. The literature on SSCM is very limited and performance measures need to have a systematic framework. The recently developed balanced scorecard (BSC) is a measurement system that requires a balanced set of financial and non-financial measures. The purpose of this paper is to evaluate the SSCM performance based on four aspects i.e. sustainability, internal operations, learning and growth, and stakeholder.

Design/methodology/approach – This paper developed a BSC hierarchical network for SSCM in a close-loop hierarchical structure. A generalized quantitative evaluation model based on the Fuzzy Delphi Method (FDM) and Analytical Network Process (ANP) were then used to consider both the interdependence among measures and the fuzziness of subjective measures in SSCM.

Findings – The results of this study indicate that the top-ranking aspect to consider is that of stakeholders, and the top five criteria are green design, corporate sustainability, strategic planning for environmental management, supplier cost-saving initiatives and market share.

Originality/value – The main contributions of this study are twofold. First, this paper provides valuable support for supply chain stakeholders regarding the nature of network hierarchical relations with qualitative and quantitative scales. Second, this paper improves practical performance and enhances management effectiveness for SSCM.

Keywords Balanced scorecard, Stakeholder theory, Analytical network process, Fuzzy Delphi method, Fuzzy set theory, Sustainable supply chain management

Paper type Research paper

1. Introduction

Sustainable business development has received attention over the last few decades because of the significant focus in the electronic supply chain network on environmental, social and corporate responsibility (Ahi and Searcy, 2013). In addition, the markets and operations have prompted firms to revisit their corporate, business and functional operations and to aim for sustainable supply chain management (SSCM) (Ageron *et al.*, 2012). Recognizing the importance of sustainability in supply chain management, there have been attempts made to develop an evaluation performance framework. An efficient and accurate performance measurement framework can serve as a useful tool that enables management to control, monitor and improve their firms' processes and performance. Hence, Kaplan and Norton (1992, 1996) have proposed a balanced scorecard (BSC) to assess business performance using financial and non-financial indicators. The BSC enables the expression of business performance indicators and

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thus ensures the framework required for the performance measurement of management functions. Nevertheless, the framework is a multi-hierarchical structure of dependence relations with a close-loop structure for the aspects and criteria of an organization. The existing SSCM literature fails to address these issues for performance assessment (Carter and Rogers, 2008; Seuring *et al.*, 2008; Ageron *et al.*, 2012; Gopalakrishnan *et al.*, 2012; Walker and Jones, 2012; Ahi and Searcy, 2013).

In the literature, sustainability has become a trend, and it enables firms to integrate environmental and social issues into their corporate strategies (Srivastava, 2007). Firms are increasingly aware of the importance of their responsibility toward their stakeholders to address sustainability in their strategic development, and this environmental sustainability is impossible without incorporating SSCM (Preuss, 2005; Bai and Sarkis, 2010). SSCM is characterized by the explicit integration of environmental and social objectives that extend the economic dimension to integrate environmental and social considerations (Tseng, 2013). Carter and Rogers (2008) defined SSCM as the strategic integration and achievement of an organization's social, environmental and economic goals in the systemic coordination of key internal business processes for improving the long-term performance of the individual firm and its supply chains. Gupta and Palsule-Desai (2011) presented a set of SSCM managerial practices that consider environmental impact, value chain and multi-perspectives on the entire product life cycle. However, a comprehensive review of SSCM studies has been presented in several studies (Seuring *et al.*, 2008; Seuring and Müller, 2008; Gupta and Palsule-Desai, 2011; Zailani *et al.*, 2012; Liu *et al.*, 2012; Ahi and Searcy, 2013). The SSCM on the performance measure is currently unavailable, and thus, a performance approach toward the examination of SSCM is needed.

From a theoretical perspective, the concept of SSCM integrates the environmental, social, and economic aspects that allow an organization to achieve long-term economic viability in supply chain management (Tseng *et al.*, 2008; Kuo *et al.*, 2001; Tseng and Chiu, 2013). It is also a strategic factor for increasing a firm's effectiveness and for better realizing sustainable organizational goals to enhance competitiveness, achieve better customer service and increase profitability. In particular, SSCM includes the movement and storage of sustainable raw materials and green products from the point of origin to a point of sustainable consumption (Brandenburg *et al.*, 2014). The provision of sustainable products that are required by end customers in a supply chain involves the cooperation of interconnected networks, channels and node businesses. From a traditional firm's point of view, the shareholders are the owners of a company, and the firm has a binding fiduciary duty to meet needs and increase value in a supply chain. Even competitors are counted as stakeholders, and their status is derived, in this view, from their capacity to affect the firm and its stakeholders (Donaldson and Preston, 1995; Friedman and Miles, 2002). In lieu of this, most of these firms realize that, in order to evolve, they must develop an efficient and effective sustainable supply chain, which needs to be assessed based on its performance (Tseng and Geng, 2012). Hence, the stakeholder theory and the BSC model are the basic theory and model for this performance evaluation.

In the BSC model, there are four aspects that need to be balanced for SSCM performance measurement; these include sustainability, stakeholders, internal business process, and learning and development (Kaplan and Norton, 1996), and they integrate environmental and social aspects with economic performance. Wu *et al.* (2010) proposed a corresponding fuzzy scale to evaluate the linguistic preferences within close-loop hierarchical BSC structures that can clearly reflect performance and importance weights. Chen *et al.* (2011) asserted that the BSC approach is an effective technique for a hybrid multi-criteria decision-making (MCDM) model performance evaluation in order to solve the dependence and feedback problems at a hot spring hotel. Lin *et al.* (2013) explored and built a BSC structure with fuzzy linguistic preferences for measuring and improving hospital services. The BSC quantitative models are often practically applied in an open-structure framework. In this context, the BSC framework ought to focus on close-loop evaluation in order to fulfill the existing gaps in the SSCM literature (Linton *et al.*, 2007; Matos and Hall, 2007; Miemczyk *et al.*, 2012; Zailani *et al.*, 2012; Abbasi and Nilsson, 2012; Tseng and Chiu, 2013; Zhu *et al.*, 2013; Tseng, 2013). A further understanding of the common and unique SSCM evaluation characteristics is necessary to help further catalyze this study, which offers numerous opportunities to improve firm performance.

Existing studies have informed managers of the interdependence between environmental and economic systems, but they fall short in explaining how a firm handles the performance criteria of different BSC aspects from a typical case. Few SSCM existing studies have presented an evaluation of qualitative and quantitative information together. For instance, Wu and Pagell (2011) presented theory-building through case studies to balance profitability and environmental sustainability when making supply chain decisions under uncertainty. Lin and Tseng (2014) adapts a hierarchical structure and linguistic preferences to identify the competitive priorities under SSCM. However, the previous studies are ignored the qualitative and quantitative information together. The purpose of this study is to make sense of the complex SSCM environment to address information complexity and uncertainty, and to recommend actions that induce change. Hence, this study proposes a fuzzy set theory to transform linguistics preferences into crisp numbers, the Fuzzy Delphi method (FDM), to eliminate the performance criteria under perceptions and the analytical network process (ANP) to resolve the interdependent relationships in a complex environment. Therefore, this study focuses on SSCM in both BSC aspects and practical criteria. The study questions are as follows:

(1) What are these criteria?

(2) What are the important aspects and criteria as they relate to current SSCM performance practice under uncertainty and interdependent relationships?

SSCM leads to a reduction in resources, material and waste by enabling better resource utilization and plays a significant role in achieving social, environmental, and economic performance; thus, it contributes to the field of sustainable development. Its main contribution is to present and organize the key performance aspects for BSC and the criteria concerning the effects of SSCM on the sustainable supply chain performance of the focal firm. The paper is organized as follows. First, there is a BSC performance evaluation of the role of the BSC framework in SSCM and a review of the literature on the study criteria followed by the development of the SSCM-BSC framework in Section 2. Section 3 presents the method and data analysis. Then, data from an expert linguistic preference questionnaire survey of professionals in a focal electronic manufacturing firm are used to examine the answers to the study questions. The data were then analyzed using the FDM and the fuzzy ANP. The results are discussed in Section 4. This discussion is a hierarchical model, for which the aspects and criteria are presented in hierarchical and interdependent relationships under the condition of uncertainty. The last section presents the discussion, implications, contributions and limitations, and conclusions.

2. Literature review

In SSCM literatures, non-financial indicators are widely used for operational management. There are two major perspectives: financial indicators for management teams and the view of the SSCM professionals. The BSC measurement models aim to effectively integrate these two perspectives. This section examines the BSC model and corporate with stakeholders; SSCM development and the aspects and criteria are discussed.

