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Ranking of Performance Measures of GSCM towards Sustainability: Using Analytic Hierarchy Process

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***Abstract*—**During recent years, the natural environment has become a challenging topic that business organizations must consider due to the economic and ecological impacts and increasing awareness of environment protection among society. Organizations are trying to achieve the goals of improvement in environment, low cost, high quality, flexibility and more customer satisfaction. Performance measurement frameworks are very useful to monitor the performance of any organization. The basic goal of this paper is to identify performance measures and ranking of these performance measures of GSCM performance measurement towards sustainability framework. Five perspectives (Environment, Economic, Social, Operational and Cost performances) and nineteen performance measures of GSCM performance towards sustainability have been have been identified from extensive literature review. Analytical Hierarchy Process (AHP) technique has been utilized for ranking of these performance perspectives and measures. All pair comparisons in AHP have been made on the basis on the experts' opinions (selected from academia and industry). Ranking of these performance perspectives and measures will help to understand the importance of environmental, economic, social, operational performances and cost performances in the supply chain.

***Keywords*—**Analytical Hierarchy Process (AHP), Green Supply Chain Management, Performance Measures (PM), Sustainability.

I. Introduction

IN the competitive business environment achieving sustainable supply chains is an issue that is still to be solved Green Supply Chain management (GSCM) has emerged as a key approach for enterprises aiming to become environmentally sustainable [1]. Performance measurement frameworks are useful tools that aid to collect and monitor the evolution of performance of any organization [2]. Managers in Supply Chain Management (SCM) are still wrestling with issue of performance measurement of GSCM because generally accepted framework does not exist [3].

With the increasing awareness on environmental sustainability issues, manufacturing firms nowadays start to think and act green [4**]**. There are difficulties in measuring performance within organizations and even more difficulties arise in inter-organizational environmental performance measurement [5].

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Faced with rising pressures to develop more environmental and social responsibility, companies are developing new communication approaches in conjunction with attempts to incorporate sustainability measures into strategic performance measurement systems [6]. Sustainable supply chain performance measurement is aimed at addressing environmental, social and economic aspects of sustainable supply chain management. It is not easy to reduce all dimensions of sustainable supply chain to a single unit. Therefore, Multi-criteria evaluation framework is required for adequate assessment of sustainable supply chain performance measures [7]. Hence need arises to identify and rank GSCM performance measures towards sustainability in using multi criteria technique i.e. Analytical Hierarchy Process (AHP) technique.

The remainder of this paper is organized as follows. Relevant literature on GSCM performance measures towards sustainability has been presented in Section II. Methodology of the research has been explained in Section III. Data analysis and results have been presented in Section IV. Discussions of finding have been given in Section V. Concluding remarks have been given with the limitations of this research and the directions for future research in the last section.

II. Literature Review: GSCM Performance Measures towards Sustainability

Extensive literature review has been made to identify performance measures of GSCM towards sustainability. Five performance perspectives (Environment, Economic, Social, Operational and Cost) and nineteen performance measures has been identified as follows:

A. Environmental Performance Perspective

Implementation of GSCM of Indian industries are expected to improve environmental performances like decrease in waste i.e. extent of recycling and reuse, reduction in air emissions, liquid and solid wastes, decrease in use of harmful / hazardous materials etc., which will reduce organizational environmental risks.

B. Reduction in Air Emissions, Liquid & Solid Wastes

Implementation of GSCM practices reduce in air emissions, liquid and solid wastes risks [9], [10], [13]-[20].

C. Extent of Recycling & Reuse

GSCM adopting a sustainable approach can produce less waste and use more recycled material, thereby using energy, water and by-products in a more efficient way [8]-[12].

D. Decrease in Use of Harmful/Hazardous Materials/ Components

GSCM practices will help elimination or reduction of environmental harmful/hazardous materials/components [20]-[22].

E. Economic Performance Perspective

Implementation of GSCM of Indian industries are expected to improve economic performances like increase in productivity, decreased cost of material purchasing and energy consumption, increase in firm's competitiveness, increase in profitability etc., which will increase market share.

F. Increase in Productivity

GSCM is the integrating environmental concerns into product flows within and beyond organizational boundaries, has become a recognized management approach to achieve productivity gains with lessened environmental harm [9], [10], [13], [16]-[19], [22], [23].

