

# Performance Analysis of Green manufacturing Criteria by Mutiple Regression Analysis in Indian SMEs

Monalisa Das

Mechanical Engineering Department,  
Imperial college of Engineering and Research  
PUNE, INDIA  
monali8in@yahoo.co.in

Ramesh Rudrapati

Mechanical Engineering Department,  
Imperial college of Engineering and Research  
PUNE, INDIA  
rameshrudrapati@gmail.com

**Abstract**—Green Manufacturing (GM) is a method which minimizes waste and pollution in manufacturing firms. GM reduces depletion of natural causes and it minimizing extensive quantities of garbage that enter in to the landfills. The present work is planned to study and analyze the performance analysis of various green manufacturing criteria's such as environment friendly procurement, implementation of green manufacturing process, environmental legislation, management initiative and application of design and technology on green manufacturing industry by taking the survey of eighty small and medium scale enterprises (SMEs) of Indian manufacturing industries with use of multiple regression analysis. Statistical analysis of variance has been used to check the significance of green manufacturing criteria's. From the study, it is found that management initiative and environmental legislation have highest impact on Indian manufacturing industries.

**Keywords**-green manufacturing, performance analysis, mutiple regression analysis, small and medium scale enterprises.

\*\*\*\*\*

## I. INTRODUCTION

Green manufacturing refers to multidisciplinary approaches aimed to reducing the energy and material intensiveness in manufacturing processes. Energy can be reduced up to 60-70 percent with only use of renewable energy sources. Apart from the innovative handling of energy demands, the green manufacturing is applied many other environmental technologies. Green manufacturing involves transformation of industrial operation in the three ways; (a) using green energy (b) developing and selling green products and (c) employing green processes in the business operation. [1]

Major manufacturing industries in India are focusing on reducing energy consumption, water consumption, hazardous substances and waste emission. Green purchasing network is spreading quite rapidly in India. The impact of Green initiatives also varies by the industry sector [2]. For example – Green initiatives in power sector have the maximum impact on reducing CO<sub>2</sub> emissions followed by transportation and then the industrial sector. Successful implementation of green manufacturing requires going beyond small standalone initiatives and adopting an integrated three step framework; (a) planning for Green as a core part of business strategy, (b) executing Green initiatives across the value chain by shifting towards Green energy, Green products, and Green processes and (c) communicating and promoting Green initiatives and their benefits to stakeholders. Successful transformation into green manufacturing will bring tremendous benefits, both tangible and intangible. For the nation and the business community. In general green manufacturing involves production processes which are highly efficient, and which generate little or no waste or pollution. Green manufacturing encompasses source reduction (also known as waste or pollution minimization, or prevention, recycling and green product design. Source reduction is broadly defined to include any action reducing the waste initially generated. Recycling includes using or reusing wastes as ingredients in a process or as an effective substitute for commercial product, or returning the waste to the original process which generated it as a substitute for raw material feedstock.

Green product designs whose design, composition, and usage minimizes their environmental impacts through their lifecycle. Source reduction and recycling activities already have been widely adopted by industrial facilities. According to U.S Environmental Protection Agency Biennial Reporting System data, which cover facilities generating large quantities, of hazardous waste, 57% and 43% of these facilities had begun, expanded, or previously implemented source reduction and recycling, respectively. Its quest to identify possible substitutes for a toxic flame retardant chemical known as decabromodiphenyl ether (decaBDE), the U.S. Environmental Protection Agency (EPA) has released a draft report on alternatives. This comprehensive assessment, developed with public participation under EPA's Design for the Environment (DFE) program, profiles the environmental and human health hazards on 30 alternatives to decaBDE, which will be phased out of product production by December 2013. DecaBDE is a common flame retardant used in electronics, vehicles, and building materials. It can cause adverse developmental effects, can persist in the environment and can bio accumulate in people and animals. This technical assessment can help manufacturers identify alternatives to decaBDE. "Virtually everyone agrees that EPA needs updated authority under the Toxic Substances Control Act (TSCA) to more effectively assess and regulate potentially harmful chemicals like flame retardants. As EPA continues to stress the need for comprehensive legislative reform to TSCA, we are also targeting actions on a broader group of flame retardants to reduce human and environmental risks."

