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Green Manufacturing (GM) Performance Measures: An Empirical Investigation from Indian MSMEs

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Abstract- Green Manufacturing (GM) practices are becoming important due to the rise in environmental awareness. Such awareness for environment is becoming an essential part of strategic planning in organizations, including the Micro, Small and Medium Enterprises (MSMEs). This paper deals with identifying factors of GM practices adoption among the MSMEs in India and application of Analytic Hierarchy Process (AHP) to validate the developed multiple-item scale for identified factors and variables with matrices hierarchies which are generally used as the multi-criteria decision making. This research has established that GM relates to greening of product design, design of raw materials, process, technology, packaging material and packaging design.

Index Terms - Analytic Hierarchy Process (AHP); Factor Analysis; Green Manufacturing (GM); MSMEs

1. INTRODUCTION

Manufacturing means making (something) on a large scale using machinery or by hand, which originated around mid 16th century to denote something made by hand from French (re-formed by association with Latin *manu factum* 'made by hand'), and from Italian *manifattura*. Green is the color between blue and yellow in the spectrum; colored like grass or emeralds. Greening is the process of transformation into a more environmentally friendly version, which has been understood to be linked with strong color often associated with life, fertility and health (Mohanty & Prakash, 2013). Green Manufacturing (GM) is about appreciating to be greening of manufacturing.

Now-a-days, manufacturing is understood as a process of converting raw material into finished product by using various processes, machines and energy for creating wealth. In manufacturing, the company procures the raw material from outside, and then makes the final product. In production, the raw material is not procured from outside, the company owns it and after processing makes the final product. That is, the underlying difference between manufacturing and production is in the raw material. Therefore, GM is basically converting raw materials into finished products by using green processes and green machines that save energy (Baines et al., 2012; Luthra et al., 2011). In fact, Melnyk & Smith (1996) defined green manufacturing as a system that integrates product and process design issues with issues of manufacturing planning and control in such a manner as to identify, quantify, assess, and manage the flow of environmental waste with the goal of reducing and ultimately minimizing environmental impact while also trying to maximize resource efficiency.

GM is more than just a fad. This phase was launched by Germany in the late 1980s and early 1990s. The concept of GM has its roots from Germany that requires importing companies to take responsibility and remove any packaging materials used for that product. In fact, the Germans have established a *de facto* global manufacturing standard instilling that any company wishing to compete globally must start making products that will comply with the green dictates of the huge European market. GM involves not just the use of environmental design of products, use of environmentally friendly raw materials, but also eco-friendly packing, distribution, and destruction or reuse after the lifetime of the product.

No other sector of the economy comes close to the manufacturing sector in generating vast volumes of waste. The Europeans have already implemented take-back laws for autos, electronics and appliances. The rest of the world is fast catching up and the only solution for the manufacturers is to find alternate ways of production and alternate resources to use (Luthra et al., 2011). This study attempts to an important research questions in Indian context relating to GM, which is to understand green manufacturing practices where Indian MSMEs are engaged.

2. REVIEW OF LITERATURE

Many researchers have tried to define Green Manufacturing but there seems to have no consensus on single definition. It is understood as an advanced manufacturing model to realize the sustainable development of industries (Corbett, 2009; Miller et al., 2010; Yang et al., 2003). Zhang & Wang (2005) appreciate it to be the application of sustainable science to the manufacturing industry. Deif (2011) defines green manufacturing as a sustainable approach to the design and engineering activities involved in product development and/or system operation to minimize environmental impact. Dornfeld (2013) recognizes that green manufacturing is about implementing any kind of substitution in the manufacturing process which leads to a reduction in energy consumption, resource consumption, waste by-products, and water usage. That is, any and every step that makes the production of a product, component or part of a system more sustainable can be termed as green manufacturing. According to Rehman & Shrivastava (2013) green manufacturing (GM) is a term used to describe manufacturing practices that do not harm the environment during any part of the manufacturing process emphasising the use of processes that do not pollute the environment or harm consumers, employees, or other members of the community. In today‘s world, green manufacturing is not a choice but an imperative for sustainable development (Miller et al., 2010). Adoption and/or adaptation of green manufacturing entail costs which are substantial especially for Micro, Small and Medium Enterprises (MSMEs). Hence, there is a need for supporting adoption of green manufacturing practices.

In Indian context, the system for defining and implementing Greener and Cleaner Technology are devised by a Committee called the Green Manufacturing Committee (GMC) comprising representatives from the concerned Ministries/Departments of the Central Government and relevant sector experts from outside government. Their criteria have to be consistent with the objective of the national action plan on climate change and the strategy for inclusive sustainable development. These criteria are reviewed by the Committee annually as technology is dynamic and evolving constantly. Some important incentives covered under GM initiatives are Environmental Audit (mandatory for industrial and institutional units), Water Conservation Audit (mandatory for industrial and institutional units), Wastewater treatment (as per CPCB and PCB norms), Rain Water Harvesting (compulsory for the developer, all industrial/institutional units as per guidelines), Renewable Energy, Green buildings (green rating under the Indian Green Building Council systems).

