Journal of Material Science and Mechanical Engineering (JMSME)
Print ISSN: 2393-9095; Online ISSN: 2393-9109; Volume 2, Number 10; April-June, 2015 pp. 30-36

http://www.krishisanskriti.org/jmsme.html

Evaluation of the Effects of Green Practices on the Performance of Indian Manufacturing Industries using FAHP

Tina Chaudhary[1] and Arindam Kumar Chanda[2]

[1]Department of Mechanical & Automation Engineering, IGDTUW, Delhi, India
[2] Mechanical & Automation Engineering department in G.B. Pant Govt. Engineering College, Delhi

Abstract—*Green Supply Chain Management is widely diffused practice in Indian industries that are seeking to improve environmental and economic performance of the manufacturing industries. This study defines the evaluation of Green supply chain practices and the effect of these practices on environmental and economic performance in manufacturing industries using Fuzzy AHP methodology. There are 2 main criteria i.e. Green practices and Green performance and 9 sub-criteria. The results shows that GSCM in industries focus more on Green practices and environmental performance. The most important criteria are cooperation with customers, green packaging, internal recovery, green suppliers, minimum use of material for packaging, reduction of use of hazardous material and selling the waste scrape. The performance of industries has been improved after implementing these criteria.*

Keywords*: Green supply chain management, GSCM practices, GSCM performance, Fuzzy AHP*

1. INTRODUCTION

In developing countries automobile manufacturing firms have started to implement green supply chain management because of increasing challenges and pressures to improve environmental and economic performance (Ali Asghar Anvary Rostamy 2013). It's not only reduces environmental issues but also improves positive and negative economic performance of industries. Green supply chain management focuses to maximize environmental profit by implementing a life cycle approach through material selection, product design, manufacturing, sales and recovery, and therefore helps the industry to realize its improvement and sustainable development (Ali Asghar Anvary Rostamy 2013). The late 1990s, and encloses the reactive monitoring of environmental management programs, moves to more proactive practices such as the reclamation, recycling, remanufacturing and RL (reverse logistics), as well as incorporating innovations (Zhu & Serkis 2004). For the last 20 years, Green supply chain has been adopted by the industries to lower environmental problems and improve ecological efficiency, therefore to gain profit and increase market share (Van Hoek 1999). Green supply chain policies are necessary for proactive strategic, reactive regulatory and competitive advantages (Rajesh kumar et. al. 2012). GSCM practices are implemented to improve the GSCM performances. Organization should follow GSCM practices like internal environmental management system, green purchasing, green packaging, internal recovery and eco designing to improve green performances such as environmental performance, positive and negative economic performances. Zhu and Sarkis(2004) developed four categories of green supply chain practices, i.e. internal environmental management system, external GSCM, eco design (design for environment practices) and investment recovery. The relationship between the green practices and environmental and economic performances were analyzed through empirical studies in the Chinese manufacturing firms (Ying & Liz 2012). However, GSCM is considered as a relatively new idea, so with current data and experiences it is very difficult to find if in practice GSCM is providing better results to the industries involved (Zhu and Sarkis, 2004). In today's world scenario of high competition and environmental uncertainty, there should be flexibility in supply chain for the existence of any supply chain business in industry. (Rituraj Chandraker et. al. 2012).

In this paper Fuzzy AHP Methodology is applied to evaluate the Green supply chain practices and performance. Multi criteria decision making (MCDM) approach is conducted to analyze the collected data. The reason of selection of method is easy understandable logics of Fuzzy AHP and MCDM.

2. LITERATURE REVIEW

Zhu and Sarkis (2004) state that GSCM supply chain is called closed-loop supply chain because it involves from manufacturers to suppliers, customers and reverse logistics (RL) throughout. Hervani et al.(2005) indicates that there are many activities involving in GSCM such as remanufacturing, reuse and recycling which are embedded in green procurement practices, green design, total quality environmental management, transportation, environmentally friendly packaging and various product end-of-life practices. Wee and

