Impact of Lean and Green Strategies on manufacturing Industry of India-An Empirical Investigation

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Abstract
Lean and Green strategies are utilized by manufacturing companies to enhance the operations by reducing manufacturing and environmental waste**.** This study has been carried out in manufacturing industry of India for assessing lean and green thinking of the organizations. Questionnaire survey of 160 manufacturing companies has been performed as ascertain the benefits occurred. Reliability statistics, correlation, single factor ANOVA, z-test and moderator methodology have been employed to achieve different objectives. Results signify that economic performance is significantly improved by implementing lean green strategies. TPM impact moderates to a very high extent between lean manufacturing and green strategies. Lean manufacturing strategies have been highly utilized by manufacturing organizations.
Key Words: Lean and Green**,** Manufacturing companies, Survey, and TPM (Total Productive Management).

1. Introduction

Sustainable system in environment management is capable of meeting issues regarding environment. Environmental needs are captured by green strategies to meet the demand of generation (Choi and Yongjian, 2015). Ecological balance, economic prospects and social responsibility are the important parameters for obtaining environmental sustainability in strategic manner (Savitz and Weber, 2006). In the past years, different dimensions of lean–green have been studied to focus on environment management and waste elimination in the operations for building unanimous structure (Christopher et al., 2004). Different strategies of lean green approach aimed at elimination of unnecessary costs by reducing wastes of environment. It saves environment from industrial wastes and resources use and addressing environmental dimensions. Social dimensions are addressed by lean – green implementation in strategic manner (Ji et al., 2015). Environmental design principles are closely related to sustainability of environment. Financial benefits are also seen by reducing resource consumption in environmental management system

(Gotschol et al., 2014). Figure 1 shows the benefits of implementing lean-green strategies.

Figure 1: Benefits of lean-green strategies implementation

Manufacturing companies are monitoring and strengthening environmental and manufacturing performance parameters. Performance parameters including environmental design reflects the performance of lean-green attributes. Environmental goals of the organization are obtained by implementing lean- green strategies in a systematic manner. (Bhattacharya et al., 2019). These companies are closely related to enhancing long term competitiveness. Performance in terms of flexibility, sustainability, reliability and productivity has been enhanced by implementing lean-green strategies (Chen and Delmas, 2011).

Manufacturing processes are created by the concept of lean-green, not only from social and ecological perceptive but also from profit point of view. The integrated lean-green concept is required to enhance production processes and green wastes to enhance productivity (Hosseini and Kaneko, 2012). There is a continuous need for understanding lean-green concept for enhancing knowledge of different benefits of implementing such strategies including enhanced environmental practices and enhancement of profit (Deif, 2011). Organizational and environmental performance has been significantly enhanced by implementing lean and green strategies. Productivity and improved quality of work life are other advantages of implementing lean and green manufacturing strategies (Shah and Ward, 2003). Sustainability attainment through lean and green strategies is the most complex task as compared to mass production paradigm. The thinking of sustainability support manufacturing practices to obtain environmental, economic and social aspects (Rosen and Kishawy, 2012). Companies are implementing critical resources of lean-green implementation and are reducing wastes that are in sustainable. Environmental emissions and resources creating pollution are critical factors leading towards lean-green implementation (Jasti and Kodali, 2014). The study has been carried in manufacturing Industry of India to assess the benefits of implementing lean-green strategies in

systematic manner. Questionnaire has been prepared containing filling of questionnaire and applying statistical and analytical techniques for analysis of the data obtained from industries.

2. Literature Review

Balan (2008) provides innovative techniques for providing environmental solutions resulting in reduced work handling, process automation, cost saving, effluent control and other operational benefits. *Darlington et al. (2009)* proposed an elimination of waste methodology for food manufacturing industries. Inventory waste has been highlighted in the study throughout the production processes. Cost analysis for monitoring the waste of production processes has been performed. *Aminuddin et al. (2014)* used ANP (Analytical Network Process) to propose the best combination of performance indicators of sustainable manufacturing. Complex decision making process for sustainable assessment has been analyzed. Lean manufacturing is less sustainable than green manufacturing. *Kaczmarek (2014)* assessed Lean green paradigms for overall improvement in maintenance engineering. The complexity of manufacturing system, and various external and internal factors responsible for maintenance outcomes have been identified. *Sabadka (2014)* explored and identified lean environmental waste from industries activities. This technique reduces waste emission and material waste leading towards resource productivity. Employee training and involvement is highly needed or implementing lean and green concept. *Hallam and Contreras (2016)* explained the integration of lean green production for its importance of synergistic effects for sustainable development and meet competitive environment. The relationship between parameters of lean green methodology has been developed. Theory of optimizing performance of firm has been developed further. *Gaikwad and Sunnapwar (2020)* assessed lean and green tools for improving economic, social and environmental performance leading towards improvement in business performance. Results indicate strong linkage between lean and green tools. This will be useful for researchers and academicians for developing sustainable manufacturing in industries. Figure 2 shows the elements of sustainable process showing different benefits.