Over the past 10 years or more, limited numbers of popular academic studies relating to Green Manufacturing (GM) have been published. This paper has identified some important issues for establishing the gap in literature. This study attempts to review these popular studies in GM in the light of changed business scenario and analyse them for suitability/need for modification in the current context, namely, (GM 01) (Jun et al., 2003), (GM 02) (Skerlos et al., 2004), (GM 03) (Liu et al., 2005), (GM 04) (Zhang & Wang, 2005), (GM 05) (Sangwan, 2006), (GM 06) (Decong, 2006), (GM 07) (Rusinko, 2007), (GM 08) (He et al., 2007), (GM 09) (Tan et al., 2008), (GM 10) (He et al., 2008), (GM 11) (Fei et al., 2009),(GM 12) (Chan et al., 2010) , (GM 13) (Yang et al., 2010), (GM 14) (Cong-bo et al., 2010), (GM 15) (Walker et al., 2010), (GM 16) (Reich-Weiser et al., 2010), (GM 17) (Deif, 2011) , (GM 18) (Jiang et al., 2011) , (GM 19) (Sangwan, 2011) , (GM 20) (Singh et al., 2012), (GM 21) (Ma et al., 2012), (GM 22) (Abbas & Yusoff, 2012), (GM 23) (Chuang & Yang, 2013), (GM 24) (Tsai et al., 2013), (GM 25) (Onsrud & Simon, 2013) , (GM 26) (Rehman & Shrivastava, 2013), (GM 27) (Heidrich & Tiwary, 2013), (GM 28) (Rehman et al., 2013). In the current context, following 19 (A to S) issues are seen important for academic study on GM in Indian manufacturing scenario:

A. Definition of Green Manufacturing (GM)
B. Use of own instrument for studying factors of GM.
C. Empirical evidence on GM coming from the developed economies
D. Adoption of GM practices
E. Motivations of GM practices
F. Barriers of GM practices
G. Impact of GM practices on environmental performance
H. Effect of demographic variables
I. ISO 14001 or certification
J. Environmental management systems (EMSs) performance
K. Only reviewing prior literature
L. Empirical research in GM involving anecdotal evidence/examples

M. Empirical research in GM involving descriptive reporting of overview
N. Empirical research in GM using case study
O. Empirical research in GM involving hypotheses testing
P. Theoretical research in GM involving conceptualizing and then defining
Q. Studies conducted in China
R. Studies conducted in developed economies
S. Studies conducted in India

We find that the growth of literature in GM has developed sequentially, providing a continuous update and learning from the findings of predecessors where several researchers have it with varying perspectives and using different methodologies have discussed the above listed 19 arguments/issues. These arguments seem to be suitable for making comparative evaluations of the research issues in GM as depicted in Table 1.

Some findings from the review of literature are as follows:

- Many researchers have attempted to define GM (Jun et al., 2003; Fei et al., 2009; Deif 2011; Ma et al., 2012; Rehman & Shrivastava, 2013) however, there seems to be no consensus on its definition.
- Many researchers have used their own instrument for studying the factors of GM (Skerlos et al., 2004; Liu et al., 2005; Rusinko, 2007; Tan et al., 2008; Chan et al., 2010; Sangwan, 2011; Singh et al., 2012; Chuang & Yang, 2013) still there is heterogeneity in determinants of GM across the world.
- Many researchers have given empirical evidence on GM (Skerlos et al., 2004;Rusinko, 2007; Tan et al., 2008; Ma et al., 2012; Onsrud & Simon, 2013; Rehman et al., 2013; Rehman et al., 2013) however, most of the studies related to GM have been conducted in China (Jun et al., 2003; Decong, 2006; He et al., 2008; Cong-bo et al., 2010; Jiang et al., 2011; Chuang & Yang 2013; Tsai et al., 2013) while some of the studies have been conducted in developed economies (Rusinko 2007; Walker et al., 2010; Reich-Weiser et al., 2010; Heidrich & Tiwary, 2013) and very few research studies have been conducted in India (Sangwan 2011; Singh et al., 2012).
- Most of the researchers have focused on adoption of GM (Skerlos et al., 2004; Zhang & Wang 2005; Sangwan 2006; He et al., 2008; Fei et al., 2009; Reich-Weiser et al., 2010; Deif 2011; Abbas & Yusoff 2012; Chuang & Yang 2013; Tsai et al., 2013).
- Some researchers have discussed the motivators and barriers of GM (Liu et al., 2005; Rusinko, 2007; Chan et al., 2010; Deif, 2011; Abbas & Yusoff 2012; Rehman et al., 2013).
- Many researchers have discussed about the impact of GM practices on Environmental Performance (Skerlos et al., 2004; Decong, 2006; Tan et al., 2008; Walker et al., 2010; Sangwan, 2011; Chuang & Yang, 2013; Heidrich & Tiwary, 2013).
- Only few researchers have discussed about the effect of demographic variables in GM practices (Skerlos et al., 2004; Rusinko, 2007; Yang et al., 2010; Rehman & Shrivastava, 2013).
- Many researchers have studied ISO 14001 certification and EMS performance of GM (Chan et al., 2010; Deif 2011; Heidrich & Tiwary, 2013).
- Some of the researchers have discussed about the adoption of GM by reviewing prior literature (Zhang & Wang, 2005; Sangwan, 2006; Jiang et al., 2011; Sangwan, 2011; Tsai et al., 2013).
- Only few researchers have discussed about empirical research in GM involving anecdotal evidences/examples and descriptive reporting overview (Skerlos et al., 2004; Fei et al., 2009; Deif, 2011; Singh et al., 2012; Chuang & Yang, 2013).
- Most of the researchers have discussed about empirical research in GM using case study (Rusinko, 2007; Cong-bo et al., 2010; Ma et al., 2012; Rehman et al., 2013) while only few researchers have discussed about empirical research in GM involving hypothesis testing (Rusinko, 2007; Cong-bo et al., 2010).
- Very few researchers have theoretical explanation of GM involving conceptualization and then defining (Rusinko, 2007; Walker et al., 2010; Sangwan, 2011; Rehman & Shrivastava, 2013).

Viewed from the perspectives of these gaps, it is therefore, important to go on with additional research relating to the greening of manufacturing with special reference to MSMEs in India. One of the ways to achieve GM in India in a large scale manner is through the promotion of Green Products from these MSMEs. The MSME sector in India is highly heterogeneous in terms of the size of the enterprises, variety of products and services, and levels of technology. The sector not only plays a critical role in providing employment opportunities at comparatively lower capital cost than large industries but also helps in industrialisation of rural and backward areas, reducing regional imbalances and assuring more equitable distribution of national income and wealth. MSMEs complement large industries as ancillary units and contribute enormously to the socioeconomic development of the country. These MSMEs have many key challenges, like, lack of availability of adequate and timely credit; limited access to equity capital; procurement of raw material at a competitive cost; inadequate infrastructure facilities, including power, water, roads; low technology levels and lack of access to modern technology; lack of skilled manpower for manufacturing, services, marketing, etc. It is also to be noted that, the attributes of 'greenness' varies from sector to sector, based upon the materials used/processes adopted while manufacturing. Therefore, this study attempts to focus on following objectives relating to GM aspects for MSMEs in India:

- To identify practices of GM in India.
- To determine factors influencing adoption of GM.
- To validate the multiple-item scale for GM using Analytic Hierarchy Process (AHP).

The AHP technique can evaluate qualitative, quantitative and intuitive criteria comprehensively, and it is possible to raise the level of confidence of it through carrying out consistency testing (Luthra et al., 2013; Tahriri et al., 2008). The AHP technique resembles the structure of human brain, and obtains quantitative results by transforming the comparative weight between elements to ratio scale. The AHP technique is based on three principles; hierarchical structuring, weighting, logical consistency (Luthra et al., 2013).

Pair-wise comparison, homogeneity, independence relation, and expectation are basic assumptions of AHP technique. They are very important and should be used properly when applied to AHP technique because they are the fundamental frames of the AHP technique logically and actually. Pair-wise comparison means that decision maker can not only compare one element of a factor with another but also determine the weighted score between them. Homogeneity means that the weighted score can be presented by settled index in fixed range, and independence relation means that there is no relationship among elements. Expectation means that hierarchical structure logically corresponds to the expectation of every decision makers. After considering many factors relative to GM projects, decision makers calculate the total weighted score sum of each element in each alternative, and then the best alternative can be concluded.

3.0 RESEARCH METHODOLOGY

The research methodology aids the researcher in allocation of limited resources by posing crucial choices. Its essentials are depicted in Figure 1. This study involves exploratory research. The identified factors and variables are validated using AHP with matrices hierarchies which are generally used as the multi-criteria decision making. In the AHP the measurement of an alternative depends on what other alternatives it is compared with. The result is that rank can change if alternatives are added or deleted, something that does not occur in one-at-a-time rating of the alternatives by comparing them with an ideal (Luthra et al., 2013; Saaty, 2005; Tahriri et al., 2008).