Quazi(2005) indicate there are seven critical criteria in their research on environmental management: total involvement of employees; top management commitment; training; supplier management; green products/process design; information management and measurement. Chandraker *et al.* (2013) evaluate and measure the performance of GSCM in Chhattisgarh manufacturing industries. In this paper Multi Criteria decision making method (MCDM) is used to determine green performance with the help of the parameters related to GSCM performance. Sarkis (2010) in this paper discussed components and elements of GSCM (green supply chain management). The decision framework was designed and solved as an ANP (analytical network process). Hu and Hsu(2010) identify factors that are critical for adopting green supply chain practices in Taiwanese electrical and electronics industries i.e. relative to European Union directives, and extract twenty critical factors along with four dimensions (supplier management, organization involvement, product recycling and life cycle management). L.K.Tokeet. all. This study aims to interactions, rank and weightage of CSF (critical success factors) of the green supply chain management in manufacturing firms. PANG Yan et. all. (2011) combined with supply chain management practices in Hunan Valin Xiangtan Iron and Steel Limited Corporation, by applying the green supply chain theory, on the basis of demonstrating the implication of environment-friendly green supply chain management, and constructs the corresponding index evaluation model by applying level fuzzy comprehensive appraisal.

3. FUZZY ANALYTIC HIERARCHY PROCESS

Analysis Hierarchical Process (AHP) is a MCDM (multi-criteria decision making) tool first proposed by Saaty (Saaty 1980). Since it was discovered, AHP is the most powerful MCDM (multi-criteria decision making) software for researchers. Conventional AHP is confusing. It is unable to reflect the way human thinks. AHP is criticized for using asymmetrical judgmental scales and its was unable to properly consider the carelessness and inherent uncertainty of pairwise comparisons (Wang & Chang ,2007). FAHP was developed to resolve these issues. Decision makers find out that distanced judgment is more effective than rigid judgments because the individual often cannot fully express his preferences regarding fuzzy nature of comparison process (Rostamy *et. el*. 2013).

4. FAHP METHODOLOGY

In this paper, Extent Analysis method is used, originally proposed by Chang(1996). In this method, the amount of Sk (triangular number), is calculated for each pair rows of pairwise comparison matrix (Hu & Hsu 2010):

$$S_k = \sum_{j=1}^{n} m_{g_i}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} m_{g_i}^{j} \right]^{-1} \quad (1)$$

K represents number of rows and columns. I and j represent alternatives and indicators respectively. The large degree compared with each other must be calculated after Sk calculation in EA analysis. A large degree on M1 with M2 is indicated as (M1 ≥ M2).

$$V(M_1 \geq M_2) = \sup \min(\mu_m(x), \mu_{m_2}(y)) \quad (2)$$

We also have:

$$V = \begin{cases} 1 & m_2 \geq m_1 \\ 0 & l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{Otherwise} \end{cases} \quad (3)$$

The large degree is calculated as:

$V(M \geq M1, M2, \ldots\ldots, Mk)$

$= V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } \ldots (M \geq M_k)]$

$= \min V(M \geq M i)$

$i = 1, 2, \ldots\ldots, k$

Suppose that d (Ai) = min V (Si ≥Sk), k=1, 2, 3,…, n, k≠ i. Then the following weight vector is obtained.

$$A_i \ (i=1, 2, \ldots, n) \quad (4)$$

That Ai(1,2, ……n) are n element. The normalized weight vector :

$$W = (d(A_1), d(A_2, \ldots, d(A_n)))^T \quad (5)$$

5. PROPOSED METHODOLOGY

In this study Fuzzy AHP model is used for evaluation of Green supply chain in manufacturing industries.

The methodology expresses in following way:

1. Establish GSCM practices and performances factors on the basis of literature review.

2. Design the questionnaires which cover all the factors of GSCM practices and performances.

3. Collect the data from expert interviews.

4. Analyze the collecting data using Fuzzy AHP method.

5. Determine the priority weight of all the factor.

The proposed model has two criteria Green practices and Green performance. Each criteria has some sub criteria. There are 9 sub-criteria. Internal environmental management system, green purchasing, green packaging, eco designing, cooperation with customers and internal recovery are the sub-criteria of Green practices. Environmental, positive and negative economic are sub-criteria of Green performance.

