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Full Length Research Paper

Performance measurement systems for green supply chains using modified balanced score card and analytical hierarchical process

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Environmental management is becoming a key strategic issue for Supply chain performance. Performance measurement systems for green supply chain is critical for its monitoring, control and improvement. A comparative analysis of some most widely cited Performance measurement systems for supply chains have been undertaken, and it indicates that the modified Balanced score card is a suitable framework for Green supply chain performance measurement. However, there are limitations in this framework when they are used for strategic alignment and planning. The frameworks do not provide weightings to the performance indicators nor does it tell the management the contribution of each performance indicator in achieving organisational goals. Use of Analytic hierarchy process, along with modified balanced score card helps in tiding over these limitations. This paper demonstrates integration of Analytic hierarchy process with modified Balanced score card to facilitate effective Green supply chain performance measurement.

Key words: Analytic hierarchy process (AHP), balanced score card (BSC), performance measurement system (PMS), green supply chain (GSC).

INTRODUCTION

Organisations are increasingly been aware and are concerned about environmental and social impact of their business activities. Environmental management is becoming a key strategic issue for Supply chain (SC) performance (Zhu et al., 2008a; Simpson et al., 2007). Environmental impacts occur across all stages of a product’s life cycle, from the raw material extraction, to manufacturing, use and reuse, final recycling, and disposal (Linton et al., 2008). Green supply chain management (GSCM) has become an important strategy for companies to achieve profit and market advantages by reducing the environmental risks and improving efficiency. According to Salam (2008), environmental response capability is an important management resource. Integrating environmental initiatives into corporate management practices can lead to increased business, improved business performance, and further enhancement of the company’s credibility with stakeholders. The enhanced environmental concerns necessitate performance measurement and reporting systems catering to green initiatives (Morhardt et al., 2002). An effective, balanced and dynamic performance measurement system is critical for monitoring, controlling and improving a Green SC.

A number of frameworks and models for Performance measurement systems (PMS) in SC have been developed since 1980s (Morgan, 2007). The traditional PMS based on financial metrics alone have been deemed inadequate, and more attention is being paid to non-financial metrics (Beamon, 1999). Several broader and balanced PMS have been designed, of which Balanced score card (BSC) has been the least criticized and most widely accepted (Kaplan and Norton, 1992; Bititci and Turner, 2000). There have been earlier attempts to use BSC for environmental performance

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measurement (Länsiluoto and Järvenpää, 2008; Naini et al., 2011). Many practical difficulties however, are associated with the implementa-tion of BSC for performance measurements in Green SC (Gomes et al., 2004; Shaw et al., 2010). The traditional BSC does not have environmental measures as its part. BSC provides little guidance on how the appropriate measures can be identified, introduced and ultimately used to manage business at the operations level (Neely, 2005). Another drawback observed in BSC is that it does not specify any mathematical logical relationships among the individual's scorecard criteria. It is thus difficult to make comparisons within and across firms using BSC (Soni and Kodali, 2010). A modified BSC framework has been proposed by Shaw et al. (2010), incorporating environmental measures within the traditional BSC. This modified BSC framework is found to be more appropriate for green Supply chain performance measurement (SCPM).

Analytic hierarchy process (AHP) is a problem-solving method useful in multi-criteria decision making based on variables that do not have exact numerical cones-quences. Integrating AHP with modified BSC will help to tide over the limitations of BSC and make the approach a suitable candidate for green Supply chain performance measurement system (SCPMS). This paper is an attempt to use AHP integrated with modified BSC and demonstrate its application and benefits. It is pertinent to mention here that there have been earlier attempts in integrating AHP with BSC for performance measurement (Sharma and Bhagwat, 2007; Jovanovic and Krivokapic, 2008). The contribution in the present research is different, in that, we are proposing a frame work to integrate AHP with modified BSC (not the traditional BSC as was considered by earlier authors) and its implementation in green SCPM whereas earlier contribu-tions did not consider the environmental aspects. The paper is organised into three major parts: (i) An analysis of Green supply chain management system (GSCM) and Green SCPMS based on literature survey; (ii) Examina-tion of BSC and the modification of BSC for Green SC; (iii) AHP and demonstration of the integration of AHP with modified BSC. The significance and the benefits of the proposed method are discussed at the end.

Green supply chain management (GSCM)

GSCM has emerged as an effective management tool and philosophy for leading organizations due to its varied benefits (Zhu et al., 2008). GSCM involves all areas of the SC from green purchasing to reverse logistics. According to Morhardt et al. (2002), organizations adapt green initiatives due to a sense of social responsibility and the desire to adhere to societal norms. There is also a feeling among firms that active environmental management retains the firm's legitimacy (Sarkis et al., 2011). Governments and licensing agencies are instituting environmental performance measures and compliances mandatory for organisations. In situations where reporting of environ-mental and social performance is not mandatory, organisations appear to be doing it because of peer pressure and to improve employees and other stake-holders' perceptions of the company's environmental performance (Morhardt et al, 2002; Darnall et al., 2009). Earlier studies also indicate that increase in environmental performance will contribute to increased profit and market share (Chien and Shih, 2007; Vachon and Klassen, 2008). Naini et al. (2011) observed that environmental SCs are the set of Supply chain management (SCM) policies practiced, actions taken, and relationships formed in response to concerns related to natural environment with regards to the design, acquisition, production, distribution, use, reuse, and disposal of the firm's goods and services. According to Hervani et al. (2005), the 'Green' in Green supply chain management (GSCM) indicates the effect the SC has on the environment. GSCM therefore can be defined as the sum of Green purchasing, Green manufacturing, Green materials management, Green distribution and marketing and Green reverse logistics. Hervani et al. (2005) has classified environment friendly activities at the different links of the SC. These greening activities at the various links of the SC are given in Figure 1.

