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COST EFFECTIVENESS OF GREEN MANUFACTURING DRIVE- A MULTIPLE REGRESSION APPROACH IN INDIAN CONTEXT

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Abstract
Today Indian industries are more concerned about sustainable development along with aspects of economical, social and environmental through Green manufacturing (GM) practices. This is a result of community pressure due to awareness about rising pollution and Indian government initiative of making the industries to follow the norms and regulations intended for environmental progress. GM emphasises on reducing and recycling waste, minimising pollution and rising efficiency. Authors have undertaken a survey of industries in Mumbai and nearby industrial areas of Maharashtra state, India through a questionnaire to investigate factors affecting cost benefits of organization's GM initiative. After testing and ensuring the data collected from respondents, the empirical model was tested using regression analysis by SPSS 21 statistical tool. The results of this research indicates that execution of green design, execution of green manufacturing and environmental Acts implementation into organization has significantly positive effect on cost benefits of organization.

Keywords: Green design(GD); Green manufacturing(GM); Dependent variable; Independent variable; Multiple regression; Environmentally conscious manufacturing (ECM); Factor analysis

I. INTRODUCTION
Traditional design and manufacturing methods were centred to the economic profit, such as fixed capital investment, less energy cost, less operation cost, and payback period. Low priority was given to the environmental impacts of design process, manufacturing methods and end use of product being launched in market. But since last two decades as a result of growing awareness of environmental issues, industrialists and concerned regulating bodies have been forced to reduce pollution and waste, to maximize recycling of materials, to increase use of Green energy etc. This

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challenge is achieved by new methods of design known as Green design (GD) and innovative manufacturing methods broadly known as Green manufacturing (GM) with the aim of sustainable development, increasing cost benefits and maximizing resources efficiency.

Due to public pressure, Government regulations and need of market implementation of Green manufacturing practices is one of the important issues in Indian enterprises. This paper focuses on statistical analysis of key factors playing significant role in the success of Green manufacturing initiative to improve cost effectiveness in Indian industries with Mumbai and nearby industries as a case study. The data collected through questionnaire from 310 Mumbai region industries is analysed by factor analysis and multiple regression method.

2 LITERATURE REVIEW

The main objective of this research work is aimed to investigate effectiveness of Green manufacturing (GM) practices being used in Indian enterprises intended for increasing cost effectiveness. So it is important to review what has been investigated by accredited scholars and researchers. The review process consists of concepts and definitions of GM by different authors. It is followed by performance measurement analysis by different researchers.

Green manufacturing is "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"[1].

Green manufacturing involves transformation of industrial operations in three ways: (1) designing and developing Green products, (2) using green manufacturing processes, and (3) using Green energy. The society's rising concern for Green can be set into three broad categories: 1) rising emissions and related climate change 2) fast depletion of scarce natural resources 3) increasing waste generation and pollution [2].

GM is an emerging field in recent years and is also helpful in sustainable development for modern manufacturing industries. Sustainable green manufacturing emerges the thought of combining technical issues of design and manufacturing, energy preservation, prevention, health and safety of communities and customers [3].

Sumit Gupta et al. [4] have adopted Analytic Hierarchy Process (AHP) Model for evaluating sustainable manufacturing processes in Indian industries with electrical panel industries as a case study. This research work presented an AHP model for different manufacturing processes viz. Process design, eco-design, green supply chain, lean practices, recovery of product and cleaner production by which firms can attain sustainability in the realm of clean environment.

Bulent Sezen et al. [5] have investigated the pressure of green manufacturing and eco-innovation on

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corporate sustainability performance Like Economic, environmental, and social by collecting data through a questionnaire-based survey across 53companies from automotive, chemistry and electronic sectors in Turkey. Regression analysis was used to test empirical model and to verify the hypothetical effect ships of the study.

The study of Abhishek Kumar Singh et al. [6] deals to identify factors of GM practices adoption among the MSMEs in India and use 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 judgment making..

The research of Denis Boret Cordoba and Alireza Veshagh [7] studies the principles of eco-design and sustainable manufacturing and also examines the application of sustainable practices in manufacturing industry for eco design and sustainable manufacturing in the food and drink sector of UK. A questionnaire based survey was conducted with 258 manufacturers in the UK to inspect the business case for eco design and sustainable manufacturing in terms of the drives, barriers, advantages and risks.

As per Basappaji K.Ma and N. Nagesha [8], Cleaner Production (CP) is a preventive environmental strategy in agro based industries. The authors presented a model developed to evaluate the CP status and execution of this model on 22 cashew processing units near Mangalore, Karnataka, India by collecting data through structured questionnaire.