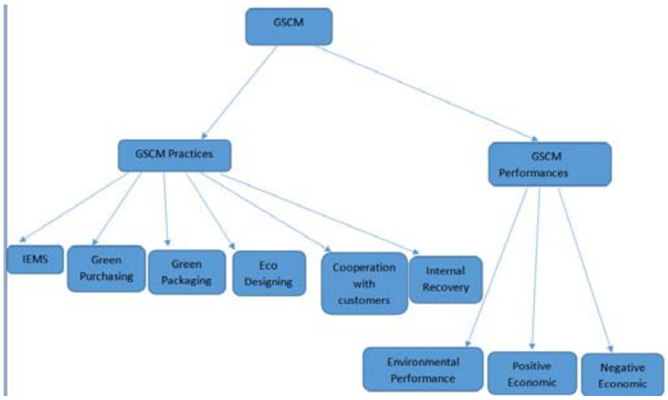

Fig. 1: Proposed Model for Green Supply Chain Management

6. RESULTS

In this section using Fuzzy AHP method, Evaluation of Green practices and Green performance has been done. Main factors and sub factors of Green supply chain management are compared in Table 1-11.

Table 1: Pairwise comparison matrix of Green Practices

	IEMS	Green Purchasing	Green Packaging	Eco Designing	Cooperation with customers	Internal Recovery
IEMS	(1,1,1)	(3,4,5)	(1/5,1/4,1/3)	(1/3,1/2,1)	(1/6,1/5,1/4)	(1/4,1/3,1/2)
Green Purchasing	(1/5,1/4,1/3)	(1,1,1)	(1/6,1/5,1/4)	(1/5,1/4,1/3)	(1/6,1/5,1/4)	(1/4,1/3,1/2)
Green Packaging	(3,4,5)	(4,5,6)	(1,1,1)	(1,2,3)	(1/3,1/2,1)	(1,1,1)
Eco Designing	(1,2,3)	(3,4,5)	(1/3,1/2,1)	(1,1,1)	(1/4,1/3,1/2)	(1/3,1/2,1)
Cooperation with customers	(4,5,6)	(4,5,6)	(1,2,3)	(2,3,4)	(1,1,1)	(1,2,3)
Internal Recovery	(2,3,4)	(2,3,4)	(1,1,1)	(1,2,3)	(1/3,1/2,1)	(1,1,1)

Table 2: Pairwise comparison matrix of Internal Environmental Management System (IEMS)

	Support of Managers	ISO14001 Certified company	Makes Eco Labeled products	Team to solve Environmental issues	Publish white paper	Training for Environmental Management
Support of Managers	(1,1,1)	(1/4,1/3,1/2)	(3,4,5)	(1/4,1/3,1/2)	(4,5,6)	(1,2,3)
ISO14001 Certified company	(2,3,4)	(1,1,1)	(5,6,7)	(1,1,1)	(5,6,7)	(2,3,4)
Makes Eco Labeled products	(1/5,1/4,1/3)	(1/7,1/6,1/5)	(1,1,1)	(1/7,1/6,1/5)	(1,1,1)	(1/5,1/4,1/3)
Team to solve Environmental issues	(2,3,4)	(1,1,1)	(5,6,7)	(1,1,1)	(5,6,7)	(2,3,4)
Publish white paper	(1/6,1/5,1/4)	(1/7,1/6,1/5)	(1,1,1)	(1/7,1/6,1/5)	(1,1,1)	(1/6,1/5,1/4)
Training for Environmental Management	(1/3,1/2,1)	(1/4,1/3,1/2)	(3,4,5)	(1/4,1/3,1/2)	(4,5,6)	(1,1,1)

Table 3: Pairwise comparison matrix of Green purchasing

	Purchase raw material from ISO14000 Certified suppliers	Cooperate with supplier for Environmental issues	Environmental audit for internal management of suppliers	Purchase Environmental Friendly product	Consider Environmental Criteria for suppliers selection
Purchase raw material from ISO14000 Certified suppliers	(1,1,1)	(1/6,1/5,1/4)	(1/3,1/2,1)	(1/5,1/4,1/3)	(1/4,1/3,1/2)
Cooperate with supplier for Environmental issues	(4,5,6)	(1,1,1)	(3,4,5)	(1,1,1)	(2,3,4)