G. Decreased Costs of Material Purchasing and Energy Consumption

GSCM practices cut the cost of materials purchasing and energy consumption; reduce the cost of waste treatment and discharge [9], [10], [15]-[21].

H. Increased Firm's Competitiveness

Organizations that proactively incorporate environmental goals into their business practices and proper strategic planning enjoy a competitive advantage [23], [24].

I. Increase in Profitability

Organizations following GSCM practices will increase competitiveness, which will help in increasing sales volumes. Increased sales volume will help in increasing profitability [9], [10], [15], [18]-[23].

J. Increased Market Share

GSCM practices, and their many related principles have become important strategies for companies to achieve profit and increase market share objectives by lowering their environmental impact and enhancing efficiency [13], [19]-[21], [25]-[28].

K. Social Performance Perspective

Implementation of green supply concept in supply chain of Indian industries is expected to improve social performances like corporate image improvement, increase in customer awareness level, satisfaction and loyalty etc.

L. Corporate Image Improvement

Green supply chain initiatives, through their focus on reducing negative impacts on the environmental and promoting environmentally friendly products, are expected to improve the image of a firm in the eyes of its stakeholders including government, customers, suppliers, employees, and the public at large. GSCM practices adoption will contribute towards sustainable development of the society [17], [18], [21], [29].

M. Contribution to Environmental Protection

Organizations implementing green supply chain management practices will contribute towards environmental protection [5], [9], [10], [13], [15], [18], [22], [30].

N. Increase in Customer Awareness Level

Customers now are becoming more aware about eco-friendly products and their benefits. More aware customers may start demanding environment friendly products [21], [31], [32].

O. Operational Performance Perspective

Operational Performances include decrease of fine for environmental accidents, Improvement in environmental quality of products/ processes, Reduction in environmental risks, increase in customer awareness level and increased customer's satisfaction & loyalty.

P. Decrease of Fine for Environmental Accidents

GSCM may reduce costs associated with energy consumption, waste treatment, waste discharge, and fines for environmental accidents [15], [17], [19]-[22].

Q. Increased Customer's Satisfaction & Loyalty

Positive image brand may lead to other intangible benefits such as gaining customer satisfaction and loyalty in addition to improved staff morale [9], [10], [13], [15], [18], [21], [33], [34].

R. Reduction in Environmental Risks

Organizations may reduce their environmental compliance costs and lessening the threat of civil and criminal liability for polluting by preventing pollution at the source [15], [18], [26], [35].

S. Improvement in Environmental Quality of Products/ Processes

Many authors reported that GSCM practices improve the environmental quality of products/processes [9], [13], [17], [19], [21], [22], [34].

T. Cost Performance Perspective

Implementation of green concept in supply chain may show negative performance also like increase in investment, increased operational costs, increased training costs, increased costs for purchasing green materials/products etc.

U. Increase in Costs for Purchasing Environment Friendly Materials/ Products

GSCM practices implementation may increase of costs for purchasing environmentally friendly materials/ products [15], [18].

V. Increase in Training Cost

Considerable costs may be involved in training of employees, suppliers/vendors and customers about the green products and their benefits [32].

W. Increase in Investment

GSCM initiatives are considered to involve considerable costs and investments, especially during initial stages [18]. Poor allocation of firm investment will generate negative returns to shareholders [36].

X. Increase in Operational Cost

GSCM practices adoption may increase operational costs, and this in turn may have a negative impact on firms' financial performance [15], [37].

These identified performance perspectives and expected performance implementing GSCM practices towards sustainability have been shown in Table I.

TABLE I
IDENTIFIED PERFORMANCE PERSPECTIVES AND EXPECTED PERFORMANCE MEASURES

Performance Perspective	Expected Performance Measures by Implementing GSCM
Environmental (ENV)	1. Reduction in air emissions, liquid & solid wastes (RAL) 2. Extent of recycling & reuse (ERR) 3. Decrease in use of harmful/hazardous materials/ components (DUH)
Economic (ECO)	1. Increase in productivity (IIP) 2. Decreased costs of material purchasing and energy consumption (DCM) 3. Increased firm's competitiveness (IFC) 4. Increase in profitability (IPF) 5. Increased market share (IMS)
Social (SOC)	1. Corporate image improvement (CII) 2. Contribution to environmental protection (EEP) 3. Increase in customer awareness level (ICL)
Operational (OPR)	1. Decrease of fine for environmental accidents (DFA) 2. Increased customer's satisfaction & loyalty (ISL) 3. Reduction in environmental risks (RER) 4. Improvement in environmental quality of products/ processes (IQP)
Cost (COS)	1. Increase in cost for purchasing environment friendly materials/products (ICP) 2. Increase in training cost (ITC) 3. Increase in investment (III) 4. Increase in operational cost (IOC)