Green supply chain performance measurement system (SCPMS)

Interest on performance measurement has notably increased in the last 20 years (Taticchi et al., 2010; Thakkar et al., 2009). Organizations have realized that for competing in the present global, dynamic business environment, continuous monitoring of its performance measurement is essential (Gunasekaran et al., 2004). Performance measurement has been recognized as a crucial element to improve business performance. Focusing on performance of the company alone is not sufficient; there is a need to focus on the performance measurement of the SC in which company is a partner (Charan et al., 2008). Many authors have defined PMS in SC with varying approaches and context. Neely et al. (2002) defined PMS as a balanced and dynamic system that enables support of decision-making processes by gathering, elaborating and analyzing information. Taticchi et al. (2010) further elaborated this definition by commenting on the concept of 'balance' and 'dynamicity'. 'Balance' refers to the need of using different measures and perspectives that tied together give a holistic view of the organization. The concept of 'dynamicity' refers to the need of developing a system that continuously monitors the internal and external context and reviews objectives and priorities. Bititci et al. (1997) defined SCPMS as the reporting process that gives feedback to employees on the outcome of actions. The objective of SCPM is to

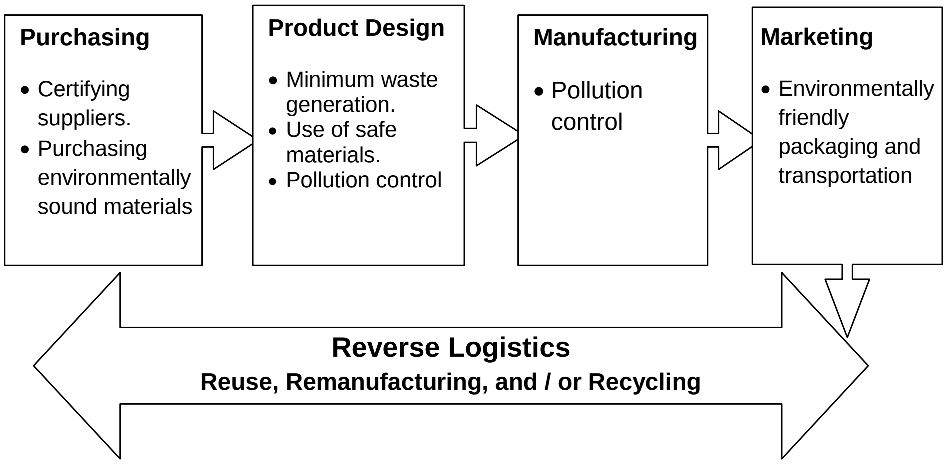

Figure 1. Green activities at supply chain links.

measure business performance, organizational effectiveness and a tool for Quality Improvement Initiatives (QII) (Gunasekaran et al., 2001; Cagnazzo et al., 2010; Lynch et al., 2000). analyze and improve business operational efficiency through better decision-making processes.

The many SCPMS frameworks developed in the last 20 years have their relative benefits and limitations (Bourne et al., 2003; Saad and Patel, 2006). The enumerated advantages of a good SCM are: (i) increased customer value; (ii) increased profitability; (iii) reduced cycle times; (iv) average inventory levels; and (v) better product designs (William et al., 2007). Authors (Tangen, 2005; Charan et al., 2008) have attributed many rewards of implementing SCPMS. Significant among them are:

(1) SCPMS act as vehicle for organizational change and improvement;
(2) Inter-understanding and integration among SC members is facilitated;
(3) It makes an indispensable contribution to decision making in SCM, particularly in re-designing business goals and strategies, and re-engineering processes.

Broadly accepted standards for measuring the total environmental footprint of a SC could not be found in literature. However, SCs are increasingly incorporating Green performance measurements in their SCPMs (Morhardt et al., 2002). There have been some significant contributions in the field of Green SCPMS in the current decade which are briefly reviewed in the succeeding paragraphs.

Taxonomy of GSCM performance

Shang et al. (2010) conducted a study to identify the taxonomy of GSCM capability and firm performance which identified, on the basis of a factor analysis, six GSCM dimensions: (i) Green manufacturing and packaging; (ii) environmental participation; (iii) Green marketing; (iv) Green suppliers; (v) Green stock; and (vi) Green eco-design. Shang et al. (2010) identified 37 performance measure attributes for Green SCPMS. However, based on respondents' perceptions, top five GSCM attributes in respondents' firms identified are as follows:

(1) Design of products to avoid or reduce use of hazardous products and manufacturing processes;
(2) Substitution of polluting and hazardous materials/parts;
(3) The manufacturing process capability to reduce the noise pollution;
(4) Production planning and control focused on reducing waste and optimizing materials' exploitation; and
(5) In purchasing, suppliers certification for green product conformance.