Minhaj Ahemad Abdul Rehman and Rakesh L. Shrivastava [9] have undertaken survey in 2009 to find the extent of awareness and execution of GM practices within various medium and small industries in the Vidharbha region of Maharashtra, India. In this study, an approach was made to develop an instrument to find the status of awareness and execution of GM in this section.

With the help of this literature review, research gaps are identified and it is decided to investigate effect of GM initiative on cost effectiveness with Mumbai and nearby industries as a case study. The geographical survey area of industries in this research is Mumbai city and adjustment towns Thane, Navi Mumbai, Dombivali, Kalyan, Ambernath, Taloja, Rasayani, and Bhivandi of Maharashtra state, India. This region pays special attention for this research due to more number of industries and highly densed population. Mumbai city is considered as financial capital of India.

3 SURVEY OF INDUSTRIES

The above Review of literature reveals that most of the authors have investigated GM practices in specific type of organization in India, either size wise or product wise with limited respondents in some cases. The case study of this research work consists of Mumbai and nearby industrial areas of Maharashtra state, India.

To ensure understandability of the questionnaire, the questions were significantly reviewed for their transparency and content many times before sending for responses.

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Questionnaires attribute:

a) Total 24 questions (total 8 factors, each consist of 3 variables)
b) Rating Scale used is five point Likert scale as shown below.
1-Not at all, 2- Limited extent, 3- To some extent,
4- Reasonable extent and 5-High extent

A typical questionnaire item is as shown in figure 1

Variable	*Not at all*	*Limited extent*	*To some extent*	*Reasonable extent*	*High extent*
Recovery of cost through recycling	*1*	*2*	*3*	*4*	*5*

Fig.1: A typical questionnaire

Respondent attribute:

After referring guidelines by various authors and Joseph Hair et al. [10] regarding sample size, 379 respondents were selected. After taking telephonic and personal follow-up, 310 complete responses received which satisfied the requirement of all authors regarding sample size.

Responses by industry sizes:

a) 126respondent having employee 100 and above, b) 114respondent having employee between 50 to 100, and c) 70 respondent having employee less than 50.

The respondent industries have product almost in all field viz. chemical, rubber/plastic, engineering, fabrication, energy, food, manufacturing, pharmaceutical, steel/iron etc**.**

4 ANALYSIS OF DATA AND RESULTS

The goal of this statistical analysis of collected data was to find effects among the variables which are grouped in two categories broadly, independent variable and dependent variable. Also the aim was to find role of factors in improving cost benefit impact through multiple regression method by using SPSS tool.

4.1 Data testing and Factor analysis

Prior to main analysis, internal consistency of variables is tested by finding reliability coefficient Cronbach's alpha which satisfied the reliability of data. It is followed by sampling adequacy test which indicated the appropriateness of applying factor analysis.

After these two tests, Principal component factor analysis is performed to expose the factor structure.

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Description of factors:
F1- Organization's effort (EO), F2- Criteria of material selection (MSC), F3- Execution of green design methods (GDE), F4- Execution of green manufacturing processes (GME), F5- Environmental Acts implementation (IEA), F6- Impact on environmental performance (EI), F7- Impact on Resources efficiency (RI), F8- Impact on cost benefits of organization (CBI)

The following table indicates the results in brief.

Table1**:** Results of Data testing and Factor analysis

.Factor	Variable	Mean	Standard deviation	Factor loading	Cronbach's alpha	Overall Cronbach's alpha	KMO value
F1	V1	3.5956	0.63685	0.815	0.757	0.866	0.813
	V2			0.756			
	V3			0.697			
F2	V4	3.6022	0.58766	0.546	0.662		
	V5			0.701			
	V6			0.655			
F3	V7	3.6774	0.54753	0.668	0.691		
	V8			0.673			
	V9			0.627			
F4	V10	3.7118	0.62036	0.633	0.796		
	V11			0.702			
	V12			0.723			
F5	V13	3.6581	0.55537	0.635	0.616		
	V14			0.554			
	V15			0.743			
F6	V16	3.7666	0.57988	0.832	0.831	0.817	0.712
	V17			0.715			
	V18			0.925			
F7	V19	3.7268	055798	0.756	0.759		
	V20			0.812			
	V21			0.771			
F8	V22	3.6625	0.57391	0.807	0.651		
	V23			0.768			
	V24			0.636			

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4.2 Hypothesis development

The objective of this analysis is to find effect of factors, F3- Execution of green design methods (GDE), F4- Execution of green manufacturing processes (GME) and F5- Environmental Acts implementation (IEA) as independent factors on F8- Impact on cost benefits of organization (CBI) as a dependent factor.