Table 1: Evaluation of studies in green manufacturing

Time Line	2003	2004	2005	2005	2006	2006	2007	2007	2008	2008	2009	2010	2010	2010	2010	2010	2011	2011	2011	2012	2012	2012	2013	2013	2013	2013	2013	2013
Paper No.	GM 01	GM 02	GM 03	GM 04	GM 05	GM 06	GM 07	GM 08	GM 09	GM 10	GM 11	GM 12	GM 13	GM 14	GM 15	GM 16	GM 17	GM 18	GM 19	GM 20	GM 21	GM 22	GM 23	GM 24	GM 25	GM 26	GM 27	GM 28
A	●	●	●	●	●		●	●		●	●	●	●	●			●	●	●		●	●	●	●	●	●	●	●
B	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
C	●	●		●		●	●	●	●	●	●	●	●	●			●	●	●	●	●	●	●	●	●	●	●	●
D	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
E	●	●	●				●	●	●		●	●		●	●		●	●	●	●	●	●		●	●	●	●	●
F			●		●		●					●		●			●		●	●	●	●		●	●	●	●	●
G		●		●	●	●	●	●	●	●	●	●	●		●	●	●		●	●	●	●	●	●	●	●	●	●
H		●					●						●		●				●							●		
I			●									●	●			●	●			●							●	●
J	●					●		●			●	●				●	●		●	●	●						●	●
K				●	●		●								●	●		●		●			●		●			
L	●	●		●	●						●	●	●				●	●	●	●	●	●	●	●		●	●	●
M						●	●								●	●				●					●			●
N	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●	●	●		●	●	●	●		●	●	●
O							●							●														
P							●								●	●		●	●	●				●	●	●		●
Q	●		●	●		●		●	●	●	●	●	●	●				●			●		●	●	●			
R		●					●								●	●	●										●	
S					●														●	●		●				●		●

Note: The markings '●' stand for the issue (in rows) are present in particular study (in columns) as (GM 01, GM 02.....GM 28).

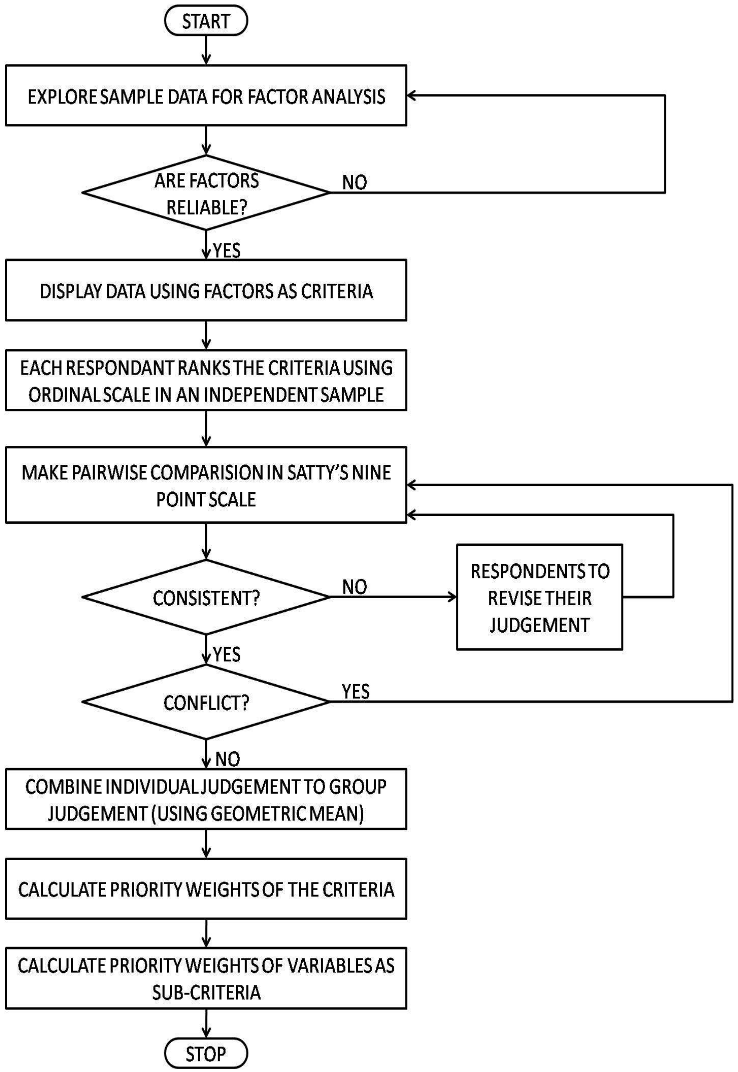

Figure 1: Schematic diagram of research methodology

3.1 Explore Sample Data for Factor Analysis

Data were collected from questionnaires administered from 20th July 2013 to 29th September 2013 for identifying factors of GM in the first stage of the survey. The questionnaire used in this research had fifteen statements (see Table 2) for mapping the profile of the target respondents in and around Ranchi in terms of environmental actions taken by their organizations at the enterprise level in the past two years, where the respondents had to agree on a scale of 1 to 5 where 1 = No, 2 = Little, 3 = Moderate, 4 = Very much, and 5 = Great. As the scope of analysis is kept at enterprise level, it includes the environmental actions at facility/factory, machine cell/line, machine tool, and machining process levels. Notably, the scope of analysis is not across the greening of supply chain.