2.1 BSC

The BSC is one of the most widely used methods for the performance measurement model. Traditionally, it is used to measure results for the vast majority of organizations, centered exclusively on financial indicators. Currently, it is widely recognized that non-financial and even intangible indicators can also provide valuable information (Leung *et al.*, 2006). However, although there have been many studies that have presented intangible indicators in the BSC model, few BSC models have included considerations of the stakeholders in the traditional model. In lieu of this, combining the BSC aspects and the stakeholders' interests, BSC helps managers to understand dependent relationships and aspects, which can lead to improved decision-making and problem solving (Marshall *et al.*, 2010; Houck *et al.*, 2012). Banerjee *et al.* (2003) defined "an environmental stakeholder as individuals or groups that can affect or be affected by the achievement of a firm's environmental goals." Environmental pressures derive from a wide variety of stakeholders, including regulators, community members, suppliers and consumers. This study has modified the customer aspect of the traditional BSC model into the stakeholders' aspects.

Tseng (2010) described the scarcity of literature regarding how the BSC, with dependent and interactive relationships, should be properly implemented under uncertain conditions and proposed an approach that hybridizes the ANP to analyze the dependent aspects, the decision-making trial and evaluation laboratory method to address the interactive criteria, and the fuzzy set theory to evaluate the uncertainty. Houck *et al.* (2012) presented the BSC as a performance measure matrix designed to capture financial and non-financial metrics that provide insight into the critical success factors for an organization, effectively aligning organization strategy to key performance indicators. The BSC has begun and continues to be a resource for performance evaluation of a given firm and its business environment. The evaluation must begin with top management and extend throughout to all employees and, therefore, to the supply chain. Houck *et al.* (2012) modified the traditional BSC evaluation within a firm and added the value chain to create the internal process value. However, the BSC approach has little chance of success because the BSC model is hard to express in closed-loop and network hierarchical relationships.

2.2 SSCM

The term "sustainability" has been interpreted in a variety of ways, ranging from an inter-generational philosophical position to a multi-dimensional term for business management. Early sustainability initiatives tended to focus on environmental issues but, over time, they have increasingly adopted environmental, economic, and social perspective-driven approaches to sustainability. The definition of SSCM is "the set of supply chain management policies held, actions taken, and relationships formed in response to concerns related to the natural environment and social issues with regard to the design, acquisition, production, distribution, use, reuse, and disposal of the firm's goods and services" (Haake and Seuring, 2009). Zailani *et al.* (2012) indicated that SSCM has had a positive effect on sustainable supply chain performance, particularly from the economic and social perspective. Few studies have presented this missing alignment for SSCM performance measurement.

Currently, operations, purchasing and supply chain managers are seeing the integration of environmental and social issues, including those embedded in related standards (e.g. ISO 9001 and ISO 14001, etc.), into their daily tasks. In addition, Seuring and Müller (2008) emphasize that there is a need for increasing cooperation along the supply chain, if sustainability goals are to be reached. The stakeholders have their roles in the supply chain to ensure sustainability. Hence, this perspective of SSCM is necessary. In previous studies, Zhu *et al.* (2008) showed that even though there are significant environmental reasons to motivate closed-loop supply chains, regulatory, competitive and economic pressures also play roles in the adoption and implementation of closed-loop supply chains across industries. Guide and van Wassenhove (2009) also introduced the closed-loop supply chain into design, control and operations to maximize value creation over the entire life cycle of products using the difference between dynamic recovery and the return volumes over time. Tseng *et al.* (2013) concluded that closed-loop green supply chain management is approximate to real practice and presented that closed-loop concept precises to conclude the green supply chain management. These prior studies have provided the missing link for performance measures and necessary of thinking closed-loop in analytical framework.

Nonetheless, only few studies are able to describe the results of the real close-loop supply chain framework. The limited understanding of the SSCM close-loop hierarchical structures has hindered the development of a widely accepted framework that can characterize and categorize the BSC activities of relevant firms. This study aims to integrate the importance and performance scales together and demonstrates this in a close-loop hierarchical structure using the BSC model approach.

2.3 The methods

In SSCM literatures, Wu and Pagell (2011) explored the SSCM decision process to understand how firms handle the interplay of business and environmental needs under environment uncertainty. Lin *et al.* proposed a hub-and-spoke integration model to integrate green marketing and SSCM from six dimensions and test the validated integration model. Lin and Tseng (2014) applied interval-valued triangular fuzzy numbers (TFN) to represent the linguistic preferences and used multi-criteria decision-making to assess the hierarchical structure in identifying the ranking of competitive priorities and the tradeoffs of SSCM under uncertainty. Ahi and Searcy (2015) indicated a lack of agreement on how performance should be measured in SSCM using literature review method and anticipated the analysis and composed framework provide a strong basis for academic and practitioners. There are still many shortages from the previous literatures. For instance, the validated method aspect and criteria selection is still lacking and the nature of hierarchical structure is unaddressed in the analytical process (Leung *et al.*, 2006; Lee *et al.*, 2008; Tseng, 2010; Chen *et al.*, 2011; Hsu *et al.*, 2011). In addition, the performance and importance levels are unaddressed on how to evaluate and integrate together.

Prior studies have combined the BSC approach with MCDM techniques, rare studies in SSCM in environment uncertainty. In a rapidly changing information environment, the evaluation of qualitative information is based on perception preferences, and the sources of these perceptions are typically reluctant to assign exact values to their preferences. These qualitative evaluation measures, a more desirable evaluation tool, are governed by the fuzzy set theory (Ishikawa *et al.*, 1993), which is helpful when dealing with the vagueness of human perception. In particular, the fuzzy set theory addresses the ambiguities involved in the process of linguistic estimation by converting linguistic terms into TFN. Hence, this study considers human perception among different qualitative measures using the TFN approach (Tseng *et al.*, 2009a, b). There many studies have adopted the ANP to perform the interdependence relations for performance measurement.

The ANP is a mathematical theory that can systematically handle a multitude of interdependent relationships (Saaty, 1996). This method has been successfully applied in many industrial fields, for example, the electronics industry (Tseng *et al.*, 2009a, b; Tseng and Geng, 2012), information technology (Lee *et al.*, 2008), the semiconductor and manufacturing industry (Yüksel and Dağdeviren, 2010; Hsu *et al.*, 2011), and the hotel industry (Chen *et al.*, 2011). In addition, SSCM has been studied in various industries such as British Aerospace (Gopalakrishnan *et al.*, 2012), the manufacturing industry (Ageron *et al.*, 2012), and semiconductors (Hsu *et al.*, 2011). Furthermore, Hsu *et al.* (2011) applied FDM and ANP together for their open hierarchical structure framework to enhance competitiveness for sustainable operations. Tseng *et al.* (2013) indicated that the evaluation process should have a closed-loop hierarchical structure and closed-loop framework is more accurate to approach on real status. ANP is necessary to form several pairwise comparisons to select the appropriate measures that are based on the perceptions of the relative important, few of them integrated the importance and performance together.

Most of the studies did not address how the proposed aspects and criteria to be formed and have eliminated qualitative and quantitative criteria. Hence, this study proposes to apply FDM that employing an expert's perception for criteria elimination in order to enhance the resource efficacy. Hence, FDM is the integration of decision-making with fuzzy logic theory (Murry *et al.*, 1985). TFN is employed to consolidate fragmented expert opinions (Tsai *et al.*, 2010). Ma *et al.* (2011) applied FDM and the Gray Delphi Method to quantify experts' attitudes on regional road safety, urban road safety and highway safety and found FDM to be feasible and practical for the administrative authority of road safety. Kardaras *et al.* (2013) presented FDM to highlight the service features preferred by the customers and to adapt the presentation media and layout. Hence, FDM is used to capture expert knowledge regarding the SSCM selection. Hence, this study proposes a BSC closed-loop networking hierarchical structure for SSCM evaluation

2.4 The SSCM-BSC measures

"There is a causal relationship between the four perspectives of the balanced scorecard approach" (Kaplan and Norton, 1996, 2004). These causal relations are complex and influence the organization's strategies and are related to its structure. Financial results are the ultimate focus of any business enterprise; learning and growth serve as the foundation. Thus, financial performance can be improved by focusing on learning and growth, internal processes and customers. However, the stakeholders are involved in the sustainable supply chain network. The firm thus has a binding fiduciary duty to put stakeholders' needs first and then to increase value for the firm. The stakeholder view traditionally involves employees, customers, suppliers and other groups. This study proposes a broadening of the stakeholders (Friedman and Miles, 2002) to encompass learning and growth, internal processes, stakeholders and sustainability aspects.

In SSCM, sustainable development and the use of natural resources (fuel, land and water) are considered in the development of a strategic plan, transparent integration, life cycle assessment, and the achievement of an organization's social, environmental and economic goals in the systemic coordination of internal business processes for improving the long-term performance of the individual firm and its supply chains (Gupta and Palsule-Desai, 2011; Kuo *et al.*, 2001; Tseng and Geng, 2012). Preuss (2005) outlines the environmental benefits from their partners in the supply chain, which indicate that the upstream and downstream partners play a key role in supply chain performance and customer satisfaction. Tang and Zhou (2012) observed that the environmental dimension includes the consumption of natural resources and the emission of waste and pollution, while stakeholder aspects are traditionally only related to the customers and supplier. Assessing the literature's usage of sustainability dimensions in the BSC framework in greater detail, e.g. considering which metrics are suitable to represent sustainability factors in formal SSCM and which criteria are used in a holistic SSCM performance framework, would identify what avenues could help further integrate holistic measures and the resulting performance impacts into SSCM.