Various Null and alternate hypothesis in the regards of Multiple regression are designed as shown in table 2.

Table 2: Hypothesis for Multiple regressions

Sr. No	Research objective	Null hypothesis	Alternate hypothesis
1	To identify effect of execution of green design on cost benefit impact	$H1_0$: There is no positive effect of execution of green design on cost benefit impact	H1a: There is positive effect of execution of green design on cost benefit impact
2	To identify effect of execution of green manufacturing on cost benefit impact	$H2_0$: There is no positive effect of execution of green manufacturing on cost benefit impact	H2a: There is positive effect of execution of green manufacturing on cost benefit impact
3	To identify effect of environmental acts implementation on cost benefit impact	$H3_0$: There is no positive effect of environmental acts implementation on cost benefit impact	H3a: There is positive effect of environmental acts implementation on cost benefit impact

5 MULTIPLE REGRESSION ANALYSIS

Multiple regression analysis is a statistical technique that can be used to analyse the effect ship between a single dependent (criterion) variable and several independent (predictor) variables. The objective of multiple regression analysis is to use the independent variables whose values are known to predict the single dependent value selected by researcher. Each Independent variable is weighed by the regression analysis procedure to ensure maximal prediction from the set of independent variables [10].

Tool used and assumptions**:**

By using SPSS21 software tool, multiple regressions was carried out with following assumptions,

a) Dependent variable: F8- Impact on cost benefit (CBIAVG)

b) Independent variables: F3- Execution of green design methods (GDEAVG), F4- Execution of green manufacturing processes (GMEAVG), and F5- Environmental Acts implementation (IEAAVG)

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5.1 Model summery

Table 3: Linear regression for cost benefit impact (CBI): Model summery

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.489[a]	0.239	0.232	0.50293
a. Predictors: (Constant), IEAAVG, GDEAVG, GMEAVG b. Dependent Variable: CBIAVG				

Multiple R and Adjusted R square values in this case are 0.489 and 0.232 respectively. This indicate that 23.2% variation in cost benefit impact (dependent variable) is explained by this regression model .This much variance explained with sample size of 310 is sufficiently high and hence model is accepted[10].

5.2 *ANOVA test for overall model fit (Regression model for factors affecting cost benefit impact)*

Table 4 shows ANOVA summary providing statistical significant test for the overall model

Table 4 **:** ANOVA statistical test for overall model Fit

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	24.373	3	8.124	32.119	0.000[b]
	Residual	77.399	306	0.253		
	Total	101.772	309			
a. Dependent Variable: CBIAVG b. Predictors: (Constant), IEAAVG, GDEAVG, GMEAVG						

Here total sum of squares are 101.772 .This much error would have occurred if only mean of dependent variable i.e. cost benefit impact is used to predict dependent variable.
Reduction in error by use of this model= (24.373/101.772)x100= 23.948%
This reduction is found to be statistically significant with F-ratio of 32.119 and significance level of 0.000.

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5.3 Analyzing the regression coefficients β (for Regression model for factors affecting cost benefit impact)

Table 5**:** Regression Coefficients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.494	0.228		6.554	0.000
	GDEAVG	0.121	0.065	0.115	1.848	0.066
	GMEAVG	0.141	0.058	0.152	2.416	0.016
	IEAAVG	0.328	0.062	0.318	5.323	0.000
a. Dependent Variable: CBIAVG						

Standardized regression coefficients i.e. β values are calculated from standardized data. It helps to find mathematical effect between dependent and independent variables as shown below.

$$CBIAVG=0.115[GDEAVG] + 0.152[GMEAVG] + 0.318[IEAAVG]$$

Here IEA is showing highest positive impact on cost benefit impact among all considered independent variables in this model.

5.4 *Checking for Multicollinearity issue in the regression model for factors affecting cost benefit impact*

Table 6: Checking for Multicollinearity issue in the regression model for factors affecting cost benefit impact

Model	Collinearity Statistics	
	Tolerance	VIF
GDEAVG	0.638	1.568
GMEAVG	0.627	1.595
IEAAVG	0.697	1.434

Tolerance values indicate the amount of variability in the selected independent variable which is not explained by other independent variable [10].Variance inflation factor (VIF) is reciprocal of tolerance value. Threshold value as suggested in literature is 0.1 i.e. tolerance value should be greater than 0.1.Here in this model all the cases very well satisfy these norms indicating that Multicolinearity in this model is well within control.