The most widely cited SCPMS are the SMART (1988), the Performance measurement matrix (1989), the BSC (1992), and the Integrated dynamic PMS (1997). The frameworks catering specifically for Green SCPMS are the ISO 14031, Green supply chain operations reference (Green SCOR) model, and the modified BSC proposed by Shaw et al. (2010). Hart (1995) introduced a conceptual framework called the 'Natural Resource Based View' composed of three interconnected strategies: pollution prevention, product stewardship, and sustainable development. The ISO 14031: 1999 Environmental management-Environmental performance evaluation-guidelines gives guidance on the design and use of environmental performance evaluation, and on identification and selection of environmental performance indicators (Environmental management, 2011). ISO 14031 is not a standard for certification. This allows any

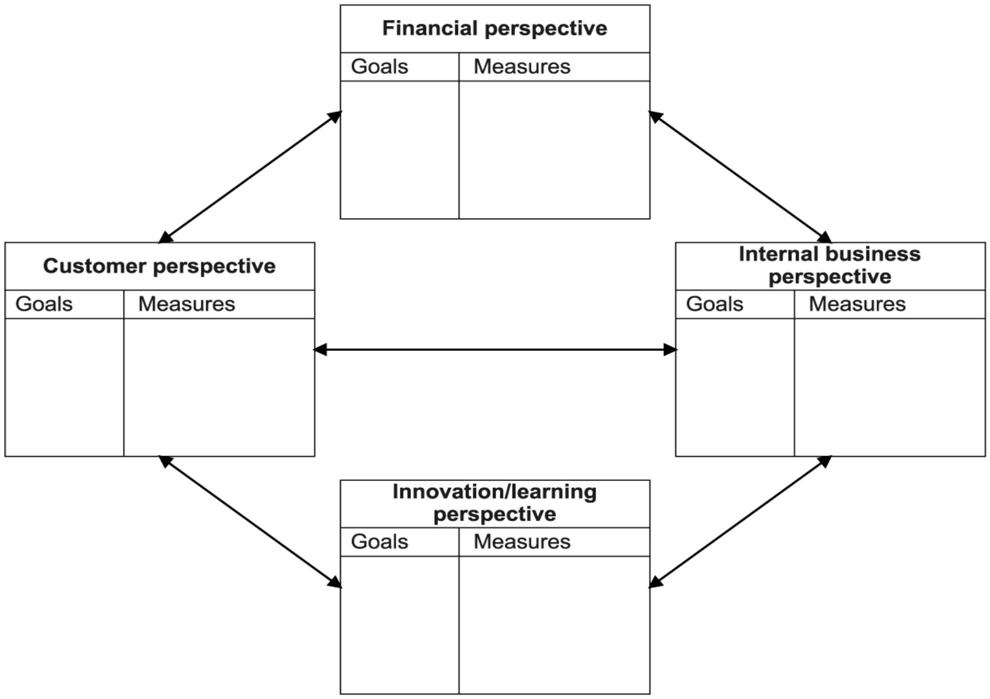

Figure 2. Balanced score card (Source: Kaplan and Norton, 1992).

organisation to measure their environmental performance on an on-going basis (ISO, 2009). ISO 14031 defines environmental performance indicators as a specific expression that provides information about an organisation's environmental performance and divides environmental performance indicators into three classifications: (i) Management performance indicators (MPI); (ii) Operational performance indicators (OPI); and (iii) Environmental condition indicators (ECI). Supply-chain operations reference-model (SCOR) is a process reference model developed by the management consulting firm PRTM, and endorsed by the Supply-chain council (SCC) as the cross-industry performance measurement tool for SCM (Lockamy and McCormack, 2004). SCOR enables users to address, improve, and communicate SCM practices within and between all interested parties in the SC (Huan et al., 2004). SCC, in 2008, incorporated additional elements that define environmental processes, performance metrics and best practices, and these additions allow the framework to be used as a framework for environmental accounting. The SCOR framework ties emissions to the originating processes, providing a structure for measuring environmental performance and identifying where performance can be improved. The hierarchical nature of the model allows strategic environmental footprint goals to be translated to specific targets and activities. GreenSCOR integrates environment best practices and metrics into the entire SC planning process. It also enables a systematic study of the SC to unearth opportunities for making the SC greener. (SCC, 2010, 2011).

Modified balanced score card (BSC) for green SCPMS

The Balanced score card (BSC) was developed in 1992 by Robert Kaplan and David Norton, as an innovative approach to performance measurement (Kaplan and Norton, 1992). The BSC complements financial measures of past performance with measures of the drivers of future performance (Paranjape et al., 2006). BSC proposes that a company should use a balanced set of measures that allows top managers to take a quick but comprehensive view of the business from four important perspectives.

These perspectives (Figure 2) provide answers to four fundamental questions (Kaplan and Norton, 1992; Tangen, 2004): (i) How do we look to our shareholders (financial perspective)? (ii) What must we excel at (internal business perspective)? (iii) How do our customers see us (the customer perspective)? And (iv) How can we continue to improve and create value (innovation and learning perspective)? The BSC includes financial performance measures giving the results of actions already taken. It also complements the financial performance measures with more operational non-financial performance measures, which are considered as drivers of future financial performance (Kaplan and