Usually, the market conditions influence an organization's decision to develop SSCM practices. This influence can be seen at different levels. Customers are aware of their personal environmental impact, and in the name of being environmentally friendly, they are willing to pay more for green products (Rao, 2002). Lambert *et al.* (2006) wrote that SSCM refers to "the integration of key business processes from end-user through original suppliers, that provides products, services, and information that add value for customers and other stakeholders." Tseng (2013) identified the sustainable production indicators for overhauling the production process to achieve the firm's goal of waste elimination, reduce environmental impact and enable the firm's continuous improvement regarding environmental matters, with great emphasis on green product development in a competitive and sustainable market. Additionally, a green product is characterized by a key rule: it should be designed to close the materials loops to minimize the impact on the environment (Tseng *et al.*, 2013; Wang *et al.*, 2015).

The perspective of sustainable development focuses on the environment, economy, and society. Consequently, a firm typically prioritizes the organization, working towards profit maximization within the ambit of laws and ethics, in an attempt to be socially responsible and responsive to the society. However, profitability is not a major advantage associated with sustainability. For instance, implementing sustainable development (corporate social responsibility, CSR) activities build a good reputation and enhance employees' commitment, morale, and productivity from an internal business process. Moreover, Hodgson (2005) has underlined other crucial benefits of CSR to enhance brand recognition, responsibility to stakeholders and sustainable product brand loyalty. In addition, the management of environmental factors is typically included in collaborative planning monitoring, forecasting and supplier replenishment. Suppliers contribute to performance and play an essential role in the function of a supply chain; thus, suppliers must be carefully evaluated and selected (Tseng *et al.*, 2008). Firms depend on suppliers to enhance their performance and that of the entire supply chain network. Firms stress their sustainability and outsource activities to their suppliers, thus creating values for the customer that is beyond the boundaries of upstream and downstream stakeholders. The firm thus increases its competitive advantage by being proactive with regard to SSCM. In this context, firms have to integrate sustainable practices with supplier management (Linton *et al.*, 2007; Bai and Sarkis, 2010).

Regarding the internal process, this aspect is more on controlling the internal process. Tseng noted that firms have begun to use environmental, health and safety, and social indicators to improve their environmental practices. A firm's ability to provide a safe environment for its workers is composed of several indicators, including having zero lost workdays due to work-related injuries and illnesses, increasing the rate of employee-suggested improvements in quality, social and environmental health and safety performance, improving employee training on green knowledge, and increasing employee well-being and job satisfaction. Green design is primarily influenced by the fact that green products can be disassembled, reused or recycled for raw materials, are free from hazardous materials, and so on (Tang and Zhou, 2012; Wang *et al.*, 2014). Hence, the green product aspect signifies the promotion and sale of green products on the basis of understanding customer demands (Tseng *et al.*, 2008).

The learning and growth aspect is an important intangible component of the BSC model. It is related to internal business processes and therefore to stakeholders and sustainability. This aspect serves as a basis for the firm's management. It can be very difficult to achieve effective means to improve the performance of people and internal business processes. Firms have agreed that employee satisfaction is a precondition for overall business success. Tseng *et al.* (2013) showed that firms with satisfied employees usually provide the best customer satisfaction. Hence, there are ways to improve employee satisfaction, employee retention and employee productivity. In a successful organization, the employees are educated and thus have access to product information. This is important to understand in terms of management, for instance, technology improvement, friendly management systems, environmental certificates and so on. Learning and growth success is a source of empowerment for employees, information systems and SSCM organizational alignment (Haake and Seuring, 2009).

As mentioned, the proposed SSCM-BSC framework is integrated from the relevant literature. The business activities, components and characteristics that are found to be associated with this evaluation framework are put forward as BSC model criteria (see Table I). Table I presents the BSC aspects and criteria.

3. Method

To determine the evaluation of BSC performance aspects and criteria, the criteria are frequently structured in an evaluation framework with qualitative and quantitative approaches. The proposed methods and proposed solution steps are described below.

3.1 Transformation of the quantitative data

The crisp numbers from the performance measures are characterized by various units that cannot be directly compared. Therefore, crisp values must be normalized to achieve criteria values that are unit-free and therefore comparable. The normalized crisp values of C_{ij} are calculated using Equation (1) (Tseng *et al.*, 2009b):

$$C_{ij} = \left(c_{ij}^{N} - \min c_{ij}^{N}\right) / \left(\max c_{ij}^{N} - \min c_{ij}^{N}\right) X_{ij} \in (0,1); \quad N = 1, 2, \ldots n \qquad (1)$$

where $\max C_{ij}^{N} = \max\left\{c_{ij}^{1}, c_{ij}^{2}, \ldots . c_{ij}^{N}\right\}$ and $\min C_{ij}^{N} = \min\left\{c_{ij}^{1}, c_{ij}^{2}, \ldots .. c_{ij}^{N}\right\}$

Aspects	Criteria	
Sustainability	C1	Operating expenditures
	C2	Profit margin
	C3	Resource productivity
	C4	Market share
	C5	Recycling revenues
	C6	Revenues from green products
	C7	Green image
	C8	Growth from new services or products
	C9	Recycle/reuse/reduce for material saving
	C10	Encourage customers to participate in protection initiatives.
	C11	Encourage customers to be environmentally friendly in the property
	C12	Strategic planning for your environmental management
	C13	Reduce carbon emissions
Stakeholders	C14	Signing the code of conducts or voluntary initiatives
	C15	Customer satisfaction
	C16	Corporate sustainability
	C17	Health and safety of employee
	C18	Health and safety of customer
	C19	Foresee customers' product or service needs
	C20	Employee satisfaction
	C21	Product take back
	C22	Awards of sustainability
	C23	Community investment
	C24	Supplier environmental standards
	C25	Supplier assistance in solving technical problems
	C26	Supplier ability to respond to quality problems
	C27	Supplier cost-saving initiatives
	C28	Supplier's booking in procedures
	C29	Evaluates the social impact of the business
	C30	Collaborate with social and charity projects
Internal business process	C31	Days work stoppages
	C32	Life Cycle Assessment performed
	C33	Environmental and social standard certified
	C34	Green supply chain management
	C35	Green purchasing
	C36	Water consumption
	C37	Monitoring energy consumption
	C38	Waste volume decreases
	C39	Lost workdays
	C40	Employee accidents
	C41	Greenhouse gas emissions
	C42	Packaging volume decreases
	C43	Green design
	C44	Collaboration support services
	C45	Decrease the generation of toxic and hazardous matters
	C46	Corporate social responsibility promotion
Learning and growth	C47	R&D for green technologies
	C48	Environmental information systems
	C49	Employee volunteer hours
	C50	Employee awareness
	C51	Employees with disabilities
	C52	Total supply chain cycle time
	C53	Proportion of disabilities for management executives
	C54	Environmental certificates
	C55	Vendor managed inventory, consignment stock
	C56	Collaborative planning, forecasting, and replenishment with suppliers
	C57	Physical integration of the supplier into the plant

Sources: Rao (2002); Preuss (2005); Lambert *et al.* (2006); Tang and Zhou (2012); Tseng (2013)

Table I.
The initial set of BSC aspects and criteria

3.2 FDM

FDM was proposed by Ishikawa *et al.* (1993) and derived from the traditional Delphi technique and fuzzy set theory. Noorderhaben (1995) applied the FDM to group decision to solve the fuzziness of the common understanding of expert perceptions because the efficiency and quality of questionnaires required improvement. Assuming the value of the significance of no. j element given by no. i experts is $\tilde{a} = (l_{ij}, m_{ij}, u_{ij})$, $i = 1,2,3, \ldots n; j = 1,2,3, \ldots m$. The weighting $\tilde{a}_j$ of no. j element is $\tilde{a}_j = (l_j, m_j, u_j)$ which $a_j = \min\{l_{ij}\}$, $b_j = \left(\prod_1^n m_{ij}\right)^{1/n}$, $c_j = \max\{u_{ij}\}$. Table II displays the linguistic scales and the TFNs for intangible linguistic scales in which the terms are defined.

Using convex combination method, the H is presented as follows:

$$H = \int \left(u_{ij}, l_{ij}\right) = \lambda\left[u_{ij} + (1-\lambda)l_{ij}\right]$$

$$\begin{cases} u_{ij} = u_{ij} - \alpha\left(u_{ij} - m_{ij}\right) \\ l_{ij} = l_{ij} - \alpha\left(m_{ij} - l_{ij}\right) \end{cases} \tag{2}$$

The method uses a finite set [0,1] that represents the range of the view, from optimistic to pessimistic, of the specific objects, and Equation (3) is used to acquire the definite value, $\tilde{R}_j$:

$$\tilde{R}_j = \lambda\left[u_{ij} + (1-\lambda)l_{ij}\right] \tag{3}$$

The proper criteria can be screened out from numerous criteria by setting the threshold value (δ). The following rules are applied for the criteria, whether accepted or unaccepted. If $\tilde{R}_j \geqslant \delta$, the no. j criterion is accepted for the evaluation criteria; if $\tilde{R}_j < \delta$, then the criterion is not accepted.