III. METHODOLOGY: ANALYTIC HIERARCHICAL PROCESS

Analytical Hierarchy Process (AHP) methodology compares criteria, or alternatives with respect to a criterion, in a natural, pair wise mode. The resultant can be used to compare and rank the alternatives and, hence, assist the decision maker in making a choice. AHP has the following steps [38]-[40]:

Step 1. Establishing the Hierarchical Structure.

Construct the hierarchical structure with decision elements, decision-makers are requested to make pair-wise comparisons between decision alternatives and criteria using a nine-point scale.

Step 2. Constructing the Pair Wise Comparison Matrix.

Construct a set of pair wise comparison matrices.

Step 3. Calculating the Consistency.

To ensure that the priority of elements is consistent, the maximum eigenvector or relative weights and max l are calculated. Then, compute the consistency index (CI) for each matrix order n using (1). Based on the CI and Random Consistency index (RI), the consistency ratio (CR) is calculated using (2). The CI and CR are defined as follows [40].

$$\mathbf{CI} = (\lambda max - n)/ (n-1) \quad (1)$$

The consistency ratio is then calculated using the formula

$$\mathbf{CR}=CI/RI \quad (2)$$

where RI varies depending upon the order of matrix. Table II shows the value of the RI for matrices of order (N) 1 to 8 obtained by approximating random indices using a sample size of 500.

TABLE II
RANDOM INDEX FOR MATRICES OF ORDER 1 TO 8

N	1	2	3	4	5	6	7	8
R.I.	0	0	0.58	0.90	1.12	1.24	1.32	1.41

The acceptable CR range varies according to the size of matrix i.e. 0.05 for a 3 by 3 matrix, 0.08 for a 4 by 4 matrix and 0.1 for all larger matrices, n>= 5. If the value of CR is equal to, or less than that value, it implies that the evaluation within the matrix is acceptable or indicates a good level of consistency in the comparative judgments represented in that matrix. In contrast, if CR is more than the acceptable value, inconsistency of judgments within that matrix has occurred and the evaluation process should therefore be reviewed, reconsidered and improved. An acceptable consistency ratio helps to ensure decision-maker reliability in determining the priorities of a set of criteria [41], [42].

IV. DATA ANALYSIS AND RESULTS

We conducted a workshop to obtain experts' opinions to make pair wise comparisons between performance perspectives and performance measures. Four experts were from academia and two were from industry. Based on the ratings obtained through the questionnaire by experts during workshop, matrices are formed and the priorities are synthesized using the methodology of AHP.AHP framework of ranking of performance measures is structured as a hierarchy which includes three levels: Goal: GSCM performance measurement towards sustainability framework; 2nd level: five performance perspectives; and 3rd level: nineteen performance measures under various performance perspectives.

A. Constructing the Hierarchy of Five Perspectives of GSCM Performance Framework towards Sustainability

Five GSCM performance perspectives (Environmental, Economic, Social, Operational and Cost) have been checked for hierarchy. Table III shows weights given by experts to these dimensions.

TABLE III
RANKING OF PERSPECTIVES OF GSCM PERFORMANCES TOWARDS SUSTAINABILITY

Performance Perspective	ENV	ECO	SOC	OPR	COS	Global priority weighting	Rank
ENV	1	2	3	2	4	0.374	1st
ECO	0.5	1	2	1	3	0.215	2nd
SOC	0.33	0.5	1	0.5	3	0.136	4th
OPR	0.5	1	2	1	2	0.200	3rd
COS	0.25	0.33	0.33	0.5	1	0.075	5th

Maximum Eigen value= 5.11621
C.I. = 0.0290526
Pair wise comparison matrix of perspectives of GSCM performances towards sustainability

From the analytical results shown in Table III, 'Environmental performances perspective (0.374)' of GSCM performances towards sustainability has been reported the most important perspective of GSCM performances towards sustainability followed by 'Economic performances (0.215)'; 'Operational performances (0.200)'; 'Social performances (0.136)' and 'Cost performances 0.075)'.