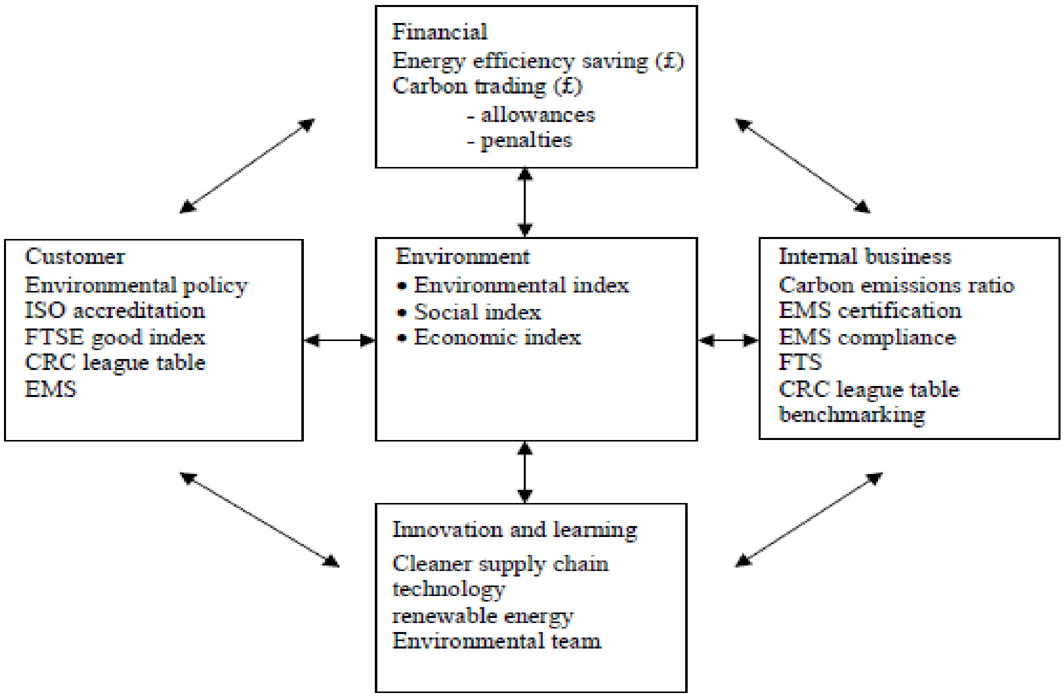

Figure 3. Modified BSC for Green SCPMS (Source: Shaw and Grant, 2010).

Norton, 1996). By giving information from four perspectives, the BSC minimizes information overload by limiting the number of measures used. It also forces managers to focus on the handful of measures that are most critical. Further, the use of several perspectives also guards against sub-optimisation by compelling senior managers to consider all measures and evaluate whether improvement in one area may have been achieved at the expense of another (Tangan, 2004; Kurien and Qureshi, 2011).

The balanced scorecard provides a high level strategic view of corporate performance (Kaplan, 2005) and could be adapted for Green SCPMS. There have been earlier studies where attempts were made to integrate environmental measures with BSC. Länsiluoto and Järvenpää (2008) discuss a case study in which a Finnish food manufacturing company implemented environmental management system (EMS) using BSC. They have found, based on the case study, that it is beneficial and possible to integrate environmental issues with BSC. Naini et al. (2011) proposes a mixed performance measurement system using a combination of evolutionary game theory and the BSC in environmental supply chain management in the context of automobile industry. The study analyses the suitability and limitations of BSC in environmental performance measures, and suggest a new method, an intellectual knowledge-based BSC for strategic planning that sets or selects the firm's strategy using the evolutionary game theory. Shaw et al. (2010) proposed the use of modified BSC by incorporate environmental measures. The two ways in which Green or environmental measures could be expressed within the balanced scorecard are: (1) As a fifth environmental perspective; or (2) as part of the four existing perspectives.

By incorporating environmental measures within the balanced scorecard framework as a fifth perspective or as part of the four existing perspectives, organisations are identifying that environmental management is one of their strategic goals. It raises the profile and importance of environmental management and satisfies the stakeholders that it is being treated as a core value. A modified BSC framework, proposed by Shaw et al., (2010), incorporating environmental measures within the balanced scorecard framework as well as a fifth perspective as shown in Figure 3. Review of related literature indicates certain limitations and weaknesses to the BSC approach. The main weakness of BSC is that it is primarily designed to provide senior managers with an overall view of performance (Ghalayini and Noble, 1996). Thus, it is not intended for (nor is it applicable to) the factory operations level.

Another limitation of BSC is that it provides little guidance on how the appropriate measures can be identified, introduced and ultimately used to manage business (Neely, 2005). BSC is more like a strategic management tool, rather than a true complete PMS. BSC does not specify any mathematical logical relationships among the individual's scorecard criteria.

It is thus difficult to make comparisons within and

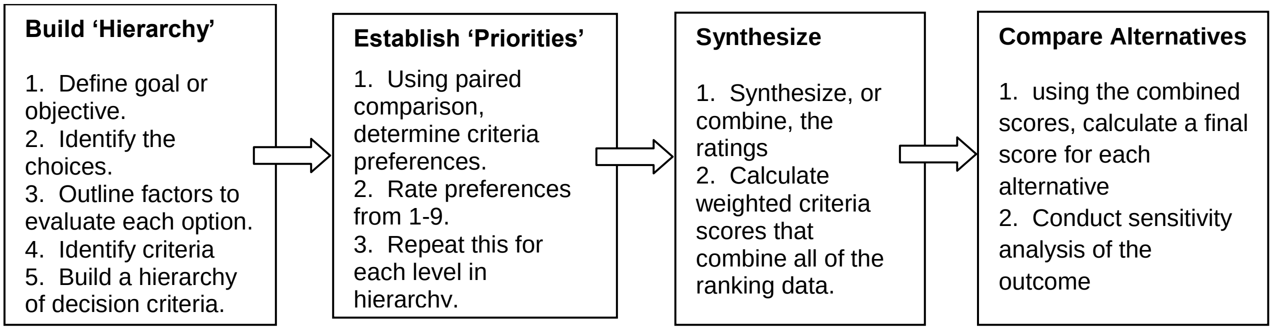

Figure 4. Overview of Analytical hierarchical process (AHP).

across firms using BSC (Soni and Kodali, 2010). The present work is an attempt to provide a framework which overcomes these limitations of BSC by providing a mathematical and logical relationship within the scorecard criteria by integrating AHP with modified BSC.