## II. LITERATURE SURVEY

In the context of present work, a literature survey is made. This survey covers green manufacturing criteria's relating to performance analysis in various manufacturing organizations of Reference [3] show the efforts are taken by leading firms for Prevention of potential hazards to the environment as well as getting ISO 14001 certification. Few of the manufacturing firms had ensured to comply with the reduction of hazardous substance (RoHS) directive. Economic growth plays a crucial role for overall society development. However, economic development and environmental sustainability are not

supplementary to each other hazardous substance) directive. Economic growth plays a crucial role for overall society development. However, economic development and environmental sustainability are not supplementary to each other.

Green manufacturing is a key technology to realize eco-industry and sustainable development; it is causing people's great attention. The implementation of green manufacturing has produced revolutionary influence on the products of the manufacturing industry and manufacturing industry. Through analyzing and researching historical evolvement of product attribute, this thesis summarizes the evolving law of product attribute, and indicates developing trends of manufacturing industry green products [4].

The concept of environmental sustainability with a focus on global efforts had used to achieve sustainability [5]. The purpose of this capstone is to assess efforts made to curb the impact of environmental degradation on the society by some developed and developing countries such as Switzerland, United States of America and China. Excessive emphasis on environmental sustainability using some policies could hurt the economic activities of a country through loss of jobs and societal mishaps while on the other hand too much emphasis on economic growth could result into health risks, global warming and environmental degradation within the society. This thesis further discusses the need to strive towards a balance between environmental sustainability can only be achieved through the integration of policies that connect the environment, the economy and the society. Also, the paper analyses a number of strategic initiatives adopted by some developed countries that other countries can adopt to achieve the balance between environmental sustainability and growth through the integration of policies that connect the environment, society and economy.

Reference [6] recommended specific performance measures by listing seven factors identified as the key elements of Green manufacturing through reliability and validity analyses top management commitment to environmental management, total involvement of employees, training green product/process design, supplier management, measurement, and information management. According to Wee and Quazi, there is a need to focus on environmental issues for improving the performance of organizations.

There are many drivers which are expanding the boundaries for green manufacturing. A growing number of executives today feel that going green will help them to compete more effectively in the marketplace in the long term. In summary the major drivers can be grouped into three key areas competitiveness, corporate social responsibility and legislation [7]. Reference [8] show design a production process with low carbon emissions and low environmental impact as well as high manufacturing performance is a key factor in the success of low-carbon production. It is important to address concerns about climate change for the large carbon emission source manufacturing industries because of their high energy consumption and environmental impact during the manufacturing stage of the production life cycle. In this paper, methodology for determining a production process is developed that you use in an equation. The aim of the methodology presented here is to provide decision support for implementing EBM and low-carbon production to subsequently improve the environmental performance of the manufacturing

industry. The most notable difference between the methodologies presented in this paper and traditional methodology is that this method considers not only the traditional characteristics, such as cost, quality and time, but also considers resource consumption and environmental impact.

Reference[9], identified various performance measurement for the deployment of GM strategies includes, change in production planning, procurement policies, cleaner technologies, Involvement of employees and Top managerial in design and development phase, recycling base activities. EOL, LCA, Takeback economic value creation monitoring physical indices (waste water, air emission, solid waste & energy consumption).

Green manufacturing is an emerging field in recent years and is also the sustainable development model for modern manufacturing industries [10]. Sustainable green manufacturing encompasses the concept of combining technical issues of design and manufacturing, energy conservation, prevention, health and safety of communities and consumers. Many industries are directing their resources to reduce the environmental impact of their produced products and services. To remain competitive in the global economy, these industries need to train engineering and technology professionals to understand the impact of their decisions on the environment and society. It is important for universities to prepare these future engineering technologists to meet this need. Many technology programs do not offer this type of information to their under graduate students. The goal of this paper is to assess the current undergraduate mechanical engineering technology program curriculum at Metropolitan State College of Denver (MSCD) with regard to sustainable green manufacturing predominantly metal working based manufacturing curriculum. In this paper we will discuss key topics that can be infused into manufacturing coursework at MSCD to include sustainability principles. Finally, the ABET process and the existing curriculum will be reviewed to identify barriers and inclusion of sustainable green manufacturing course into current curriculum.