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5.5 Checking for the assumption of linearity and homoscedasticity (for Regression model for factors affecting cost benefit impact)

All the partial plots of residual were analyzed for checking both the assumptions. These plots are shown in figure 2, figure 3 and figure 4

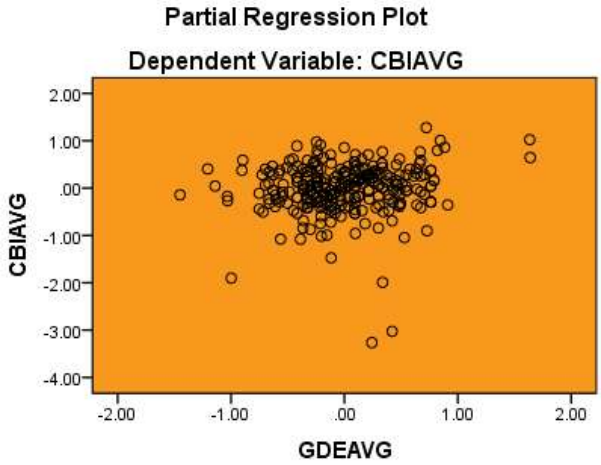

Fig.2: Partial Regression plot for Execution of green design versus Cost benefit impact

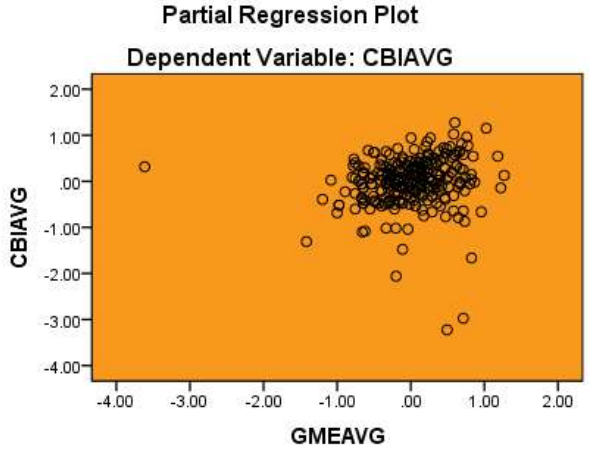

Fig.3: Partial Regression plot for Execution of green manufacturing versus Cost benefit impact

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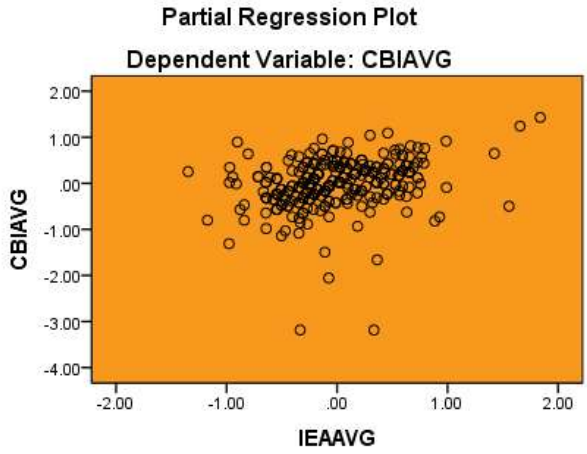

Fig.4: Partial Regression plot for Implementation of environmental acts versus Cost benefit impact

5.6 Checking for the assumption normality of error terms (for Regression model for factors affecting cost benefit impact)

This assumption checks the normality of error term. This assumption can be checked by visual inspection of normal probability plot and histogram. Figures 5 and 6 shows histogram and normal probability plot respectively.