3.3 Fuzzy set theory

A fuzzy set $\tilde{A}$ in a universe of discourse X is characterized by the membership function $\mu_{\tilde{A}}(x)$ that assigns each element x in X a real number in the interval [0, 1]. The numerical value $\mu_{\tilde{A}}(x)$ represents the grade of membership of x in $\tilde{A}$ (Braae and Rutherford, 1978; Wu *et al.*; Tseng *et al.*, 2008). Table I presents the corresponding interval-valued TFNs with linguistic preferences.

Definition. A TFN $\tilde{a}$ is defined by a triangular $\tilde{a} = (l, m, u)$ with membership function:

$$\mu_{\tilde{A}}(x) = \begin{cases} 0, x < l \\ (x-l)/(m-l), \quad m \geqslant x \geqslant l \\ (u-x)/(u-m), \quad m \geqslant x \geqslant u \\ 0, \quad otherwise \end{cases} \tag{4}$$

The TFN is based on a three-value judgment: the minimum possible value l, the mean possible value m and the maximum possible value u. The criteria values depend on linguistic preferences.

Linguistic terms (performance/importance)	Linguistic values $\tilde{a} = (l, m, u)$
Extreme	(0.75, 1.0, 1.0)
Demonstrated	(0.5, 0.75, 1.0)
Strong	(0.25, 0.5, 0.75)
Moderate	(0, 0.25, 0.5)
Equal	(0, 0, 0.25)

Table II. Triangular fuzzy numbers

Let M_{ij} be the importance weighted value of perspective i and criterion j. The membership function of TFN $M_{ij} \in S$. Let P_{ij} be the performance value of perspective i and criterion j. The membership function of TFN is $P_{ij} \in T$:

$$M_{ij}^{n} = \left(wl_{ij}^{n}, wm_{ij}^{n}, wu_{ij}^{n}\right), \quad \mathrm{M}_{ij} \in S, \quad where \quad 0 \leqslant wl_{ij} \leqslant wm_{ij} \leqslant wu_{ij} \leqslant 1 \tag{5}$$

$$P_{ij}^{n} = \left(pl_{ij}^{n}, pm_{ij}^{n}, pu_{ij}^{n}\right), \quad \mathrm{M}_{ij} \in T, \quad where \quad 0 \leqslant pl_{ij} \leqslant pm_{ij} \leqslant pu_{ij} \leqslant 1 \tag{6}$$

where M_{ij} are the value of respondents for perspective i and criterion j and the expert weights in the evaluation, respectively. Because the output of the fuzzy system is a fuzzy set, the defuzzification procedure is used to convert the fuzzy results into crisp numbers. The center-of-area yields better results than the mean of maximum. The center-of-area is a simple and practical method for calculating best non-fuzzy performance (BNP) values (Lin *et al.*, 2013). Equations (7) and (8) determine the BNP values of the fuzzy weights:

$$\mathrm{BNP}_{i}^{w} = \left[\left(wu_{ij}^{n} - wl_{ij}^{n}\right) + \left(wm_{ij}^{n} - wl_{ij}^{n}\right)\right]/3 + wl_{ij}^{n}, \quad \forall_{i} \tag{7}$$

$$\mathrm{BNP}_{i}^{p} = \left[\left(pu_{ij}^{n} - pl_{ij}^{n}\right) + \left(pm_{ij}^{n} - pl_{ij}^{n}\right)\right]/3 + pl_{ij}^{n}, \quad \forall_{i} \tag{8}$$

Lastly, the final performance score (FPS) is calculated with Equations (7) and (8). Where n is the number of aspect or criteria:

$$\mathrm{FPS} = \left(\sum \mathrm{BNP}_{i}^{w} \times \mathrm{BNP}_{i}^{p}\right)/n \tag{9}$$

3.4 Close-loop ANP

ANP must satisfy the characteristic of interdependence among the criteria before it can proceed to decision-making (Saaty, 1996). This is a generalization of the analytical hierarchical process (AHP). While the AHP represents a framework with a unidirectional hierarchical AHP relationship, the ANP allows for complex interrelationships among hierarchical levels. The feedback approach replaces hierarchies with networks in which the relationships between levels are not easily represented as higher or lower, dominant or subordinate. Hence, given the problems encountered in reality, a dependent and feedback relationship is usually generated among the evaluation criteria, and such an interdependent relationship usually becomes more complex with a change in the scope and depth of the decision-making problems (Tseng *et al.* 2009a, b). A two-way arrow among different levels of criteria may graphically represent the interdependence in a BSC model. If interdependencies are present within the same level of analysis, a "looped arc" may be used to represent this interdependence.

Then, the converged, weighted supermatrix M^* that is based on Equation (10) is obtained, which allows for gradual convergence of the interdependent relationship to obtain the accurate relative weights among the criteria.

$$M^* = \lim_{k \to \infty} M^k \tag{10}$$

Figure 1 presents the interdependence structure with close-loop and interdependent relationships of the proposed framework. The following descriptions are the equations applied to this approach.

To determine the evaluation of aspects and criteria, multiple measures are frequently structured in a BSC evaluation framework with qualitative and quantitative information. The proposed methods and proposed solution steps are described below.

3.5 Proposed approach

This study attempts to apply the FDM and ANP methods to the evaluation of twenty-six criteria for the performance of SSCM. The study objective is to analyze how the proposed methods can be used to rank the aspects and criteria in a close-loop network hierarchical structure. The expert group proposed the following five-step approach for the solution:

(1) Identify the BSC aspects and criteria and the stakeholders that are involved in this SSCM performance evaluation study. This BSC approach is necessary to form an expert committee for evaluation and to achieve the study objective.

(2) The BSC aspects and criteria have interdependent relationships and contain qualitative and quantitative information from the SSCM criteria. It is necessary to first transform the quantitative data to a comparable scale, Equation (1). Because there are many performance criteria gathered from the case firm, the FDM is employed to eliminate some of the criteria based on the expert opinions, using Equations (2) and (3). The threshold value is computed for expert validity. Table II presented the TFN scales for FDM and linguistic preferences.

(3) Use Equation (4) to justify the membership function of TFN, applying Equations (5)-(8) to compute the performance and weighting scores. This approach applies the final performance score, calculated by Equation (9), to integrate perceptions on the performance and importance levels.

(4) ANP techniques are the most appropriate for this approach. It is necessary to consult a group of experts to confirm the reliability of information regarding the description of the criteria. The e-vectors are composed of the unweighted supermatrix based on the interdependent and close-loop relationships, as presented in Figure 1.

(5) Use Equation (10) to obtain the result for the normalized unweighted supermatrix from the multiplied result and raise it to limiting powers to acquire a converged supermatrix.

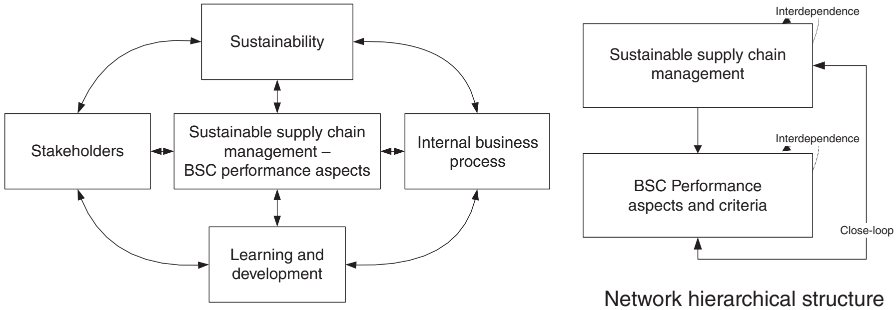

Figure 1. BSC performance close-loop network hierarchical structure

4. Results

This section uses an empirical example from the Taiwanese printed circuit board (PCB) electronics focal firm to demonstrate the proposed hybrid technique in SSCM performance analysis. This section is divided into two subsections: case information and results. To illustrate the utility of the proposed hybrid method, the BSC performance model was applied to the focal firm in SSCM.

4.1 Case information

A Taiwanese electronic manufacturing focal firm wishes to evaluate SSCM performance measurement competencies by initiating a BSC evaluation. This firm is globally ranked in the top five PCB. Hence, this firm is a focal firm that exports products all over the world. This firm has been continuously developing eco-innovative, remarkably sustainable products that consider social, environmental and economic factors in their supply chain in recent years. The BSC model is proposed to enhance competitiveness and fully satisfy market and customer demands by developing a systematic performance evaluation. Because the BSC can take four aspects into consideration, the management sought to conduct a sustainable performance evaluation of the supply chain network. There are difficulties involved in the evaluation due to the fact that the relevant aspects and criteria are hierarchical and interdependent.