### III. RESEARCH METHODOLOGY

The quantitative approach was chosen as the research design. Hypothesis testing was used to test the relationships that exist among variables. The dependent variable or measured outcome in this research is performance of optimized resources, performance assessment of industrial emissions, and performance assessment of Green Cost whereas the independent variable research design. Hypothesis testing was used to test the relationships that exist among variables. The dependent variable or measured outcome in this research is Performance of optimized Resources, Performance Assessment of Industrial Emissions, and Performance Assessment of Green Cost whereas the independent variable .

A set of questionnaires, which is adapted based on past research, was used to measure these variables. All variables were examined individually to determine whether significant relationship exist between them. The data was collected from marketing managers, operation managers and those managers who have been involved in Green manufacturing operation. The unit of analysis in this Patalganga, turbhe in Navimumbai.

Based on their feedback, with each sub-criteria falling under their respective criteria/major criteria. At the end of pre-testing stage, 24 sub-criteria under the heading of 8 major criteria were finalized. Each criterion in the questionnaire was judged on a 5 point. Likert Scale, where, 1 = very low, 2 = low, 3 = moderate, 4 = high and 5 = very high.

• *Data collection Method*

The primary data in this study was collected through interviews with marketing managers, operating managers, general managers, or managing directors with experiences in product development. The data collection was conducted within one-month period using personal interviews. This study mainly depended on personal interviews because it gave higher response rate compared to other methods. Telephone calls explaining the purpose of the study were made to relevant departments of each organization before any arrangements of appointment being made. About 90 sets of questionnaires were distributed to the manufacturing companies. Out of this, only 80 sets of questionnaires were collected and 80 were usable for further analysis. Secondary data in the form of public records, journals, books, master's theses, and magazines that reflect the area of investigation were also being extensively collected.

IV. MULTIPLE REGRESSION ANALYSIS, RESULT AND DISCUSSION

The effect of one or more independent variables (predictors or covariates) on a dependent variable (output response) is studied by regression analysis method. First stage of the data analysis is often involves investigative analysis. One has to study the nature of relationships in the dataset instead of imposing preconceived models. The fundamental phenomena may have produced from the observed data. Traditional multiple regression techniques are fail to produce accurate results because it usually require a priori assumptions about the functional forms those are related to the response(s) and predictor variable [11]. In regression analysis, the effects of covariates on response variable can be achieved in a simplified manner by properly transmuting the independent variables. Number parameters have to be considered for predicting the continuous variables accurately in regression analysis.

TABLE I. MODEL SUMMARY

Model	MODEL SUMMARY <sup>a</sup>			
	R	R <sup>2</sup>	Adjusted R <sup>2</sup>	Std. error of the estimate.
1	.554 <sup>a</sup>	0.307	.260	.55603

a. Predictors: (Constant), ELAVG, IGMPAVG, AGDTAVG, MIAVG, EFPVAVG  
 b. Dependent Variable: PAIEAVG

TABLE II. ANOVA

Model	ANOVA <sup>b</sup>				
	Sum of square	df	Mean square	F	Sig.
1. Regression	10.122	5	2.204	6.548	0.000 <sup>a</sup>
Residual	22.878	74	.309		
Total	33.000	79			

a. Predictors: ELAVG, IGMPAVG, AGDTAVG, MIAVG, EFPVAVG.  
 b. Dependent Variable: PAIEAVG

TABLE III. COEFFICIENTS

Model		coefficient <sup>a</sup>			
		Unstandardized Coefficient	Standardized Coefficient of beta(β)	t	Sig.
1		<i>B</i>	<i>Std. error</i>		
	(constant)	2.519	0.351	7.186	.000
	MIAVG	.172	.085	2.033	.046
	EFPVAVG	-.156	.094	-1.650	.106
	AGDTAVG	.131	.070	1.858	.067
	IGMPAVG	.016	.067	.232	.817
	ELAVG	.270	.092	2.942	.004