B. Constructing the Hierarchy of GSCM Performance Measures towards Sustainability

In next level, performance measures under each perspective have been rated by experts and checked for hierarchy. The maximum Eigen values, C.I. and pair wise comparison matrix of performances measures under "Environmental Perspective" have been shown in Table IV as follows:

TABLE IV
RANKING OF PERFORMANCE MEASURES UNDER "ENVIRONMENTAL PERSPECTIVE"

Performance Measures	RAL	ERR	DUH	Global priority weighting	Rank
RAL	1	2	1	0.4	1st
ERR	0.5	1	0.5	0.2	2nd
DUH	1	2	1	0.4	1st

Maximum Eigen value= 3
C.I. = 2.22045e-16
Pair wise comparison matrix of performance measures in Environmental perspective of GSCM performances towards sustainability

In Table IV shows that 'Reduction in air emissions, liquid & solid wastes (0.4)' and 'Decrease in use of harmful/hazardous materials/components (0.4) have been found the most important performance measures and 'Extent of recycling and reuse activities (0.2)' least important performance measures in "Environment perspective" of GSCM performances towards sustainability.

Similarly, perspective 2 to 5 of performance measures by implementing GSCM practices towards sustainability (Tables V to VIII) has been ranked respectively.

TABLE V
RANKING OF PERFORMANCE MEASURES UNDER "ECONOMIC PERSPECTIVE"

Performance Measures	IIP	DCM	IFC	IPF	IMS	Global priority weighting	Rank
IIP	2	1	0.5	1	0.5	0.157	4th
DCM	1	0.5	0.33	0.5	0.33	0.087	5th
IFC	3	2	1	2	1	0.298	1st
IPF	2	1	0.5	1	2	0.224	3rd
IMS	3	2	1	0.5	1	0.233	2nd

Maximum Eigen value= 5.22323
C.I. = 0.0558076
Pair wise comparison matrix of performance measures in Economic perspective of GSCM performances towards sustainability

Table V shows that Increased firm's competitiveness (0.298)' has been found the most important performance measures in "Economic perspective" of GSCM performances towards sustainability, followed by 'Increased market share (0.233)'; 'Increase in profitability (0.224)'; 'Increase in productivity (0.157)' and 'Decreased costs of material purchasing and energy consumption (0.087)'.

TABLE VI
RANKING OF PERFORMANCE MEASURES UNDER "SOCIAL PERSPECTIVE"

Performance Measures	CII	EEP	ICL	Global priority weighting	Rank
CII	1	3	1	0.443	1st
EEP	0.33	1	0.5	0.169	3rd
ICL	1	2	1	0.388	2nd

Maximum Eigen value= 3.01829
C.I. = 0.00914735
Pair wise comparison matrix of performance measures in Social perspective of GSCM performances towards sustainability

'Corporate image improvement (0.443)' has been reported the most important performance measure in "Social perspective" of GSCM performances towards sustainability, followed by 'Increase in customer awareness level (0.388)' and 'Contribution to environmental protection (0.169)' have been shown in Table VI.

TABLE VII
RANKING OF PERFORMANCE MEASURES UNDER "OPERATIONAL" PERSPECTIVE"

Performance Measures	DFA	ISL	RER	IQP	Global priority weighting	Rank
DFA	1	0.33	2	0.5	0.169	3rd
ISL	3	1	3	2	0.451	1st
RER	0.5	0.33	1	0.5	0.119	4th
IQP	2	0.5	2	1	0.261	2nd

Maximum Eigen value= 4.07101
C.I. = 0.0236709
Pair wise comparison matrix of perspectives of GSCM performances towards sustainability

From the analytical results shown in Table VII, 'Increased customer's satisfaction & loyalty (0.451)' has been reported the most important performance measure in "Operational perspective of GSCM performances towards sustainability, followed by 'Improvement in environmental quality of products/ processes (0.261)'; 'Decrease of fine for

environmental accidents (0.169)' and 'Reduction in environmental risks (0.119)'.