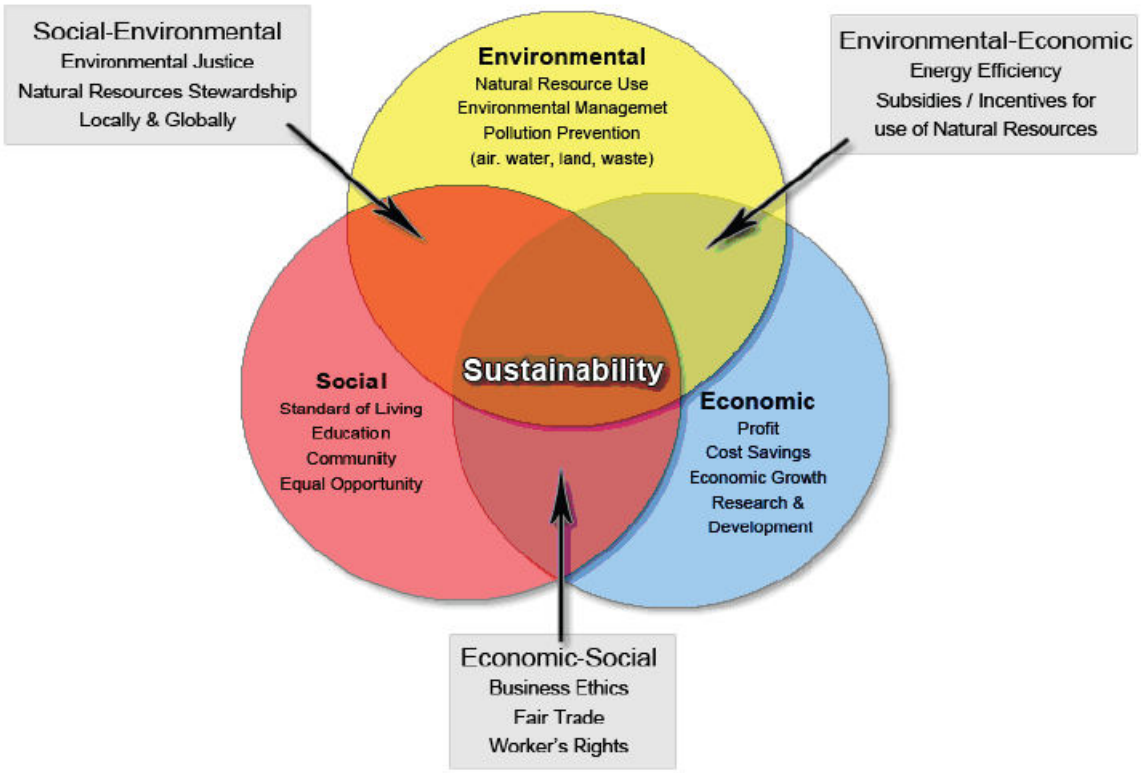

Figure 2: Sustainability Process

Kumar et al. (2020) explained that sustainable lean manufacturing are characterized by critical success factors as identified from literature. Interpretive structural modeling has been employed for finding relationship between various success factors. Top management role plays a significant role in implementing critical success factors. *Bouazza et al. (2021)* conducted survey in Morocco in 50 different companies to assess the status of lean green strategies. Environmental performance is greatly affected by these strategies. Results indicated that correct use of these tools will have positive impact on profit enhancement. *Rusinko (2021)* claimed that green manufacturing include pollution prevention, waste elimination and affluent treatment. It is viewed as continuous improvement technique or preventing pollution and is advantageous over competitor in global economy.