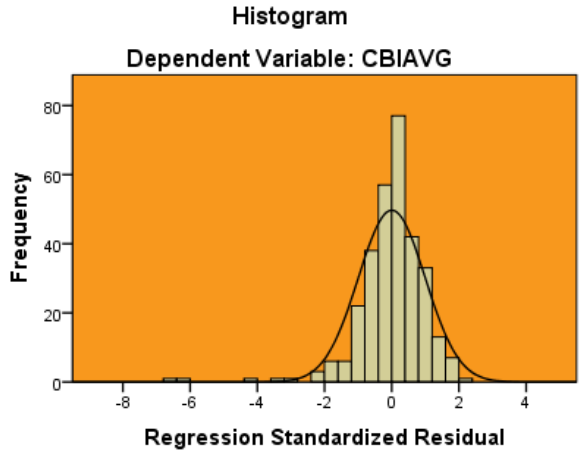

Fig. 5**:** Histogram for check of normality of error terms

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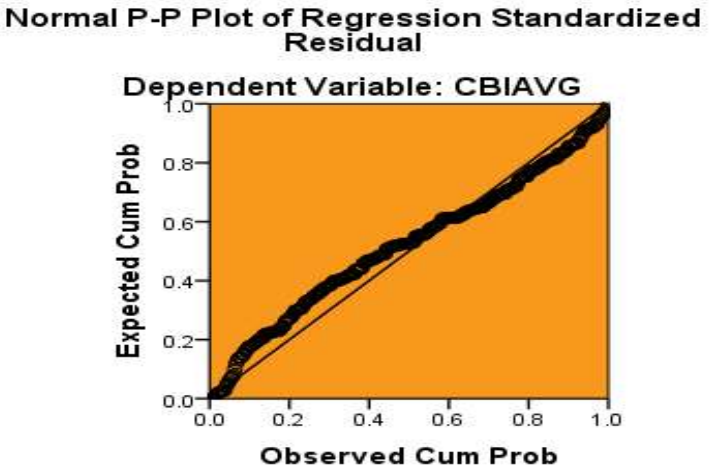

Fig. 6: Normal probability plot for standardized residuals

6 RESULTS AND DISCUSSION

Table 7 shows the results of acceptance of hypothesis.

Table 7: Results of hypotheses testing (for Regression model for factors affecting cost benefit impact)

Sr. No	Null hypothesis	Alternate hypothesis	Result of acceptance of hypothesis
1	$H1_0$: There is no positive effect of execution of green design on cost benefit impact	$H1_a$: There is positive effect of execution of green design on cost benefit impact	Null hypothesis is rejected and alternate hypothesis is accepted
2	$H2_0$: There is no positive effect of execution of green manufacturing on cost benefit impact	$H2_a$: There is positive effect of execution of green manufacturing on cost benefit impact	Null hypothesis is rejected and alternate hypothesis is accepted
3	$H3_0$: There is no positive effect of environmental acts implementation on cost benefit impact	$H3_a$: There is positive effect of environmental acts implementation on cost benefit impact	Null hypothesis is rejected and alternate hypothesis is accepted

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All above hypotheses testing reveals that, execution of green design, execution of green manufacturing and environmental acts implementation into organization significantly affect cost benefit impact of organization. Multiple regressions was conducted with all checks on fundamental assumptions and validities clearly confirmed the positive influence of Green design execution, Green manufacturing execution and Implementation of environmental Acts on Cost benefit impact of organization. The standardized β values confirms the highest effect of environmental acts implementation, secondly execution of green manufacturing and thirdly execution of green design.
This clearly gives implications about which critical success factors influences Cost benefit impact and relative magnitude of impact of each critical success factors.

7 CONCLUSIONS

The objective of this research was intended to investigate the present status of cost benefit outcomes and critical success factors affecting it by green manufacturing initiative and practices being followed by industries in Mumbai and nearby industrial areas of Maharashtra state, India. The results of primary testing and analysis showed that the questions of questionnaire are properly designed with the help of literature reviewed. It also indicates that the sample size is significantly sufficient to do the analysis; data is internally consistent and adequate. The principal factor analysis has resulted into proper loading of factors suitable for further analysis.
Multiple regressions was carried out with mean values of execution of green design, execution of green manufacturing and environmental acts implementation as independent variables and cost benefit impact as a dependent variable. The hypotheses testing reveals that, execution of green design, execution of green manufacturing and environmental acts implementation into organization have positive impact on cost benefit impact of organization. Multiple regressions was conducted with all checks on fundamental assumptions and validities clearly confirmed the positive influence of execution of green design, execution of green manufacturing and environmental acts implementation on cost benefit impact of organization. The standardized β (table 5) values confirmed the highest effect of environmental acts implementation, secondly execution of green manufacturing and thirdly execution of green design.
This clearly gives idea that the critical success factor is ‘environmental acts implementation’ to improve the cost benefits of organization. On the basis of concerned variables of this critical success factor, it can be concluded that cost benefit is improved by adopting government acts related to resources conservation, emissions, recovery, clean air, waste minimization and waste management in Mumbai and nearby industrial areas of Maharashtra state, India.

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