Dependent Variable: PAIEAVG

After running multiple linear regression models in SPSS software data given in Table I, some significant empirical results related to hypotheses have been discussed. Further in this section the most important statistical findings will be presented and discussed. The discussion will be separated into four sub-sections – each of them dedicated to one of the four models. Five are the main factors on which evaluation and discussion of the models have been made – model fit (represented by the R<sup>2</sup> value), model significance (represented by the ANOVA F-value), significance of the independent variables (represented by the T-values), direct effect of each of the independent variables on companies' market share (represented by the sign and value of the un-standardized β coefficients) and the relative importance of each independent variable (represented by the standardized β coefficients). In the discussion, a significance level of 5% i.e. 95% confidence level has been used to define if will be separated into four sub-sections – each of them dedicated to one of the four models. Five are the main factors on which I will base my evaluation and discussion of the models – model fit (represented by the R<sup>2</sup> value), model significance (represented by the ANOVA F-

value), significance of the independent variables (represented by the T-values), direct effect of each of the independent variables on companies` market share (represented by the sign and value of the Unstandardized  $\beta$  coefficients) and the relative importance of each independent variable (represented by the standardized  $\beta$  coefficients). In the discussion, a significance level of 5% will be used to define if a  $\beta$  coefficient has significant contribution to the model.

• *Model-1*

Model 1 is the one, which aims to support the first hypothesis made in the paper Management initiative, environment friendly procurement, application of green design and technology, and implementation of green design and technology on and environmental legislation on performance assessment industrial emissions. The largest beta ( $\beta$ ) coefficient excluding the negative sign is -0.359 i.e. for environmental legislation. This result is suggesting that environmental legislation is a significance predictor of green manufacturing process. The beta value for Management initiative (0.258), Environmental friendly procurement (-0.213), Application of green Design and Technology (0.220), and Implementation of green design and technology (0.027) were less significance predictors on green technology.

From table (I), the  $R^2$  value is estimated at 0.307. This means that green manufacturing process with five control variables, management Initiative, Environment Friendly procurement, Application of green Design and Technology and Implementation of green Design Technology and environmental legislation manage to explain the 30.7% of performance assessment of Industrial emissions.

From the analysis, factor (2) and factor (4) i.e. environmental Friendly procurement and implementation of green design and technology did not contribute significantly to the performance Assessment of Industrial Emissions.(significant value=0.817 and ,0.103>0.005) and factor(5) Environmental legislation , Management initiative and application of green design technology contribute significantly to the dependent variable Performance Assessment of Industrial Emission.

• *ANNOVA*

The purpose of this analysis is to investigate the relationship between the independent variables (classification data) and dependent variables. The ANOVA F-statistic has a P-value lower than 0. 005 and, therefore, the model, as a whole, are statistically significant

The variables, which appear to contribute significantly to the model are management initiative, environment friendly procurement, application of green design and technology, implementation of green design and technology and environmental legislation.

The linearity and normality assumptions prove to be correct according to the scatter plots and the normality test

TABLE IV. MODEL SUMMARY

Model	MODEL SUMMARY <sup>A</sup>			
	R	R <sup>2</sup>	Adjusted R Square	Std. Error of the Estimate
1	.537 <sup>a</sup>	.288	.240	.64640
a.Predictors: (Constant), ELAVG, IGMPAVG, AGDTAVG, MIAVG, EFPAVG b.Dependent variable;PAORAVG.				

TABLE V. ANOVA

MODEL	ANOVA <sup>B</sup>					
		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	12.524	5	2.505	5.995	.000 <sup>a</sup>
	Residual	30.920	74	.418		
	Total	43.443	79			

a. Predictors: (Constant), ELAVG, IGMPAVG, AGDTAVG, MIAVG, EFPAVG

b. Dependent Variable: PAORAVG

TABLE VI. COEFFICIENTS

Model	Coefficients					
		Unstandardized Coefficients	Standardized Coefficients of Beta( $\beta$ )	t	Sig.	
1		<b>B</b>	<b>Std.error</b>			
	Constant	2.057	.408		5.047	.000
	MIAVG	.191	.098	.250	1.940	.056
	EFPAVG	.101	.110	.120	.919	.361
	AGDTAVG	.159	.082	.234	1.945	.056
	IGMPAVG	-.044	.078	-.065	-.558	.579
ELAVG	.114	.107	.131	1.063	.291	

a. Dependent Variable: PAORAVG

• *Model-2*

The goal of model (2) was to identify the if there is any correlations between Management initiative , environment friendly procurement, application of green design and technology a.implementaion of green design and technology and environmental legislation on Performance analysis of optimized resources .