Environmental audit for internal management of suppliers	(1,2,3)	(1/5,1/4,1/3)	(1,1,1)	(1/5,1/4,1/3)	(1/4,1/3,1/2)
Purchase Environmental Friendly product	(3,4,5)	(1,1,1)	(3,4,5)	(1,1,1)	(1,2,3)
Consider Environmental Criteria for suppliers selection	(2,3,4)	(1/4,1/3,1/2)	(2,3,4)	(1/3,1/2,1)	(1,1,1)

Table 4: Pairwise comparison matrix of Green packaging

	Recycle & Reuse of outer packaging	Use ecological material for packaging	Minimum use of material for packaging
Recycle & Reuse of outer packaging	(1,1,1)	(1,1,1)	(1/4,1/3,1/2)
Use ecological material for packaging	(1,1,1)	(1,1,1)	(1/3,1/2,1)
Minimum use of material for packaging	(2,3,4)	(1,2,3)	(1,1,1)

Table 5: Pairwise comparison matrix of Eco designing

	Reduction of consumption of material for manufacturing	Reuse recycle and recover the components parts material	Design product to reduce use of hazardous material	Minimum use of natural resources	Less energy consumption use during manufacturing	Use renewable energy resources for manufacturing
Reduction of consumption of material for manufacturing	(1,1,1)	(1,2,3)	(1/4,1/3,1/2)	(1,1,1)	(1,1,1)	(3,4,5)
Reuse recycle and recover the components parts material	(1/3,1/2,1)	(1,1,1)	(1/4,1/3,1/2)	(1/3,1/2,1)	(1/3,1/2,1)	(3,4,5)
Design product to reduce use of hazardous material	(2,3,4)	(2,3,4)	(1,1,1)	(2,3,4)	(2,3,4)	(4,5,6)
Minimum use of natural resources	(1,1,1)	(1,2,3)	(1/4,1/3,1/2)	(1,1,1)	(1,1,1)	(3,4,5)
Less energy consumption use during manufacturing	(1,1,1)	(1,2,3)	(1/4,1/3,1/2)	(1,1,1)	(1,1,1)	(3,4,5)
Use renewable energy resources for manufacturing	(1/5,1/4,1/3)	(1/5,1/4,1/3)	(1/6,1/5,1/4)	(1/5,1/4,1/3)	(1/5,1/4,1/3)	(1,1,1)

Table 6: Pairwise comparison matrix of Cooperation with customers

	Cooperation with customers for Eco designing	Cooperation with customers for clean production	Cooperation with customers for green packaging	Cooperation with customers for green logistics	Cooperation with customers for reverse logistics
Cooperation with customers for Eco designing	(1,1,1)	(1/3,1/2,1)	(1,1,1)	(1,1,1)	(2,3,4)
Cooperation with customers for clean production	(1,2,3)	(1,1,1)	(1,2,3)	(1,2,3)	(3,4,5)
Cooperation with customers for green packaging	(1,1,1)	(1/3,1/2,1)	(1,1,1)	(1,1,1)	(2,3,4)

Cooperation with customers for green logistics	(1,1,1)	(1/3,1/2,1)	(1,1,1)	(1,1,1)	(1/4,1/3,1/2)
Cooperation with customers for reverse logistics	(1/4,1/3,1/2)	(1/5,1/4,1/3)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1,1,1)

Table 7: Pairwise comparison matrix of Internal recovery

	Sell excess inventory	**Sell waste scrape**	**Sell excess equipment**
Sell excess inventory	(1,1,1)	(1/6,1/5,1/4)	(1/4,1/3,1/2)
Sell waste scrape	(4,5,6)	(1,1,1)	(3,4,5)
Sell excess equipment	(2,3,4)	(1/5,1/4,1/3)	(1,1,1)

Table 8: Pairwise comparison matrix of Green performance

	Environmental	**Negative economic**	**Positive economic**
Environmental	(1,1,1)	(4,5,6)	(2,3,4)
Positive economic	(1/6,1/5,1/4)	(1,1,1)	(1/3,1/2,1)
Negative economic	(1/4,1/3,1/2)	(1,2,3)	(1,1,1)