Table 2: Critical performance measures for GM implementation emphasized by selected authors

Variable No.	Critical performance measures	Representative reference
VAR01	Processes to reduce wastes	Yang et al., 2010; Deif 2011; Chuang & Yang, 2013
VAR02	Environmental improvement of production facilities	Chan et al., 2010; Jiang et al., 2011
VAR03	Technical innovation capabilities to raise production eco-standards	Chan et al., 2010; Jiang et al., 2011
VAR04	Comprehensiveness of eco-standard test reports	Jiang et al., 2011; Singh et al., 2012
VAR05	Processes to recycle materials internal to the company	Yang et al., 2010; Deif 2011; Chuang & Yang, 2013
VAR06	Process to use remanufacturing	Yang et al., 2010; Chuang & Yang, 2013

VAR07	Reusable packaging	Yang et al., 2010 ; Chuang & Yang, 2013
VAR08	Ease of acquisition	Ma et al., 2012; Rehman & Shrivastava, 2013
VAR09	Application of eco-material for packaging	Yang et al., 2010; Ma et al., 2012
VAR10	Eco-impact during product life cycle	Yang et al., 2010; Deif 2011; Chuang & Yang, 2013
VAR11	Ease of replacement	Chan et al., 2010; Ma et al., 2012
VAR12	Compatibility with living environment	Yang et al., 2010; Chuang & Yang, 2013
VAR13	Ease of simplification	Chan et al., 2010; Ma et al., 2012
VAR14	Integration of eco-marks into packaging design	Yang et al., 2010; Chuang & Yang, 2013
VAR15	Recovery rate of packaging material	Chan et al., 2010; Ma et al., 2012

3.2. Displaying Data using Factors

In the first stage of survey based on convenience sampling, 195 completed questionnaires comprising of 15 items revealed a six-factor structure that explained 76.551% of total variance in the shown in Table 3. The criteria for retaining the six factors were Eigen values greater than one and the ability to describe and label each factor. To assess the reliability of responses, Cronbach's alpha coefficient was calculated, and is found to be acceptable for the items within each factor solution. Also, Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was found to be 0.502, which is considered adequate. There is the obligatory requirement of 0.60 or above for Cronbach's alpha coefficient to demonstrate internal consistency of the established scales (Nunnally, 1988). Likewise, the minimum acceptable value of KMO is 0.5 (Prakash et al., 2011). Therefore, it can be concluded that the matrix did not suffer from multicollinearity or singularity.

Table 3: Factor analysis of environmental actions statements

	Factor Loading	Percent Variance Explained	Cronbach's Alpha
[F1] Factor 1: GREEN PRODUCT DESIGN		14.669	0.631
1. [VAR10] Eco-impact during product life cycle	0.818		
2. [VAR12] Compatibility with living environment	0.676		
[F2] Factor 2: GREEN DESIGN OF RAW MATERIALS		14.246	0.611
1. [VAR08] Ease of acquisition	0.724		
2. [VAR11] Ease of replacement	0.835		
3. [VAR13] Ease of simplification	0.641		
[F3] Factor 3: GREEN PROCESS		13.082	0.625
1. [VAR01] Processes to reduce wastes	0.704		
2. [VAR05] Processes to recycle materials ...	0.704		
3. [VAR06] Process to use remanufacturing	0.822		
[F4] Factor 4: GREEN TECHNOLOGY		12.466	0.609
1. [VAR02] Environmental improvement of production ...	0.893		
2. [VAR03] Technical innovation capabilities ...	0.808		
3. [VAR04] Comprehensiveness of eco-standard test reports	0.537		
[F5] Factor 5: GREEN PACKAGING MATERIAL		11.435	0.613
1. [VAR09] Application of eco-material for packaging	0.870		
2. [VAR15] Recovery rate of packaging material	0.838		

[F6] Factor 6: GREEN PACKAGING DESIGN		10.653	0.634
1. [VAR07] Reusable packaging	0.811		
2. [VAR14] Integration of eco-marks into packaging design	0.803		

3.3 Display Data Using Factors as Criteria

Analytic Hierarchy Process (AHP) is Multi Criteria Decision Making (MCDM) method that was originally developed by Prof. Thomas L. Saaty. It is a method to convert ordinal scales to ratio scales from paired comparisons of factors and even allows checking its consistency for making validation. Following six factors of GM as criteria are made to undergo paired comparisons:

- [F1] Factor 1: GREEN PRODUCT DESIGN
- [F2] Factor 2: GREEN DESIGN OF RAW MATERIALS
- [F3] Factor 3: GREEN PROCESS
- [F4] Factor 4: GREEN TECHNOLOGY
- [F5] Factor 5: GREEN PACKAGING MATERIAL
- [F6] Factor 6: GREEN PACKAGING DESIGN

There are total 15 comparisons for which the input can be obtained from actual measurement or from subjective opinion such as satisfaction feelings and preference. AHP is inbuilt to allow some small inconsistency in judgment because human-mind is not always consistent. The ratio scales are derived from the principal Eigen vectors and the Consistency Index (CI) is derived from the principal Eigen value.

3.4 Each Respondent Ranks the Criteria Using Ordinal Scale in an Independent Sample

Data were collected using independent samples in the second stage of survey from questionnaires administered from 1st October 2013 to 15th October 2013 for studying the 15 paired comparisons of factors as criteria and variables under each factor as sub-criteria.

3.5 Make Pair wise Comparison in Satty's Nine Point Scale

The AHP (Tahriri et al., 2008; Yang et al., 2009) uses fundamental scale for verbal judgment to validate a MCDM problem (see Table 4). The fundamental scale has been shown to be a scale that seizes individual preferences with respect to quantitative and qualitative aspects just as well or better than other scales.

Table 4: Pair wise comparison scale

Verbal Judgment	Numerical Rating
Extremely less important	1/9
	1/8
Very strongly less important	1/7
	1/6
Strongly less important	1/5
	1/4
Moderately less important	1/3
	1/2
Equal importance	1
	2
Moderately more important	3
	4
Strongly more important	5
	6
Very strongly more important	7
	8
Extremely more important	9

The discrete scale, from 1 to 9, instrument is used in this research where 1 representing the equal importance of two factors and 9 represents the highest possible importance of the factor over another factor, as shown in Table 4.

In this comparison, the importance of i^{th} criteria is compared with j^{th} criteria is calculated. To obtain this, the number of factors is selected as criteria and in our case it is 6. A 6 × 6 matrix was formed and for filling this matrix following procedure was adopted:

1. The diagonal elements of the matrix are always remains 1.
2. Upper triangular matrixes were filled as per the data obtained through respondents from participating companies.
3. For filling the lower triangular matrix, reciprocal values of the upper diagonal was used, that is, if a_{ij} is the element of row i^{th} and column j^{th} of the matrix, then the lower diagonal is filled using this formula $a_{ji} = 1/a_{ij}$.

3.6 Testing For Consistentency

A comparison matrix A is said to be consistent if $a_{ij}.a_{jk} = a_{ik}$ for all i, j and k. However, we shall not force the consistency. For consistent reciprocal matrix, the largest Eigen value is equal to the number of comparisons, or $Lambda_{max} = n$, where n is the number of items being compared. Accordingly, a measure of consistency, called Consistency Index (CI) or degree of consistency can be obtained using the following formula. Consistency Index (CI) = $(\lambda_{Max} - n)/(n-1)$.

Next the consistency ratio is calculated which is a comparison between Consistency Index and Random Consistency Index (RI), using the formula. Consistency Ratio (CR) = CI/ RI.

RI is the consistency index of a randomly generated pairwise comparison matrix for 500 runs. The value of RI depends on the number of items being compared and is given as follows (see Table 5):

Table 5: Random Consistency Index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

3.6.1 Respondents to Revise Their Judgement

The value of CR is compared with threshold 0.1 to judge whether the comparison is consistent. The major shortcoming when using CR as the consistency index for comparison matrices is to make calculation for CR repeatedly for each comparison matrix to test the consistency.

If the calculated value of CR is more than 0.1, the respondents are hinted to revise their judgments. Further, only such responses are considered valid where CR is less than 0.1.

3.7 Testing For Conflict

AHP still suffers from some theoretical disputes. The rank reversal is surely the most debated problem. This phenomenon is still not fully resolved and maybe it will never be because the aggregation of preferences transposed from scales of different units is not easily interpretable and even questionable. Still, this research has included only such responses which have been considered free from any conflict.

3.8 Combine Individual Judgement to Group Judgement (Using Geometric Mean)

A natural way to find the group judgment for eligible responses is to take the geometric average of all the calculated weights.

3.9 Calculate Priority Weights of the Criteria

Only 31 eligible responses have been obtained for finalizing the priority weights of the criteria. The variation in values of priority weights for eligible responses is shown in Figure 2. The geometric means of weights of criteria have been shown in Table 6. The variability in AHP decision parameters of weights for criteria has been shown in Table 7.