In the second model management initiative has a greater beta coefficient value excluding the negative sign. This result is

suggesting that management initiative is the important predictor of green manufacturing. The beta value for management initiative (0.250), environmental Friendly procurement (.120), application of green design and technology (0.234), implementation of green design and technology(-0.065) , and environmental legislation (0.131) were the less significant predictors on green manufacturing Technology.

The R<sup>2</sup> value is estimated at 0.288. This means that green manufacturing process with five control variables, Management Initiative, Environment Friendly procurement, Application of green design Technology ,Implementation of green manufacturing process, environmental legislation explain the 28.8%of Performance assessment of optimized Resources,.

From the factor analysis factor (5) and factor (4) i.e. Environmental Legislation and implementation of Green Design and Technology friendly procurement which has a lesser contribution to the Performance Assessment of optimized Resources (i.e. Significant value p> 0.291, p>0.571, and p.>0.361) and management initiative and Application of Green Design and technology has some significant value on green manufacturing process (i.e.>0.056).

- ANOVA

The ANOVA F-statistic has a P-value lower than 0.05 and, therefore, the model, as a whole, is statistically significant .If we are not conducting multiple regression analysis test the value should be comes as 43.445 per cent in spite of 12.524.

TABLE VII. MODEL SUMMARY

MODEL	Model summary <sup>a</sup>			
	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.516 <sup>a</sup>	.266	.216	.68758
a. Predictors: (Constant), ELAVG, IGMPAVG, AGDTAVG, MIAVG, EFPVAVG . b. Dependent variable:PAGCAVG				

TABLE VIII. ANOVA

Model	ANOVA <sup>b</sup>					
		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	12.682	5	2.536	5.365	.000a
	Residual	34.985	74	.473		
	Total	47.667	79			

a. Predictors: (Constant), ELAVG, IGMPAVG, AGDTAVG, MIAVG, EFPVAVG  
 b. Dependent Variable: PAGCAVG .

TABLE IX. COEFFICIENTS

Model	Coefficients					
	Unstandardized Coefficients		Standardized Coefficients of beta(β)	t	Sig.	
	B	Std.error				
1	(Constant)	2.049	.434		4.726	.000
	MIAVG	.338	.105	.423	3.235	.002
	EFPVAVG	-.026	.117	-.030	-.225	.823
	AGDTAVG	.065	.087	.091	.743	.460
	IGMPAVG	.083	.083	-.117	-.993	.324
	ELAVG	.150	.114	.165	1.317	.192

a) Dependent Variable: PAGCAVG

- Model-3

The goal of model (3) was to identify the is there any correlations between Management Initiative , Environment Friendly Procurement , Application of green design and Technology and implementation of green design and technology and Environmental legislation with performance assessment of Green Cost.

In the third model management initiative has a greater value of beta co-efficient value excluding the negative sign. This result is suggesting that management Initiative is the important predictor of green manufacturing. The Environmental Friendly Procurement (-0.030), application of green design and technology (0.091), implementation of Green Design and Technology (-0.117), and environmental legislation (0.165) were the less significance predictors for green manufacturing process.

The R<sup>2</sup>value estimated is 0.266. This means that green manufacturing process with five control variables, Management Initiative, Environment Friendly procurement, Application of green design Technology ,Implementation of green manufacturing process and environmental legislation explain the 26.6% of Performance Assessment of Green cost.