The first of these difficulties stems from the fact that the criteria in the ANP model are not quantitative by nature. ANP is a technique that is used to solve MCDM problems for which there is interdependencies among the aspects and criteria that are both qualitative and quantitative described in nature. Therefore, this study proposes this analytical approach – the FDM is intended to satisfy the requirement for expert validity due to there being many indicators from ISO 9001 and ISO 14001, etc. The ANP performed a SSCM performance evaluation for the hierarchical, close-loop and interdependent relations. An expert team, which contained five professors and six management professionals with extensive experience consulting, was formed for this study. After a long interview with these experts, the expert group was confident that they fully understood what FDM and ANP meant to the analysis of the BSC for the weighting process. Figure 2 illustrates the proposed approach for this study.

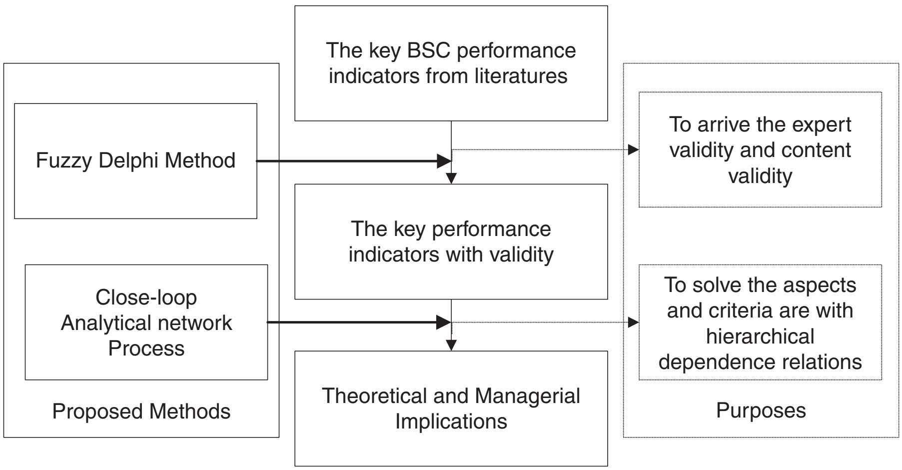

Figure 2.
Proposed approach

4.2 The results

(1) There are many SSCM criteria due to the stakeholders being involved in this performance evaluation study. This BSC approach uses four aspects. The expert committee is composed of five professors and six management professionals with extensive experience. The initial aspects and criteria are presented. There are four modified BSC aspects and 57 criteria from ISO 9001 and ISO 14001, see Table I.

(2) The BSC aspects and criteria are composed of qualitative and quantitative information from the aspects and criteria of SSCM. The modified aspects are sustainability, the internal business process, the stakeholders, and learning and growth. This study transposes quantitative data onto a comparable scale using Equation (1). The performance criteria that are gathered from operations and stakeholders are related. Hence, the FDM is employed to eliminate part of the criteria based on expert opinions; FDM judgment is presented in Table III for the initial 57 sets (Criteria 1-57). The threshold value (0.429) is computed. Finally, the 26 accepted criteria (NC 1-26) are presented with expert validity.

(3) Table IV presents the importance, performance and final performance score under AS1 and applies Equations (5)-(8) to compute the BNP performance and BNP importance weighting scores. The integration of the BNP importance weighting scores is applied using Equation (9) to derive the FPS. The FPS is calculated to be 0.176, 0.170, 0.175, and 0.180. These data are now ready for the matrix of aspects under AS1.

This study repeats the same computational process that was used for AS1 under AS2, AS3, and AS4 to develop the matrix under AS1, which is presented in Table V. By decomposing the matrix, the Eigen vector and local weights are obtained. The local weights are 0.257, 0.242, 0.247, and 0.254. These numbers are now ready to be entered into the unweighted supermatrix:

(1) Moreover, ANP uses a supermatrix to deal with the feedback and interdependence among the aspects and criteria. If no interdependent relationship exists among the criteria, then the pairwise comparison value is 0. If an interdependent feedback relationship exists among the criteria, then such value would no longer be 0 and an unweighted supermatrix M could be obtained. This study has repeated the process for 26 criteria in order to compose the closed-loop network hierarchical structure and create the unweighted supermatrix. The e-vectors for each aspect and criterion are entered into the unweighted supermatrix based on the interdependencies and closed-loop relationships, presented in Figure 1. The unweighted supermatrix is presented in Table VI.

(2) If the normalized unweighted supermatrix from the multiplied result is not column stochastic, the decision maker can provide the weights to adjust it into a supermatrix that is column stochastic, raising it to limiting powers using Equation (10) to acquire a converged weighted supermatrix. The result is presented in Table VII.

The ranking sequence of the aspects is AS2 Stakeholders – (0.1253), AS3 Internal business process – (0.1252), AS4 Learning and growth – (0.1250), and AS1 Sustainable – (0.1239). The criteria ranking sequence is NC22(0.0.02358), NC10(0.02300), NC6(0.02297), NC16(0.02232), NC1(0.02128), NC8(0.02125), NC18(0.02089), NC25(0.02059), NC5(0.02048),

Criteria	Re-name	l	m	u	l	u	$\tilde{R}_j$	Judgment
C1		0.000	0.647	1.000	−0.323	0.823	0.323	Unaccepted
C2		0.000	0.824	1.000	−0.412	0.912	0.412	Unaccepted
C3		0.000	0.701	1.000	−0.351	0.851	0.351	Unaccepted
C4	NC1	0.500	0.923	1.000	0.289	0.961	0.586	Accepted
C5		0.000	0.791	1.000	−0.396	0.896	0.396	Unaccepted
C6		0.000	0.577	1.000	−0.289	0.789	0.289	Unaccepted
C7		0.000	0.662	1.000	−0.331	0.831	0.331	Unaccepted
C8	NC2	0.250	0.837	1.000	−0.044	0.919	0.481	Accepted
C9	NC3	0.500	0.785	1.000	0.357	0.893	0.518	Accepted
C10	NC4	0.500	0.851	1.000	0.324	0.926	0.551	Accepted
C11	NC5	0.500	0.851	1.000	0.324	0.926	0.551	Accepted
C12	NC6	0.500	0.923	1.000	0.289	0.961	0.586	Accepted
C13	NC7	0.500	0.886	1.000	0.307	0.943	0.568	Accepted
C14	NC8	0.250	0.791	1.000	−0.021	0.896	0.458	Accepted
C15	NC9	0.250	0.772	1.000	−0.011	0.886	0.449	Accepted
C16	NC10	0.500	0.818	1.000	0.341	0.909	0.534	Accepted
C17	NC11	0.500	0.923	1.000	0.289	0.961	0.586	Accepted
C18	NC12	0.500	0.923	1.000	0.289	0.961	0.586	Accepted
C19	NC13	0.500	0.818	1.000	0.341	0.909	0.534	Accepted
C20		0.000	0.495	1.000	−0.248	0.748	0.248	Unaccepted
C21		0.000	0.601	1.000	−0.301	0.801	0.301	Unaccepted
C22		0.000	0.718	1.000	−0.359	0.859	0.359	Unaccepted
C23		0.000	0.760	1.000	−0.380	0.880	0.380	Unaccepted
C24	NC14	0.500	0.886	1.000	0.307	0.943	0.568	Accepted
C25		0.000	0.555	1.000	−0.277	0.777	0.277	Unaccepted
C26	NC15	0.500	0.886	1.000	0.307	0.943	0.568	Accepted
C27	NC16	0.500	0.961	1.000	0.270	0.980	0.605	Accepted
C28	NC17	0.250	0.772	1.000	−0.011	0.886	0.449	Accepted
C29		0.000	0.730	1.000	−0.365	0.865	0.365	Unaccepted
C30		0.000	0.701	1.000	−0.351	0.851	0.351	Unaccepted
C31	NC18	0.750	1.000	1.000	0.625	1.000	0.688	Accepted
C32		0.000	0.577	1.000	−0.289	0.789	0.289	Unaccepted
C33		0.000	0.507	1.000	−0.253	0.753	0.253	Unaccepted
C34		0.000	0.568	1.000	−0.284	0.784	0.284	Unaccepted
C35	NC19	0.500	0.923	1.000	0.289	0.961	0.586	Accepted
C36	NC20	0.500	0.818	1.000	0.341	0.909	0.534	Accepted
C37		0.000	0.701	1.000	−0.351	0.851	0.351	Unaccepted
C38	NC21	0.500	0.923	1.000	0.289	0.961	0.586	Accepted
C39		0.000	0.601	1.000	−0.301	0.801	0.301	Unaccepted
C40		0.000	0.626	1.000	−0.313	0.813	0.313	Unaccepted
C41		0.000	0.760	1.000	−0.380	0.880	0.380	Unaccepted
C42		0.000	0.495	1.000	−0.248	0.748	0.248	Unaccepted
C43	NC22	0.500	0.886	1.000	0.307	0.943	0.568	Accepted
C44		0.000	0.662	1.000	−0.331	0.831	0.331	Unaccepted
C45		0.000	0.718	1.000	−0.359	0.859	0.359	Unaccepted
C46	NC23	0.250	0.804	1.000	−0.027	0.902	0.465	Accepted
C47	NC24	0.500	0.923	1.000	0.289	0.961	0.586	Accepted
C48		0.000	0.636	1.000	−0.318	0.818	0.318	Unaccepted
C49		0.000	0.626	1.000	−0.313	0.813	0.313	Unaccepted
C50		0.000	0.791	1.000	−0.396	0.896	0.396	Unaccepted
C51		0.000	0.701	1.000	−0.351	0.851	0.351	Unaccepted
C52		0.000	0.601	1.000	−0.301	0.801	0.301	Unaccepted
C53		0.000	0.626	1.000	−0.313	0.813	0.313	Unaccepted
C54		0.000	0.701	1.000	−0.351	0.851	0.351	Unaccepted
C55	NC25	0.500	0.785	1.000	0.357	0.893	0.518	Accepted
C56	NC26	0.500	0.961	1.000	0.270	0.980	0.605	Accepted
C57		0.000	0.690	1.000	−0.345	0.845	0.345	Unaccepted