Table 9: Pairwise comparison matrix of Environmental performance

	Reduction of gas emission	**Reduction of waste water emission**	**Reduction of solid waste emission**	**Reduction of use of toxic material**	**Decrease in environmental disaster**
Reduction of gas emission	(1,1,1)	(1/3,1/2,1)	(1,2,3)	(1/4,1/3,1/2)	(1/3,1/2,1)
Reduction of waste water emission	(1,2,3)	(1,1,1)	(1,2,3)	(1,1,1)	(1,1,1)
Reduction of solid waste emission	(1/3,1/2,1)	(1/3,1/2,1)	(1,1,1)	(1/4,1/3,1/2)	(1/4,1/3,1/2)
Reduction of use of toxic material	(2,3,4)	(1,1,1)	(2,3,4)	(1,1,1)	(1,1,1)
Decrease in environmental disaster	(1,2,3)	(1,1,1)	(2,3,4)	(1,1,1)	(1,1,1)

Table 10: Pairwise comparison matrix of Positive economic

	Decrease in material purchasing cost	**Decrease in energy consumption cost**	**Decrease in waste treatment cost**	**Decrease in waste discharge fee**	**Decrease in fine for environmental disasters**
Decrease in material purchasing cost	(1,1,1)	(1/6,1/5,1/4)	(1/3,1/2,1)	(1,1,1)	(1/4,1/3,1/2)
Decrease in energy consumption cost	(4,5,6)	(1,1,1)	(3,4,5)	(4,5,6)	(1,2,3)
Decrease in waste treatment cost	(1,2,3)	(1/5,1/4,1/3)	(1,1,1)	(1,1,1)	(1/3,1/2,1)
Decrease in waste discharge fee	(1,1,1)	(1/6,1/5,1/4)	(1,1,1)	(1,1,1)	(1/4,1/3,1/2)
Decrease in fine for environmental disasters	(2,3,4)	(1/3,1/2,1)	(1,2,3)	(2,3,4)	(1,1,1)

Table 11: Pairwise comparison matrix of Negative economic

	Increase in investment	Increase in operational cost	Increase in training cost	Increase in cost of purchasing green material
Increase in investment	(1,1,1)	(4,5,6)	(3,4,5)	(1,2,3)
Increase in operational cost	(1/6,1/5,1/4)	(1,1,1)	(1/4,1/3,1/2)	(1/5,1/4,1/3)
Increase in training cost	(1/5,1/4,1/3)	(2,3,4)	(1,1,1)	(1/3,1/2,1)
Increase in cost of purchasing	(1/3,1/2,1)	(3,4,5)	(1,2,3)	(1,1,1)

To identify the computation clearly, the pairwise comparison matrix from Table 1 is evaluated as follows.

From Table 1

SIEMS = (4.949, 6.283, 8.083) * (1/76.249, 1/58.849, 1/43.515) = (0.064, 0.106, 0.185)

SGP1 = (1.983, 2.233, 2.666) * (1/76.249, 1/58.849, 1/43.515) = (0.026, 0.037, 0.061)

SGP2 = (10.333, 13.5, 17) * (1/76.249, 1/58.849, 1/43.515) = (0.135, 0.229, 0.39)

SED = (5.916, 8.333, 11.5) * (1/76.249, 1/58.849, 1/43.515) = (0.077, 0.14, 0.264)

SCC = (13, 18, 23) * (1/76.249, 1/58.849, 1/43.515) = (0.170, 0.305, 0.528)

SIR = (7.333, 10.5, 14) * (1/76.249, 1/58.849, 1/43.515) = (0.096, 0.178, 0.321)