TABLE VIII
RANKING OF PERFORMANCE MEASURES UNDER "COST PERSPECTIVE"

Performance Measures	ICP	ITC	III	IOC	Global priority weighting	Rank
ICP	1	2	0.25	0.33	0.131	3rd
ITC	0.5	1	0.25	0.5	0.101	4th
III	4	4	1	3	0.525	1st
IOC	3	2	0.33	1	0.243	2nd

Maximum Eigen value= 4.15959
C.I. = 0.0531961
Pair wise comparison matrix of perspectives of GSCM performances towards sustainability

'Increase in investment (0.525)' has been reported the most important performance measure in "Cost perspective" of GSCM performances towards sustainability, 'Increase in operational cost (0.243)'; 'Increase in cost for purchasing environment friendly materials/products (0.131)' and 'Increase in training cost (0.101)' have been shown in Table VIII.

Consistency ratio (C.R.) values are well in acceptable range for matrices shown in Tables III to VIII, which ensures decision-maker reliability.

V. DISCUSSIONS OF FINDINGS

GSCM has recently received considerable attention in business management literature. Managers well educated in SCM are wrestling with issue of performance measurement because generally accepted framework does not exist [43]. This paper provides identification and ranking of various performance perspectives and performance measures of GSCM towards sustainability from the available literature review and experts' opinions. A comprehensive literature review was conducted to identification of performance measures. Idea engineering workshop was carried out to make pair wise comparisons of these identified performance measures. AHP methodology has been used for ranking of these identified performance perspectives and measures.

"Environment performances" perspective has been found highest global weighting and "Cost performances" perspective lowest global weighting. These have been ranked as 1st and 5th respectively. Further, ranking of various performance measures in each perspective has been done:

- ✓ 'Reduction in air emissions, liquid & solid wastes' and 'Decrease in use of harmful/ hazardous materials/ components' have been found the most important performance measures and 'Extent of recycling and reuse activities' least important performance measures in "Environment performances" perspective of GSCM performances towards sustainability.
- ✓ Similarly, 'Increased firm's competitiveness' has been found as the most important performance measure and 'Decreased costs of material purchasing and energy consumption ' as least important performance measure in Perspective 2 of GSCM performances towards sustainability (Economic performances).
- ✓ In perspective 3 Social performances) of GSCM performances towards sustainability, 'Corporate image improvement' performance measure has obtained highest rank and 'Contribution to environmental protection' performance measure has obtained lowest rank.
- ✓ 'Increased customer's satisfaction & loyalty' has been reported as highest ranked performance measure and 'Reduction in environmental risks' as lowest ranked performance measure in perspective 4 (Operational performances) of GSCM performances towards sustainability.
- ✓ 'Increase in investment has been reported as highest ranked performance measure and 'Increase in training cost' as lowest ranked performance measure in perspective5 (Cost performances) of GSCM performances towards sustainability.

This paper may play important role to understand various performance perspectives and measures. Ranking of these performance perspectives and measures will help to understand the importance of environmental, economic, social, operational performances and cost performances in the supply chain.

VI. CONCLUDING REMARKS

In the past decade there has been received significant attention in the field of environment friendly and sustainable practices in supply chain management worldwide. Due to globalization, intense global competition, rapid technological changes, shorter product life cycles, environment and social issues, industries are under tremendous pressure to implement GSCM practices. Generally accepted GSCM performance measurement framework does not exist. In this paper, we have identified GSCM performance measures and ranking of these performance measures. Five perspective (Environment, Economic, Social, Operational and Cost performances) and nineteen performance measures of GSCM performance towards sustainability have been ranked. This paper has presented a benchmarking framework to make complicated decisions of GSCM performances towards sustainability. The proposed framework permits managers/practitioners to make decision about performance measures in their organization to achieve sustainability in the supply chain. Manufacturers of related industries may use our proposed model to evaluate their GSCM sustainability in efficient way in their organizations.

We have used AHP methodology for ranking of GSCM performance measures towards sustainability. All pair comparisons in AHP have been made on the basis on the experts' opinions (selected from academia and industry). As it is natural, opinions of experts may be different or biased.

From the literature review and expert opinions in detail, different multi-criteria decision making models may be applied for the same problem and results can be compared in the further studies. The sensitivity analysis can be performed to examine the influence of the preferences given by the

decision makers for the selection of sustainability performances. Real world case studies can be used to validate this research work.

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