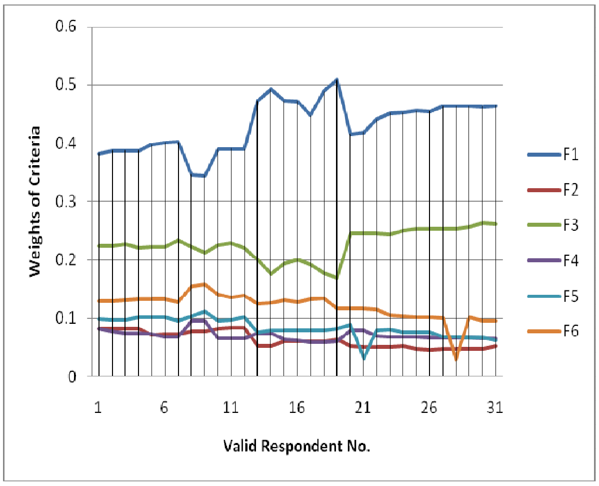

Figure2: Variation of Valid AHP Weights of Factors

Table 6: Geometric Mean of Weights for Criteria

CRITERIA	GEOMETRIC MEAN
[F1] Factor 1: GREEN PRODUCT DESIGN	0.432
[F2] Factor 2: GREEN DESIGN OF RAW MATERIALS	0.064
[F3] Factor 3: GREEN PROCESS	0.227
[F4] Factor 4: GREEN TECHNOLOGY	0.073
[F5] Factor 5: GREEN PACKAGING MATERIAL	0.085
[F6] Factor 6: GREEN PACKAGING DESIGN	0.119

Table 7: Variability in AHP Decision Parameters of Weights for Criteria

CRITERIA	AIRTHMETIC MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION
LAMBDA	6.561	0.047	0.721
CI	0.112	0.009	8.447
CI/RI	0.091	0.008	8.475

3.10 Calculate Priority Weights Of Variables As Sub-Criteria

As the natural way to find the group judgment for eligible responses is to take the geometric average of all the calculated weights, the geometric means of weights of sub-criteria were calculated as shown in Table 8, which is in accordance with Figure 3.

Table 8: Geometric Mean of Weights for Sub-criteria

Items	Geometric Mean
[F1] Factor 1: GREEN PRODUCT DESIGN	
• [VAR10] Eco-impact during product life cycle	0.667
• [VAR12] Compatibility with living environment	0.333
[F2] Factor 2: GREEN DESIGN OF RAW MATERIALS	
• [VAR08] Ease of acquisition	0.247
• [VAR11] Ease of replacement	0.140
• [VAR13] Ease of simplification	0.613
[F3] Factor 3: GREEN PROCESS	
• [VAR01] Processes to reduce wastes	0.134
• [VAR05] Processes to recycle materials ...	0.509
• [VAR06] Process to use remanufacturing	0.357
[F4] Factor 4: GREEN TECHNOLOGY	
• [VAR02] Environmental improvement of production ...	0.465
• [VAR03] Technical innovation capabilities ...	0.356
• [VAR04] Comprehensiveness of eco-standard test ...	0.179
[F5] Factor 5: GREEN PACKAGING MATERIAL	
• [VAR09] Application of eco-material for packaging	0.500
• [VAR15] Recovery rate of packaging material	0.500
[F6] Factor 6: GREEN PACKAGING DESIGN	
• [VAR07] Reusable packaging	0.500
• [VAR14] Integration of eco-marks into packaging design	0.500