Note: Threshold value = 0.429

Table III.
The results of Fuzzy Delphi method

NC4(0.01983), NC12(0.01969), NC13(0.01951), NC21(0.01945), NC2(0.01901), NC15(0.01900), NC20(0.01885), NC7(0.01860), NC26(0.01816), NC17(0.01759), NC19(0.01752), NC9(0.01747), NC11(0.01700), NC14(0.01633), NC24(0.01544), NC23(0.01456), and NC3(0.01513). The top five criteria are first, green design (NC22); second, corporate sustainability (NC10); third, strategic plan for your environmental management (NC6); fourth, supplier cost-saving initiatives (NC16); and fifth, market share (NC1).

5. Theoretical and managerial implications

As its main result, this study identified the need to understand stakeholder involvement in making decisions about the use of their resources. This study advances such an understanding of theoretical and managerial implications by considering the stakeholders in the BSC model evaluation.

5.1 Theoretical implications

In real situations, stakeholder groups sometimes resist proposed sustainable resource management due to the belief that the economic performance may decrease. Given the direct effects that key stakeholder groups have over firm activities, supply chain networks need to go beyond current practices to better understand how stakeholders respond to marketing and sustainable raw material sourcing. The stakeholder's approach focuses on how firms can identify, explain and manage stakeholders to achieve desired SSCM outcomes. This is attributed to the current focal firms' performances. Although the existing literature lacks sufficient knowledge regarding SSCM performance measures, which remains a serious limitation, a variety of general theories are available for identifying, categorizing or prioritizing stakeholders for the purpose of managing their SSCM activities (Seuring and Müller, 2008; Hsu *et al.*, 2011; Liu *et al.*, 2012). This study uses the stakeholder approach as a basis for assessing stakeholder performance because of its ability to focus on four BSC aspects related to stakeholders in the supply chain and sustainability aspects.

	AS1								
	Importance			Performance					
Aspects	l	m	u	l	m	u	BNP_i^w	BNP_i^p	FPS
As1	0.498	0.743	0.873	0.478	0.635	0.720	0.704	0.611	*0.176*
As2	0.490	0.735	0.980	0.450	0.563	0.750	0.735	0.588	*0.170*
As3	0.643	0.888	0.980	0.468	0.603	0.750	0.837	0.607	*0.175*
As4	0.735	0.980	0.980	0.495	0.630	0.750	0.898	0.625	*0.180*

Table IV. Importance (BNP_i^w), performance (BNP_i^p) and final performance score (FPS)

(AS1)	AS1	AS2	AS3	AS4	E-vector	Weights
AS1	*0.176*	*0.170*	*0.175*	*0.180*	0.512	*0.257*
AS2	0.166	0.160	0.165	0.170	0.483	*0.242*
AS3	0.169	0.163	0.168	0.173	0.492	*0.247*
AS4	0.176	0.169	0.175	0.180	0.507	*0.254*

Notes: CI = 0.075; CR = 0.066

Table V. Matrix of aspects under AS1

Table VI. Unweighted supermatrix

	AS1	AS2	AS3	AS4	NC 1	NC 2	NC 3	NC 4	NC 5	NC 6	NC 7	NC 8	NC 9	NC 10	NC 11
AS1	*0.257*	0.226	0.323	0.238	0.256	0.312	0.240	0.271	0.167	0.183	0.370	0.182	0.360	0.163	0.250
AS2	*0.242*	0.208	0.209	0.208	0.189	0.315	0.155	0.286	0.257	0.382	0.220	0.220	0.176	0.348	0.317
AS3	*0.247*	0.224	0.253	0.270	0.345	0.269	0.347	0.167	0.298	0.260	0.259	0.140	0.359	0.179	0.123
AS 4	*0.254*	0.342	0.215	0.284	0.210	0.104	0.258	0.276	0.278	0.175	0.151	0.458	0.105	0.310	0.310
NC 1	0.0520	0.0463	0.0120	0.0350	0.0103	0.0550	0.0560	0.0850	0.0510	0.0360	0.2590	0.0360	0.0170	0.0105	0.0108
NC 2	0.0444	0.0485	0.0511	0.0108	0.0112	0.0570	0.0163	0.0360	0.0170	0.0360	0.0000	0.0360	0.0196	0.0170	0.0620
NC 3	0.0105	0.0210	0.0462	0.0425	0.0210	0.0163	0.0163	0.0170	0.0170	0.0170	0.0170	0.0184	0.0170	0.0170	0.0390
NC 4	0.0515	0.0481	0.0360	0.0470	0.0169	0.0320	0.0360	0.0125	0.0360	0.0170	0.0550	0.0256	0.0700	0.0220	0.0520
NC 5	0.0458	0.0520	0.0630	0.0421	0.0152	0.0340	0.0680	0.0108	0.0109	0.0108	0.0108	0.0108	0.0108	0.0750	0.0230
NC 6	0.0470	0.0477	0.0447	0.0060	0.0510	0.0410	0.0750	0.0620	0.0880	0.1910	0.0111	0.1050	0.0447	0.0660	0.0340
NC 7	0.0103	0.0130	0.0582	0.0581	0.0000	0.0268	0.0118	0.0670	0.0118	0.0158	0.0690	0.0530	0.0534	0.0522	0.0389
NC 8	0.0458	0.0470	0.0406	0.0510	0.0380	0.0160	0.0420	0.0070	0.0071	0.0158	0.0071	0.0432	0.0418	0.0560	0.0500
NC 9	0.0442	0.0446	0.0421	0.0050	0.0860	0.0530	0.0118	0.0540	0.0201	0.0158	0.0158	0.0470	0.0950	0.0489	0.0170
NC 10	0.0510	0.0477	0.0504	0.0510	0.0159	0.0410	0.0750	0.0170	0.0170	0.0370	0.0170	0.0497	0.0170	0.0170	0.0600
NC 11	0.0452	0.0070	0.0423	0.0448	0.0102	0.0360	0.0159	0.0350	0.0159	0.0960	0.0071	0.0106	0.0390	0.0620	0.0388
NC 12	0.0443	0.0517	0.0120	0.0523	0.0560	0.0320	0.0159	0.0410	0.0399	0.0135	0.0158	0.0515	0.0520	0.0407	0.0400
NC 13	0.0490	0.0438	0.0100	0.0560	0.0420	0.0830	0.0380	0.0380	0.0376	0.0124	0.0106	0.0106	0.0230	0.0440	0.0320
NC 14	0.0406	0.0399	0.0020	0.0450	0.0210	0.0380	0.0240	0.0240	0.0440	0.0259	0.0179	0.0106	0.0340	0.0422	0.0230
NC 15	0.0386	0.0376	0.0560	0.0290	0.0520	0.0240	0.0276	0.0276	0.0390	0.0125	0.0380	0.0399	0.0399	0.0230	0.0500
NC 16	0.0483	0.0440	0.0442	0.0590	0.0160	0.0276	0.0930	0.0320	0.0125	0.0540	0.0240	0.0376	0.0376	0.0437	0.0390
NC 17	0.0120	0.0390	0.0506	0.0468	0.0105	0.0760	0.0000	0.0500	0.0590	0.0399	0.0276	0.0440	0.0440	0.0230	0.0404
NC 18	0.0429	0.0230	0.0470	0.0456	0.0950	0.0320	0.0520	0.0260	0.0660	0.0376	0.0253	0.0390	0.0390	0.0600	0.0407
NC 19	0.0170	0.0459	0.0436	0.0102	0.0860	0.0240	0.0340	0.0550	0.0480	0.0440	0.0108	0.0230	0.0520	0.0520	0.0369
NC 20	0.0540	0.0290	0.0396	0.0210	0.0260	0.0380	0.0210	0.0390	0.0438	0.0390	0.0230	0.756	0.0560	0.0560	0.0408
NC 21	0.0250	0.0520	0.0520	0.0240	0.0405	0.0411	0.0580	0.0416	0.0389	0.0412	0.0425	0.0230	0.0389	0.0389	0.0389
NC 22	0.0560	0.0560	0.0230	0.0690	0.0800	0.0427	0.0610	0.0420	0.0437	0.0393	0.0960	0.0700	0.0437	0.0437	0.0437
NC 23	0.0350	0.0170	0.0070	0.0397	0.0407	0.0156	0.0560	0.0405	0.0960	0.0410	0.0443	0.0108	0.0200	0.0108	0.0200
NC 24	0.0200	0.0200	0.0200	0.0400	0.0402	0.0389	0.0070	0.0650	0.0600	0.0403	0.0630	0.0402	0.0170	0.0125	0.0600
NC 25	0.0250	0.0530	0.0220	0.0690	0.0800	0.0427	0.0610	0.0420	0.0437	0.0393	0.0780	0.0600	0.0437	0.0437	0.0437
NC 26	0.0450	0.0250	0.0840	0.0000	0.0382	0.0360	0.0275	0.0334	0.0365	0.0319	0.0146	0.0286	0.0340	0.0220	0.0252