Therefore weight vector is calculated as

After determining these results

V (SIEMS ≥ SGP1) = 1 V (SED ≥ SIEMS) = 1

V (SIEMS ≥ SGP2) = 0.289 V (SED ≥ SGP1) = 1

V (SIEMS ≥ SED) = 1.21 V (SED ≥ SGP2) = 0.594

V (SIEMS ≥ SCC) = 0.07 V (SED ≥ SCC) = 0.364

V (SIEMS ≥ SIR) = 0.552 V (SED ≥ SIR) = 0.819

V (SGP1 ≥ SIEMS) = 0 V (SCC ≥ SIEMS) = 1

V (SGP1 ≥ SGP2) = 0 V (SCC ≥ SGP1) = 1

V (SGP1 ≥ SED) = 0 V (SCC ≥ SGP2) = 1

V (SGP1 ≥ SCC) = 0 V (SCC ≥ SED) = 1

V (SGP1 ≥ SIR) = 0 V (SCC ≥ SIR) = 1

V (SGP2 ≥ SIEMS) = 1 V (SIR ≥ SIEMS) = 1

V (SGP2 ≥ SGP1) = 1 V (SIR ≥ SGP1) = 1

V (SGP2 ≥ SED) = 1 V (SIR ≥ SGP2) = 0.784

V (SGP2 ≥ SCC) = 0.743 V (SIR ≥ SED) = 1

V (SGP2 ≥ SIR) = 1 V (SIR ≥ VCC) = 0.543

Therefore the weight vector of Green practices are (0.025, 0.273, 0.133, 0.367, 0.199) The same systematic approach is considered to calculate priorities weight of all the factors. The normalized weight vectors are shown in Table 12.

Table 12: Results of Normalized priorities weight of Green practices factors and sub factors

Factors	Weightage	Sub Factors	Weightage
IEMS	0.025	Support of managers ISO14001 certified company Makes eco labeled products Team to solve environmental issues Publish white paper Training for environmental management	0.170 0.357 0 0.357 0 0.115
Green Purchasing	0	Purchase raw material from ISO14000 certified suppliers Cooperate with supplier for environmental issues Environmental audit for internal management of suppliers Purchase environmental friendly product Consider environmental criteria for suppliers selection	0 0.433 0 0.367 0.198
Green Packaging	0.273	Recycle & Reuse of outer packaging Use ecological material for packaging Minimum use of material for packaging	0 0.122 0.877

Eco Designing	0.133	Reduction of consumption of material for manufacturing Reuse recycle and recover the components parts material Design product to reduce use of hazardous material Minimum use of natural resources Less energy consumption use during manufacturing Use renewable energy resources for manufacturing	0.159 0.073 0.447 0.159 0.159 0
Cooperation with customers	0.367	Cooperation with customers for Eco designing Cooperation with customers for clean production Cooperation with customers for green packaging Cooperation with customers for green logistics Cooperation with customers for reverse logistics	0.204 0.387 0.204 0.204 0
Internal Recovery	0.199	Sell excess inventory Sell waste scrape Sell excess equipment	0 0.990 0.087

Table: 13 Results of Normalized priorities weight of Green performance factors and sub factors

Factors	Weightage	Sub Factors	Weightage
Environmental	0.945	Reduction of gas emission Reduction of waste water emission Reduction of solid waste emission Reduction of use of toxic material Decrease in environmental disaster	0.116 0.213 0.143 0.278 0.247
Positive Economic	0.054	Decrease in material purchasing cost Decrease in energy consumption cost Decrease in waste treatment cost Decrease in waste discharge fee Decrease in fine for environmental disasters	0 0.680 0 0 0.319
Negative Economic	0.001	Increase in investment Increase in operational cost Increase in training cost Increase in cost of purchasing green material	0.570 0 0.095 0.334

7. CONCLUSION

The results show the current level of Green supply chain management in Indian manufacturing industries. The most important Green practices are cooperation with customers, green packaging and internal recovery. Industries focus more on cooperation with suppliers for environmental issues, purchase environmental friendly product, team to solve environmental issues, minimum use of material for packaging, design product to reduce use of hazardous material, less energy consumption, minimum use of material, cooperation with customers for clean production, green logistics & green packaging and selling waste scrape. The performance of industries has been improved after adopting Green practices. There is a reduction of use of toxic material, waste water emission and environmental disasters. There is a decrement of energy consumption cost and fine for environmental disasters. There is a little increment in negative economic but the increment in positive economic is more than the increment in negative economic. Hence the overall performance is improved after implementing GSCM.