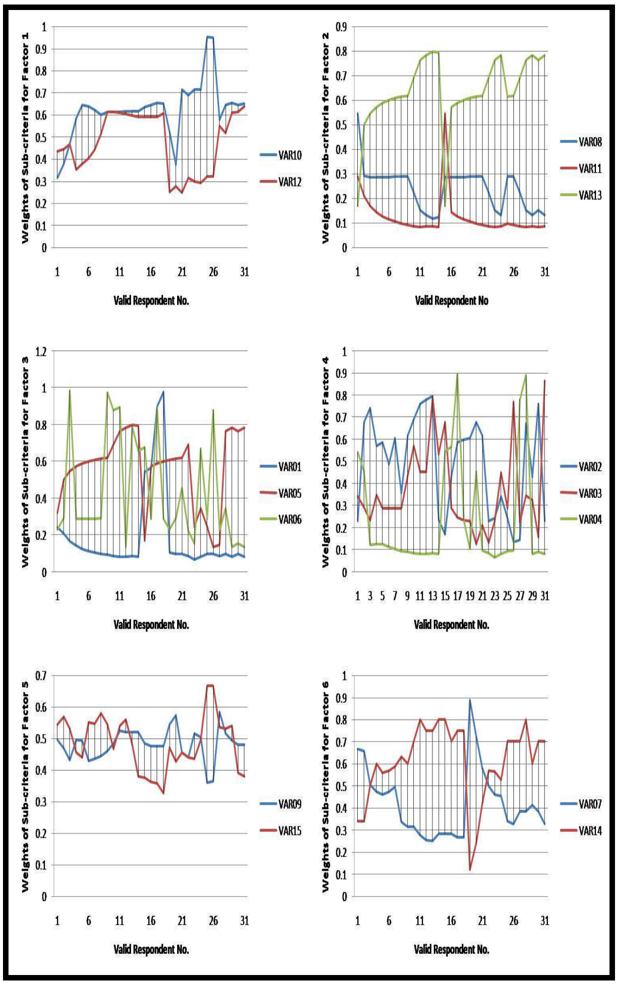

Figure3: Variation of Valid AHP Weights of Variables for Different Factors

4. RESULTS AND DISCUSSION

This research has established that GM relates to greening of product design, design of raw materials, process, technology, packaging material and packaging design using factor analysis.

Making decisions is part of business life. Some of the most important business decisions relate to GM practices. The choice of the best GM practice among the proposed or the possible ones is always an important and topical issue. In the opinion of 31 experts who provided valid responses for AHP, the Green Product Design is the most important with a score of 0.432, followed by the Green Process, and the Green Packaging Design for GM practices in respect of MSMEs in India. The compatibility with living environment is dominated by the eco-impact during product life cycle for the Green Product Design. In the Green Process, the processes to recycle materials are the key. And, in the Green Packaging Design, both the reusable packaging and the integration of eco-marks into packaging design are the key.

The AHP technique as demonstrated above helps prioritize factors of GM. In this application, AHP has been used for capturing the perceptions of respondents on the relative importance of different impacts relating to GM, which will help the authorities in prioritising their environmental management plan for greening of manufacturing. Taking cue from this study, environmental agencies may influence MSMEs in India for improving product designs and process decisions for better environmental outcomes.

5. MANAGERIAL IMPLICATIONS

No environmental standards can be universal and accordingly MSMEs in India needs to set out its own standards in terms of national priority, policy objectives and resources. Managers needs to understand and develop systems and structures within their business that satisfy the requirements of green manufacturing practices while still achieving strategic business goals. The effect of green manufacturing practices requires an in-depth knowledge of manufacturing processes requirements together with the ability to satisfy these requirements while attempting to contribute for environmental sustainability, for example, use of green products (Environmental Certification Standards, ISO14000) and green packaging would lead to new marketing opportunities. There is a need to continually advertise green products to increase customer awareness of the impact and benefits thereof. Businesses must institute green accounting policies such as moving to a paperless administrative environment and taking part in socially responsible investment. Furthermore, businesses should be committed to invest in green research and development initiatives.

This study has validated subjective observations made by experts or by experienced people with their perceptions is what we intend to deal with here on the subject of GM using AHP to understand influences that they have internalized over a period of time. This study has captured the importance of these influences by making pairwise comparison judgments expressed using the AHP fundamental scale in a matrix which results in a priority vector or in a hierarchical AHP model composed of a number of pairwise comparison matrices. Priority vectors can be compared to measures that have been transformed into relative form, that is, they have been normalized so that they sum to 1 as a means to rank the alternatives and choose the best one.

6. CONCLUSION

This study intended to provide a mechanism for the transition of basic research on green manufacturing to industry and government for finding manufacturing solutions to enable a sustainable future with verifiable data. This study has its scope limited to enterprise level alone for studying GM practices it includes identification of variables for GM construct, identifying factors followed by a calculation the weights of evaluating factors through AHP. This paper has discussed theoretical and practical issues for GM practices with special reference to MSMEs reviewing the previous literatures. This research has utilized data from India which is one of the emerging economies, and has proposed six important factors of GM practices, namely, Green Product Design, Green Design of Raw Materials, Green Process, Green Technology, Green Packaging Material, and Green Packaging Design.

This study has some key limitations. These include the acute shortage of correct participant database, weaknesses associated with cross-sectional surveys, and methodological limitations associated with convenience sampling techniques. In addition, only responses from MSMEs were included in the sample whereas larger businesses might have different perceptions regarding the impact of GM practices. Further research in the area of GM should identify some important linkages of GM to be tested using multiple regression analysis for testing a series of hypotheses. These hypotheses will be an educated guess based upon observation. An attempt would be made to adequately explain the theory of green manufacturing upon explaining sets of related observations based on proven hypotheses. Even this may not be the final theory, as it would be required to be verified multiple times by detached groups of researchers.

Future research in this area of GM is promising not only for academics interested in exploring emerging areas in manufacturing, but also for practitioners seeking to find benefits of greening in the management of their manufacturing operations in increasingly challenging and competitive global business markets.

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