Analytical hierarchical process (AHP)

The AHP is a general problem-solving method that is useful in making complex decisions (for example, multi-criteria decisions) based on variables that do not have exact numerical consequences (Saaty, 2008). The AHP is a systematic procedure for representing the elements of a problem, hierarchically. AHP uses pair wise comparisons of attributes in the decision making process. Pair wise comparison is used to determine the priorities of each pair of criteria, indicating the strength with which one element dominates the other. It helps to quantify intangible and non economic factors included in the factors affecting the decision. The AHP helps to rank and make decision in a rational and systematic way. Broad areas where AHP has been successfully employed include: selection of one alternative from many; resource allocation; forecasting; total quality management; business process re-engineering; quality function deployment (Forman and Gass, 2000) and in the present work, the BSC. The three primary functions of AHP are (Hepler and Mazur, 2007):

Structuring complexity

Structuring complexity is achieved by hierarchical structuring of complexity into homogeneous clusters of factors.

Measurement

For complex problems with hierarchical structuring, ratio scales would most accurately measure the factors that comprised the hierarchy.

Synthesis

Although AHP's hierarchical structure does facilitate analysis, a more important function is AHP's ability to help us measure and synthesizes the multitude of factors in a hierarchy (Saaty, 2008). An overview of the methodology of using AHP is given schematically in Figure 4. Detailed methodology on AHP formulation and solution including examples are available in literature (Forman and Gass, 2000; Islam and Rasad, 2005; Hepler and Mazur, 2007; Saaty, 2008).

Integration of AHP with modified BSC for GreenSCPMS

Using the framework of the Modified BSC for Green SCPMS's five perspectives, generic performance measures were identified for the purpose of analysis and developing the current model. The measures considered are in line with other researchers (Shaw et al., 2010) and is depicted in Table 1.

Step 1

Building 'hierarchy': The first step in solving a decision problem by AHP is decomposing the problem into a hierarchy of criteria and alternatives. A hierarchy is structured from the top (primary objective(s) or goals), then intermediate levels which are criteria/sub-criteria on which subsequent levels depend to the lowest level which is usually a list of alternatives from which to choose or compare. Based on the criteria selected for performance measurement using Modified BSC, given in Table 1, an AHP hierarchy model is prepared. The hierarchy model consists of the 'goal' which is 'sustainability and growth' at the top, the contributing levels of 'criteria' and 'alternatives'. The five perspectives of the modified BSC form the Level 1 criterion and the performance measures which contribute to each of the five perspective forms the second level criteria. The competing SCs form the

Table 1. List of measures used in the study.

Financial perspective (FP)	Customer perspective (CP)	Internal business perspective (IB)	Innovation and learning (IL)	Environment (EN)
Energy efficiency saving (ES)	Environment policy (EP)	Carbon emission ratio (CE)	Cleaner SC (CS)	Environment index (EI)
Carbon trading allowances (CA)	ISO Accreditation (IS)	EMS certification (EM)	Renewable energy (RE)	Social index (SI)
Carbon trading penalties (CT)	FTSE Good index (GI)	Benchmarking (BM)	Environmental team (ET)	Economic index (EC)
	EMS (EM)			