From the factor analysis factor (2) Environmental Friendly procurement, , factor(3) Application of green Design and technology ,factor(4)Implementation of green manufacturing Process, factor(5) Environmental legislation ,has a lesser contribution to the dependent variable performance assessment of Optimized resources (i.e.>0.823, p>0.460,p>0.324, p>0.192) and however factor(1)Management initiative has a significant value on the dependent variable Performance Assessment of optimized resources .

- ANOVA

The ANOVA F-statistic has a P-value lower than 0.05 and, therefore, the model, as a whole, is statistically significant .If we are not conducting multiple regression analysis test the value should be comes as 47.667 per cent in spite of 12.524.

## VI. CONCLUSION

In the present work, green manufacturing criteria's eighty manufacturing firms in India are studied with use of multiple regression analysis and analysis of variance. Based on the results of the present study, following conclusions are drawn.

1. From analysis of variance, it is found that environment-friendly procurement, implementation of green manufacturing process and application of green design and technology have no significance on green manufacturing industry because its P values are greater than 0.05.
2. Analysis of variance results also show that management initiative and environmental legislation have higher impact ( $\beta$ ) on Indian manufacturing industry because its significance (P) values are less than 0.05.
3. From the present analysis, it is notified that multiple regression analysis is very useful to study the green manufacturing aspects.

## VII. FUTURE SCOPE OF WORK

In the present study green manufacturing criteria's: environment-friendly procurement, implementation of green manufacturing process, environmental legislation and application of green design and technology of eighty manufacturing companies has been considered. In future, analyses may be carried out in respect of more green manufacturing criteria's taken from the variety of manufacturing companies.

The data of the present may be used to build up reliable Artificial Neural Network and Fuzzy logic models for more accurate results of green manufacturing.

## REFERENCES

- [1] Arindam Bhattacharya, Rahul Jain, Amar Choudhary, "Green manufacturing", energy, product and process, BCG REPORT, march 2011.
- [2] Minhaj Ahemad.A.Rehman, R.R Shrivastava, Rakesh. L Shrivastava " Validating Green Manufacturing (GM) Framework for Sustainable Development in an Indian Steel Industry" Universal Journal of Mechanical Engineering, Vol-2, pp- 49-61, 2013.
- [3] Mukherjee & Kathuria "Public Disclosures – Using Information to Reduce pollution", Journal of Environment Management, July 2006.
- [4] Xing Wen, Jian Xu & Qingshan Zhang " International Business Research." VOL.1, NO.3 July 2008.
- [5] Nkechinyere Vanessa Attah "Environmental Sustainability and Sustainable Growth: A Global Outlook", Master of Science in Organizational Dynamics, Theses, 2010.
- [6] Wee and Quazi "Development and validation of critical factors of environmental management industrial Management & Data Systems " Vol. 105 No. 1, pp. 96-114, 2005.
- [7] Lele Satish " Getting serious about Green manufacturing, "JO Market Insight Asia Pacific Industrial Technologies Frost & Sullivan, "dec 2009.
- [8] Xian-Chun Tan, Yan Yan Wang, Bai He Gu, Ze-Kun Mu and Can Yang "Improved Methods for Production Manufacturing Processes in Environmentally Benign Manufacturing" July 2009.
- [9] Azzone G, G Noci "Identifying effective PMSs for the deployment of green manufacturing strategies", International Journal of Operations & Production " , Vol. 18, Issue 4, pp.308 – 335, (1998).
- [10] Dr. Devi K. Kalla, Prof. Aaron Brown, "Infusing a sustainable Green manufacturing into manufacturing mechanical Engineering Programme", Metropolitan State College of Denver", 2008.
- [11] Aiken, L.S. & West, "Multiple regression; Testing and Interpreting action" Newbury park, CA; Sage, 1991.
- [12] Duolao Wand and Michael Murhy " Estimating optimal transformations for multiple regression using the ACE algorithm" Journal of Data Science, Vol-2, pp. 329-346, 2004.
- [13] Digalwar A. K. & K. S. Sangwan "Development and Validation of Performance Measures for World Class Manufactures" Journal of Advanced Manufacturing Systems " , Vol. 6, No. 1, 21–38, 2007.
- [14] J. Pallant, "SPSS Survival manual", Open University press, 2001.