(*continued*)

	NC 12	NC 13	NC 14	NC 15	NC 16	NC 17	NC 18	NC 19	NC 20	NC 21	NC 22	NC 23	NC 24	NC 25	NC 26
AS1	0.180	0.142	0.168	0.240	0.211	0.430	0.263	0.258	0.158	0.256	0.158	0.359	0.333	0.182	0.168
AS2	0.410	0.223	0.390	0.447	0.500	0.120	0.170	0.268	0.214	0.312	0.420	0.108	0.212	0.223	0.390
AS3	0.154	0.450	0.183	0.183	0.085	0.197	0.486	0.269	0.362	0.159	0.254	0.290	0.222	0.410	0.183
AS4	0.256	0.185	0.259	0.130	0.204	0.253	0.081	0.205	0.266	0.273	0.168	0.243	0.233	0.185	0.259
NC 1	0.0126	0.0740	0.0650	0.0570	0.0680	0.0570	0.0206	0.0950	0.0360	0.0321	0.0107	0.0596	0.0120	0.0120	0.0550
NC 2	0.0450	0.0630	0.0520	0.0106	0.0560	0.0060	0.0530	0.0520	0.0440	0.0380	0.0264	0.0236	0.0700	0.0520	0.0520
NC 3	0.0620	0.0388	0.0106	0.0630	0.0106	0.0387	0.0385	0.0529	0.0390	0.0389	0.0490	0.0393	0.0393	0.0393	0.0393
NC 4	0.0407	0.0400	0.0600	0.0022	0.0376	0.0060	0.0404	0.0407	0.0392	0.0400	0.0372	0.0407	0.0407	0.0407	0.0120
NC 5	0.0440	0.0106	0.0106	0.0560	0.0105	0.0760	0.0385	0.0234	0.0383	0.0120	0.0409	0.0440	0.0440	0.0440	0.0440
NC 6	0.0422	0.0220	0.0412	0.0580	0.0418	0.0650	0.0386	0.0422	0.0410	0.0150	0.0372	0.0422	0.0422	0.0422	0.0422
NC 7	0.0106	0.0500	0.0750	0.0405	0.0411	0.0580	0.0416	0.0389	0.0412	0.0425	0.0680	0.0389	0.0389	0.0389	0.0389
NC 8	0.0437	0.0390	0.0690	0.0800	0.0427	0.0610	0.0420	0.0437	0.0393	0.0056	0.0600	0.0437	0.0437	0.0437	0.0437
NC 9	0.0060	0.0404	0.0397	0.0407	0.0370	0.0560	0.0405	0.0106	0.0410	0.0443	0.0120	0.0201	0.0120	0.0219	0.0120
NC 10	0.0600	0.0407	0.0400	0.0402	0.0389	0.0268	0.0650	0.0600	0.0403	0.0630	0.0402	0.0600	0.0600	0.0600	0.0600
NC 11	0.0125	0.0125	0.0106	0.0387	0.0385	0.0053	0.0390	0.03S9	0.0490	0.0620	0.0620	0.0620	0.0376	0.0125	0.0399
NC 12	0.0600	0.0158	0.0376	0.0125	0.0399	0.0407	0.0392	0.0400	0.0850	0.0407	0.0080	0.0407	0.1050	0.0210	0.0376
NC 13	0.0106	0.0560	0.1050	0.0210	0.0376	0.0440	0.0383	0.0120	0.0409	0.0440	0.0440	0.0440	0.0418	0.0650	0.0440
NC 14	0.0412	0.0580	0.0418	0.0106	0.0440	0.0422	0.0410	0.0150	0.0700	0.0422	0.0422	0.0119	0.0411	0.0210	0.0390
NC 15	0.0280	0.0405	0.0411	0.0210	0.0390	0.0389	0.0412	0.0425	0.0125	0.0389	0.0389	0.0256	0.0427	0.0610	0.0420
NC 16	0.0399	0.0106	0.0427	0.0610	0.0420	0.0437	0.0393	0.0370	0.0376	0.0437	0.0437	0.0437	0.0860	0.0560	0.0405
NC 17	0.0376	0.0407	0.0220	0.0560	0.0405	0.0060	0.0410	0.0443	0.0125	0.0105	0.0210	0.0000	0.0125	0.0210	0.0650
NC 18	0.0440	0.0402	0.0125	0.0106	0.0650	0.0600	0.0403	0.0630	0.0402	0.0600	0.0240	0.0600	0.0399	0.0520	0.0372
NC 19	0.0390	0.0125	0.0399	0.0520	0.0372	0.0520	0.0369	0.0069	0.0376	0.0520	0.0520	0.0520	0.0376	0.0200	0.0280
NC 20	0.0200	0.0400	0.0376	0.0200	0.0410	0.0560	0.0408	0.0610	0.0125	0.0430	0.0560	0.0080	0.0440	0.0374	0.0413
NC 21	0.0520	0.0520	0.0440	0.0374	0.0220	0.0106	0.0520	0.0372	0.0376	0.0369	0.0372	0.0620	0.0390	0.0106	0.0400
NC 22	0.0560	0.0560	0.0390	0.0106	0.0413	0.0414	0.0106	0.0410	0.0376	0.0408	0.0413	0.0080	0.0106	0.0413	0.0410
NC 23	0.0620	0.0106	0.0106	0.0500	0.0410	0.0106	0.0060	0.0106	0.0620	0.0403	0.0372	0.0386	0.0170	0.0570	0.0393
NC 24	0.0350	0.0200	0.0210	0.0570	0.0393	0.0400	0.0406	0.0150	0.0200	0.0399	0.0372	0.0413	0.0210	0.0530	0.0348
NC 25	0.0850	0.0106	0.0210	0.0530	0.0348	0.0040	0.0348	0.0085	0.0376	0.0341	0.0346	0.0348	0.0106	0.0369	0.0103
NC 26	0.0106	0.1057	0.0106	0.0401	0.0126	0.0540	0.0403	0.0680	0.0084	0.0396	0.0395	0.0550	0.0106	0.0401	0.0206

Table VI.

Table VII. Converged supermatrix

	AS1	AS 2	AS3	AS4	NC 1	NC 2	NC 3	NC 4	NC 5	NC 6	NC 7	NC 8	NC 9	NC 10	NC 11	Ranking
AS 1	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	4
AS 2	0.1254	0.1254	0.1254	0.1254	0.1254	0.1253	0.1254	0.1254	0.1254	0.1254	0.1254	0.1254	0.1254	0.1254	0.1254	1
AS 3	0.1254	0.1253	0.1253	0.1253	0.1253	0.1253	0.1253	0.1254	0.1254	0.1253	0.1254	0.1253	0.1253	0.1253	0.1253	2
AS4	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	3
NC 1	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0113	0.0213	0.0213	5
NC 2	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	14
NC 3	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	26
NC 4	0.0198	0.0198	0.019t	0.0198	0.0198	0.0198	0.0198	0.019t	0.0198	0.019t	0.0198	0.019t	0.019t	0.0198	0.0191	10
NC 5	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	9
NC 6	0.0230	0.0230	0.0230	0.0130	0.0130	0.0230	0.0130	0.0130	0.0130	0.0130	0.0230	0.0130	0.0130	0.0130	0.0130	3
NC 7	0.0186	0.0186	0.0186	0.0186	0.0186	0.0186	0.0186	0.0186	0.0186	0.0186	0.0186	0.0186	0.0186	0.0186	0.0186	17
NC 8	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	6
NC 9	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	21
NC 10	0.0230	0.0230	0.0230	0.0130	0.0230	0.0130	0.0130	0.0130	0.0130	0.0230	0.0130	0.0130	0.0130	0.0130	0.0230	2
NC 11	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	22
NC 12	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	11
NC 13	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	12
NC 14	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	23
NC 15	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	15
NC 16	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	4
NC 17	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	19
NC 18	0.0209	0.0109	0.0209	0.0109	0.0209	0.0109	0.0109	0.0109	0.0109	0.0209	0.0109	0.0109	0.0109	0.0109	0.0209	7
NC 19	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	20
NC 20	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	16
NC 21	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	13
NC 22	0.0236	0.0236	0.0236	0.0136	0.0136	0.0136	0.0236	0.0236	0.0136	0.0136	0.0136	0.0236	0.0236	0.0136	0.0136	1
NC 23	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	25
NC 24	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	24
NC 25	0.0206	0.0206	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	8
NC 26	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	18