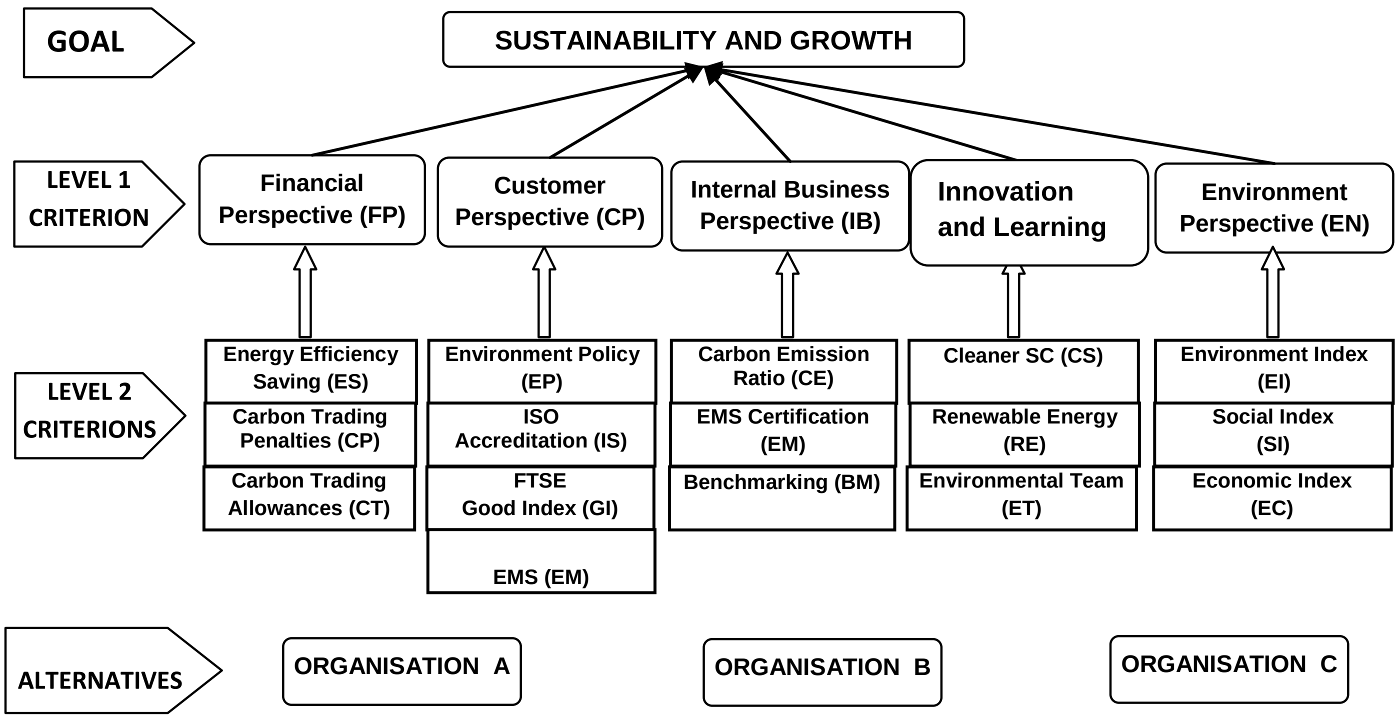

Figure 5. AHP Hierarchy Scheme for GreenSCPMS.

'alternatives' in the AHP hierarchical model. The AHP hierarchical model for modified BSC for environmental performance measurement is shown in Figure 5.

Step 2

Establishing Priorities: After decomposing problem into levels of criteria and building the hierarchy, the next step is generating the priority matrix for each level of criteria. AHP uses pair wise comparison of the same hierarchy elements in each level (criteria) using a scale indicating the

Table 2. The fundamental scale of absolute numbers.

Intensity of relative importance (Comparison values)	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment slightly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Demonstrated importance	An activity is strongly favored and its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals of above non-zero numbers	If an activity has one of the above numbers compared with a second activity, then the second activity has the reciprocal value when compared to the first	

(Source: Saaty, 2008; Sharma and Bhagwat, 2007).

Table 3. Comparison matrix for level 1 criteria.

Paired comparison	Financial perspective (FP)	Customer perspective (CP)	Internal business perspective (IB)	Innovation and learning (IL)	Environment (EN)
Financial perspective (FP)	1	1/3	2	3	2
Customer perspective (CP)	3	1	3	4	2
Internal business perspective (IB)	1/2	1/3	1	2	1/3
Innovation and learning (IL)	1/3	1/4	1/2	1	1/5
Environment (EN)	1/2	1/5	3	5	1

importance of one element over another with respect to a higher-level element. The importance of scale between elements is shown in Table 2. For each level of Criteria, by ‘Paired comparison’ and by using ‘Comparison values’, ‘Comparison matrix’ is generated. The comparison matrices are obtained through brainstorming of selected representatives of the organisation. The ‘comparison matrix’ for Level 1 criterion is shown in Table 3. Similar ‘comparison matrices’ are prepared for each group in Level 2 criteria. The ‘Comparison matrix’ forms part of the Eigen matrix.

Step 3

Generation of Eigen Vectors: Based on the Comparison matrix, Eigen Vectors are calculated for each level of criteria. The Eigen vector represents the Priority measure of each criterion. Consistency of comparative matrices are then checked to see whether the ‘paired comparisons’ are logical.

This is to check the consistency of judgment of the decision maker. The Consistency index (CI) is calculated as:

$$\mathbf{CI}=\frac{\lambda_{\max}-1}{(n-1)} \qquad (1)$$

Where:

$\lambda_{\max} = \sum(\text{Sum of column values of Comparison Matrix} \times \text{Eigen vector Element})$

n = number of criterion under paired comparison. Based on the Consistency index (CI) and the Random consistency index (RI), Consistency ratio (CR) is calculated as:

$$\text{Consistency Ratio (CR)}=\frac{\text{Consistency Index (CI)}}{\text{Random Consistency Index (RI)}} \qquad (2)$$

Random consistency index (RI) values are taken from the Random consistency index table (Table 4). RI is selected for the same order matrix from Table 4. The condition for consistency of judgement is that Consistency ratio (CR) < 10% (Saaty, 2008). Eigen vectors generated and the priority matrices for all levels of criteria are calculated and shown in Table 5. The calculated CI values are also shown in Table 5. The CGI software for AHP has been used for calculation of Eigen vectors.

Table 4. Random consistency index table.

n	1	2	3	4	5	6	7	8	9	10	11	12
R I	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.58

(Source: Saaty, 2008; Sharma and Bhagwat, 2007).

Table 5. Tables for calculated eigen vectors (E.V).

Eigen matrix for level 1 criteria						
	FP	**CP**	**IB**	**IL**	**EN**	**Eigen Vector**
FP	1	0.3333	2	3	2	0.2249
CP	3	1	3	4	2	0.3912
IB	0.5	0.3333	1	2	0.3333	0.1032
IL	0.3333	0.25	0.5	1	0.2	0.0627
EN	0.5	0.5	3	5	1	0.2179
C.I.= 0.0680892						

Eigen matrix for level 2 criteria (IL)					Eigen matrix for level 2 criteria (EN)				
IL	**CS**	**RE**	**ET**	**Eigen Vector**	**EN**	**EI**	**SI**	**EC**	**Eigen Vector**
CS	1	0.25	3	0.2255	**EI**	1	0.2	0.3333	0.1047
RE	4	1	5	0.6738	**SI**	5	1	3	0.6369
ET	0.3333	0.2	1	0.1006	**EC**	3	0.3333	1	0.2582
C.I.= 0.0428833					C.I.= 0.0192555				

Eigen matrix for level 2 criteria (FP)					Eigen matrix for level 2 criteria (IB)				
FP	**ES**	**CA**	**CP**	**Eigen Vector**	**IB**	**CE**	**EM**	**BM**	**Eigen Vector**
ES	1	4	2	0.5584	**CE**	1	5	3	0.6369
CA	0.25	1	0.333333	0.1219	**EM**	0.2	1	0.333333	0.1047
CT	0.5	3	1	0.3196	**BM**	0.333333	3	1	0.2583
C.I.= 0.00914735					C.I.= 0.0192555				

Eigen matrix for level 2 criteria (CP)					
CP	**EP**	**IS**	**GI**	**EM**	**Eigen Vector**
EP	1	3	2	4	0.447
IS	0.333333	1	0.25	2	0.1280
GI	0.5	4	1	4	0.3414
EM	0.25	0.5	0.25	1	0.0833
		C.I.=	0.0440928		

Step 4

Aggregate priority vectors: The Aggregate priority vector table provides relative weights and contribution of each criterion. This is obtained by normalizing individual Eigen matrices. The normalized priority matrix values are calculated such that the values of Sub criteria are within the weight of its corresponding higher criteria (Parent criteria). Table 6 shows the normalized priority matrix.

Step 5

Overall performance index: Overall performance score of the organization is calculated once measures of each criterion are available. The data used is of a hypothetical firm. The scales and units of the performance measures are different. Hence, the performance scores are normalised to a uniform scale of 0 to 100. The normalised performance scores are multiplied by the normalised Eigen vectors (weighting measure) to obtain the overall performance score. The overall performance score is calculated at Table 7. The aggregate of performance score at each level of criterion is calculated to provide the overall performance index of the SC.

RESULTS AND DISCUSSION

The Normalized priority matrix is a useful tool to evaluate importance of each criterion (Measure) in achieving

Table 6. Aggregate priority vectors showing contribution of all criteria.

Criteria	Eigen value	Normalized eigen value	% Contribution	
			Level 1	Level 2
Innovation and learning (IL)	0.0627	0.0627		6.27
Cleaner SC (CS)	0.2255	0.0141	1.4139	
Renewable energy (RE)	0.6738	0.0422	4.224	
Environment team (ET)	0.1006	0.0063	0.6308	
Environment (EN)	0.2179	0.2179		21.79
Environment index (EI)	0.1047	0.0228	2.2814	
Social index (SI)	0.6369	0.1388	13.878	
Economic index (EC)	0.2582	0.0563	5.6262	
Financial perspective (FP)	0.2249	0.2249		22.49
Energy Eff. saving (ES)	0.5584	0.1255	12.558	
Carbon transport allowance (CA)	0.1219	0.0274	2.7415	
Carbon transport penalties (CT)	0.3196	0.0719	7.1878	
Internal business (IB)	0.1032	0.1032		10.32
Carbon emission (CE)	0.6369	0.0657	6.5728	
EMS certification (EM)	0.1047	0.0108	1.0805	
Benchmarking (BM)	0.2583	0.0267	2.6657	
Customer perspective (CP)	0.3912	0.3912		39.12
Environment policy (EP)	0.4471	0.1749	17.490	
ISO accreditation (IS)	0.128	0.0501	5.007	
FTSE good index (GI)	0.3414	0.1336	13.355	
EMS (EM)	0.0833	0.0326	3.2587	
Total	6.0000	2.0000	100	100

organizational goal of ‘sustainability and growth’. AHP provides weightings to the performance measures which indicate its contribution in a quantitative manner. Management can know how much each criterion will contribute to achieving the organizational goal. For example, from Table 6, we can infer that at the first level of criterion, Customer perspective (CP) has the highest weighting, and its contribution to achieve ‘sustainability and growth’ is 39.12%. The percentage contributions of Level 1 criterion are represented graphically in Figure 6. At the second level, Environment policy (EP) contributes 17.49% whereas the Environmental team (ET) contributes only 0.63% to achieve ‘sustainability and growth’. The percentage contributions of Level 2 criterion are represented graphically in Figure 7. Therefore, based on this analysis, it will be prudent for the management to align its resources and processes more to the criterion which contributes most to achieve organisational objectives. The management can also use this information to look into those performance criterions which are contributing lower than expected to achieve organisational objectives to take steps to improve its contribution.

Overall performance index derived through AHP - BSC integrated model (shown in Table 7) quantifies overall performance of a SC. The calculated value of 60.35 overall performance indices is significant when it is compared with earlier performance indices or compared with performance indices of similar SC. This quantified performance index will help in comparing similar supply chains, comparing performance of sub units of a supply chain, and also in comparing with earlier performances of the same SC or sub unit. These measures can also be used for target setting and as a feedback for mid course correction and monitoring.

Conclusion

Properly planned, implemented and managed green SCs enable organisations to be responsible corporate citizens, resulting in higher profitability, and retain competitive advantage. Selection and use of appropriate Green SCPMS is critical for success of the green SC. Industry standard frameworks like SCOR version 9, ISO 14031 and Modified BSC incorporating a fifth dimension on environment are the preferred guidelines available for Green SCPMS. The limitations of BSC; that it is difficult to make comparisons within and across firms and that the measurements making the scorecards unbalanced have been overcome by incorporating AHP with BSC. The AHP framework will be a useful tool to assess importance of each criterion (Measure) in achieving organizational goal. Management can know how each criterion will

Table 7. Overall performance index.