(*continued*)

	NC 12	NC 13	NC 14	NC 15	NC 16	NC 17	NC 18	NC 19	NC 20	NC 21	NC 22	NC 23	NC 24	NC 25	NC 26	Ranking
AS 1	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.1239	0.12386	4
AS 2	0.1254	0.1254	0.1254	0.1253	0.1254	0.1254	0.1254	0.1254	0.1254	0.1254	0.1254	0.1254	0.1254	0.1254	0.12533	1
AS 3	0.1253	0.1253	0.1253	0.1253	0.1253	0.1253	0.1253	0.1253	0.1253	0.1253	0.1253	0.1253	0.1253	0.1253	0.12528	2
AS4	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.1251	0.12505	3
NC 1	0.0213	0.0213	0.0113	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.02128	5
NC 2	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.01901	14
NC 3	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.0151	0.01513	26
NC 4	0.0198	0.019t	0.0191	0.0198	0.0191	0.0198	0.019t	0.0191	0.0198	0.0198	0.0198	0.019t	0.0198	0.0198	0.01913	10
NC 5	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.0205	0.02048	9
NC 6	0.0230	0.0130	0.0130	0.0130	0.0130	0.0230	0.0130	0.0130	0.0130	0.0130	0.0130	0.0130	0.0130	0.0130	0.02297	3
NC 7	0.0186	0.0186	0.0186	0.0116	0.0186	0.0186	0.0186	0.0186	0.0116	0.0116	0.0186	0.0186	0.0186	0.0186	0.01160	17
NC 8	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.0213	0.02125	6
NC 9	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.01747	21
NC 10	0.0130	0.0130	0.0130	0.0130	0.0230	0.0130	0.0130	0.0130	0.0130	0.0230	0.0130	0.0130	0.0230	0.0130	0.02300	2
NC 11	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.0170	0.01700	22
NC 12	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.01969	11
NC 13	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.01951	12
NC 14	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.0163	0.01633	23
NC 15	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.0190	0.01900	15
NC 16	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.02232	4
NC 17	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.0176	0.01759	19
NC 18	0.0109	0.0109	0.0109	0.0109	0.0209	0.0109	0.0109	0.0109	0.0109	0.0209	0.0109	0.0109	0.0209	0.0109	0.02019	7
NC 19	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.0175	0.01752	20
NC 20	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	0.0189	16
NC 21	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.0195	0.01945	13
NC 22	0.0136	0.0236	0.0236	0.0136	0.0136	0.0136	0.0236	0.0236	0.0136	0.0136	0.0136	0.0236	0.0236	0.0236	0.02358	1
NC 23	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.0146	0.01456	25
NC 24	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.01544	24
NC 25	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0206	0.0106	0.02059	8
NC 26	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.0182	0.01816	18

Table VII.

These BSC aspects enable managers to explain how and under what circumstances they should respond to various stakeholders. This study uses this stakeholder approach to understand this aspect by incorporating customers' thoughts, supply responsibilities and employee needs; specifically, this study looks at the SSCM from the stakeholder theory and the BSC model, segments the stakeholders into four BSC aspects, and evaluates how the stakeholders have performed in SSCM over the past few years. In the case of an SSCM performance measure, a focal manufacturing firm thought it was adequately meeting the requirements of multiple stakeholders. However, all stakeholders have been implementing sustainable issues for years; thus, the performance approach is needed. In the supply chain network, all stakeholder groups should hold green design, corporate sustainability, strategic planning for environmental management, supplier cost-saving initiatives, and market share as the top five priorities with regard to SSCM performance.

5.2 Managerial implications

Green design aims to develop new and functional products in accordance with the principles of social, economic, and ecological sustainability and to completely eliminate negative environmental impact through skillful, sensitive design. The environmental blueprint of a product is primarily locked-in during the design stage, and environmental design is characterized as a practice that functions in parallel with environmental recycling remanufacturing and product disposal phases. It is also a knowledge-based resource due to its intangible nature. For instance, the talent, creativity and skill are developed and applied to fulfill market demands, and this knowledge subsequently builds competitive advantages for the supply chain stakeholders. In addition, environmentally friendly design aims to minimize the use of non-renewable resources, effectively manage renewable resources and reduce the volume of toxic emissions (Kuo *et al.*, 2001). Hence, a green design strategy is the best approach to develop a green and profit-oriented supply chain.

Strategic plans for environmental management are technological and managerial resources, as they come under the classification of knowledge-based resources and are considered to be know-how and skills for managing returns. Supply chain members should allocate a functional role dedicated to performance measures to improve the quality of the internal business process and the learning and growth through stakeholder feedback. Resource commitment is associated with green design, supplier cost savings and improved customer satisfaction. Hence, it is advantageous to enhance corporate sustainability over the long-term. This study integrates the firm's perspective of vertical and horizontal integration into their strategic plan, as shown in the proposed model (Kaplan and Norton, 1996; Tseng and Chiu, 2013; Zhu *et al.*, 2013).

Corporate sustainability addresses long-term consumer and employee values by not only creating a green strategy aimed towards the natural environment but also taking into consideration every aspect of how a business operates according to social, cultural, and economic perspectives. A firm can also form a strategy to build a company that fosters longevity through transparency and proper employee skill development that describes business practices built around social and environmental considerations. In addition, the supplier's capability to develop cost-saving initiatives, infrastructure, and Information Technology and Information Systems are essential for firms to better support SSCM. Hence, the application of cleaner production principles with preventive strategies and source-oriented approaches lead to toxic-use reduction and enhanced durability, product service combinations, updatability via software upgrades and manufacturability. Suppliers play an important role in SSCM. For instance, supplier cost-saving initiatives originate from the cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing value or ensuring proper disposal (Tseng *et al.*, 2009a).

Suppliers in a sustainable supply chain network must be carefully evaluated and selected based on their performance. Firms rely on suppliers to increase their supply chain performance. This focus on core competencies and value created for the customer is extended beyond the firms' boundaries to upstream and downstream partners; therefore, this evaluation can create a competitive advantage by enabling increased market shares.

6. Conclusions

SSCM is used to extend the responsibility of business organizations, from being reactive with regard to reducing pollution and waste and making other sustainable-related efforts to proactively assuming full responsibility for their products, from the acquisition of raw materials to the final disposal of the products, from a sustainability point of view. This study focused on developing a hybrid quantitative BSC evaluation model of SSCM using FDM and ANP to assess the final performance score by integrating importance and performance weights. The proposed qualitative criteria are typically inaccurate or uncertain and are used to collect the operations data from the operational process. The real data from the operational process have to be transposed to a comparable scale. The BSC model enables the manager to use linguistic preference with inherent imprecision in the weighting aspects and criteria related to the qualitative criteria by transforming linguistic expressions into crisp values. The TFN represents the linguistic variables in subjective judgments and reduces the evaluators' cognitive burden during the evaluations. A consequence of the representation of uncertainty in the evaluation model formulation is that the results are given in terms of the fuzzy set theory.

There are many performance criteria that could be extracted from the tactical and operational levels. The FDM seeks to eliminate unnecessary criteria in the initial stage. The analytical quantitative and qualitative data utilized in the BSC model are based on the stakeholders. The proposed hybrid method thus overcomes the major difficulty of integrating importance and performance levels based on absolute rather than relative measures of importance, namely, the tendency for all criteria to be used by firms because they appear to have equal importance. By forcing the respondents to rate the most relevant importance and performance criteria of the SSCM and ranking them by order of importance and performance, the proposed FPS method can reduce the bias of the evaluation process. In addition, the ANP method is used to analyze close-loop and network hierarchical structures in real situations.

The results demonstrate the importance of understanding SSCM performance for successful management of a firm's activities. This analysis highlighted the critical criteria that affect SSCM, and it also enhanced the BSC model, while simultaneously considering the stakeholders. These final criteria are taken from the FDM judgment results relative to their evaluation for the SSCM. Subsequently, any analytical recommendation solutions for effective management include the integration of the FPS for the importance and performance levels. If these results can be improved, the current SSCM could be enhanced. In addition, management should focus on improving the strategic plan for environmental management to address issues regarding sustainability and organization learning issues to further improve the performance of SSCM indicators. Understanding the SSCM can guide the focal firm to a more sustainable mode of operation for future generations.

This study does not assume that a perfect, mathematical, multi-criteria decision support method exists, independent of the peculiarities of the studied case. For each type of decision, one or more equally suitable method may exist, which (through understanding and appropriate use) can allow adjustments for alignment with the paradigms on which they are based, improve business performance, and permit consistent application with a well-evaluated method to the BSC performance with a focal firm. The combination of two or more methods can complement and refine the results by providing consecutive filters. Future research could utilize these concepts and results to develop a detailed practical indicator for SSCM practices.

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