Level 1 criteria	Level 2 criteria	Original scale		Score	Normalised score in scale of 0 - 100	Normalised eigen vector	Overall performance score	
		Lower limit	Upper limit				Level 1 score	Level 2 score
IL	CS	0	10	6	60.00	0.0141	4.30	0.8460
	RE	1	1000	700	69.97	0.0422		2.9527
	ET	0	100	80	80.00	0.0063		0.5040
EN	EI	1	50	20	38.78	0.0228	14.08	0.8842
	SI	1	10	7	66.67	0.1388		9.2538
	EC	-10	10	4	70.00	0.0563		3.9410
FP	ES	0	1	0.8	80.00	0.1256	13.67	10.0480
	CA	20	50	40	66.67	0.0274		1.8268
	CT	-1	1	-0.5	25.00	0.0719		1.7975
IB	CE	0	10	9	90.00	0.0657	8.65	5.9130
	EM	0	1	0.8	80.00	0.0108		0.8640
	BM	100	200	170	70.00	0.0267		1.8690
CP	EP	0	50	20	40.00	0.1749	19.65	6.9960
	IS	0	100	75	75.00	0.0501		3.7575
	GI	-10	10	0	50.00	0.1336		6.6800
	EM	0	100	68	68.00	0.0326		2.2168
				Overall Performance Index			60.35	60.35

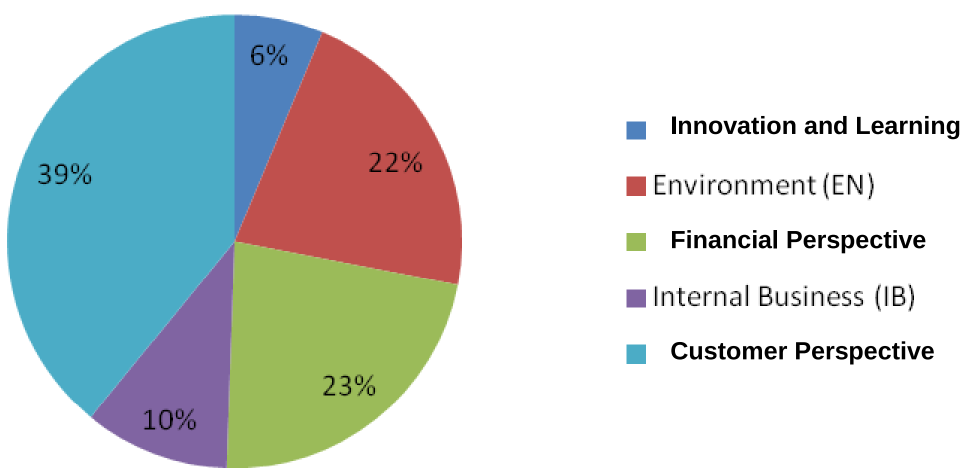

Figure 6. Percentage contribution of measures at level 1 criteria.

contribute in achieving Greening of the SC. Management can thus prioritise its resource deployment and make more informed decisions. Overall performance index derived through AHP-modified BSC integrated model may also help management for benchmarking of Green initiatives of organisations. The numerical performance index will help in comparing Green initiatives of similar SCs, comparing performance of sub units of a SC and also in comparing with earlier performances of the same SC or sub unit in the area of sustainability. These measures can also be used for target setting and as a feedback for mid course correction and monitoring.

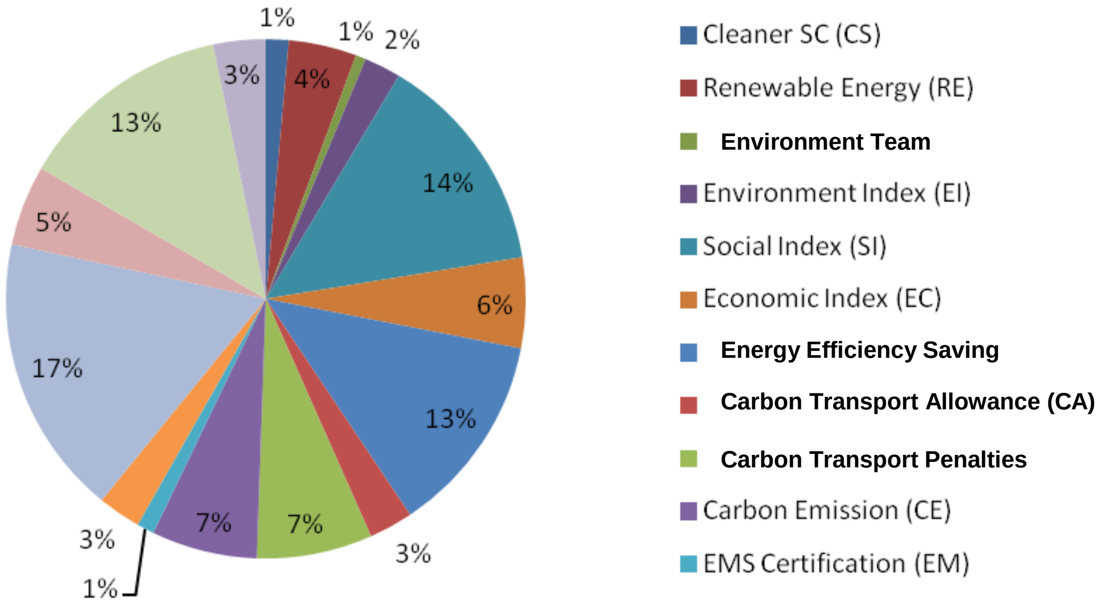

Figure 7. Percentage contribution of measures at level 1 criteria.

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