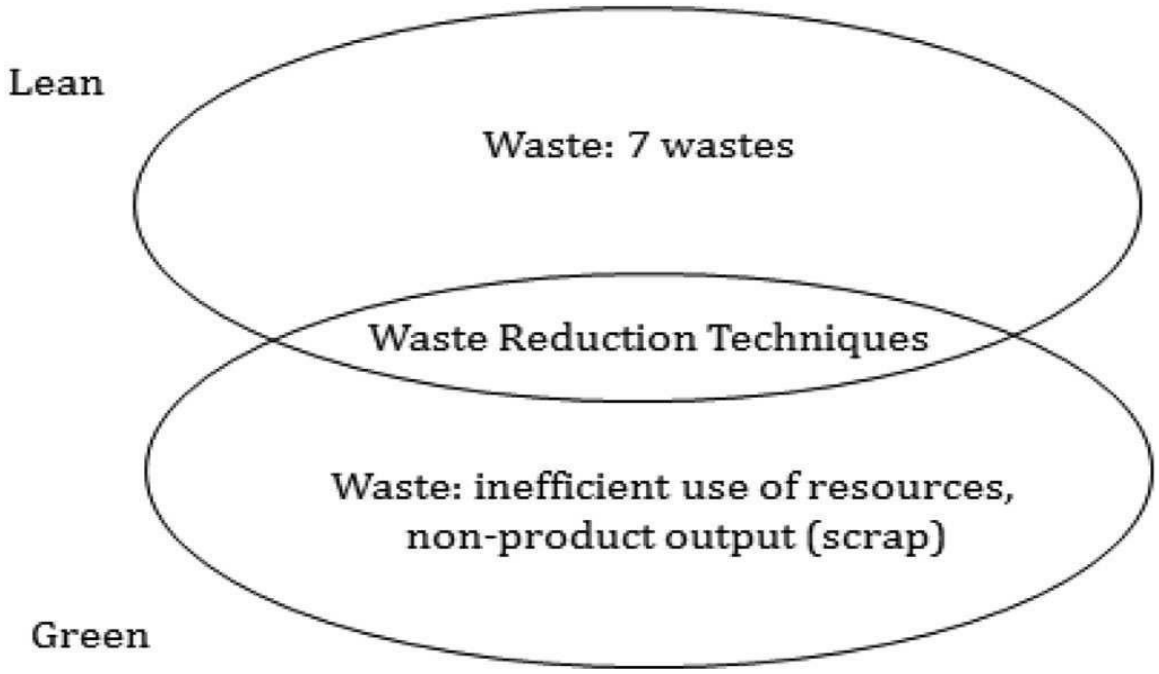

Figure 3: Overlapping of Lean and Green strategies

Singh et al. (2022) examined and identified key performance parameters of lean and green approach. It has been observed that Multi-Criteria Decision technique can be used to check the performance of key performance parameters. *Mohan et al. (2022)* determined the impact of green lean six sigma on manufacturing industry. Realization of performance has been attained by systematic application of green lean six sigma.

3. Research Design

Questionnaire survey has been performed based on convenient sampling or based on simplicity of convenience. The industry database has been created from Directorate of Indian Industry and Confederation of Industry. Northern Indian Industrial Directory has also been utilized for the survey. Snowball sampling has been done from reaching proceeding Industry from previous Industry. Figure 4 shows the methodology adopted for the proposed research.

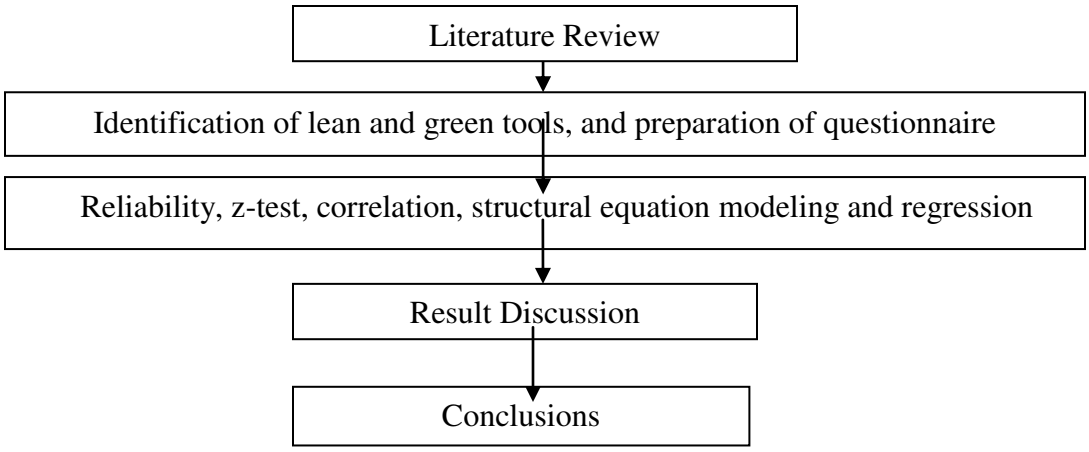

Figure 4: Research Methodology

The first section of questionnaire consists of name and location of Industry, Characteristics of respondent and product manufactured by the company. Questionnaire consists of both open and closed ended questions. The questionnaire has been sent to peers and academic experts for its content reliability (adequacy of questions). Figure 5 shows different steps to complete the questionnaire.

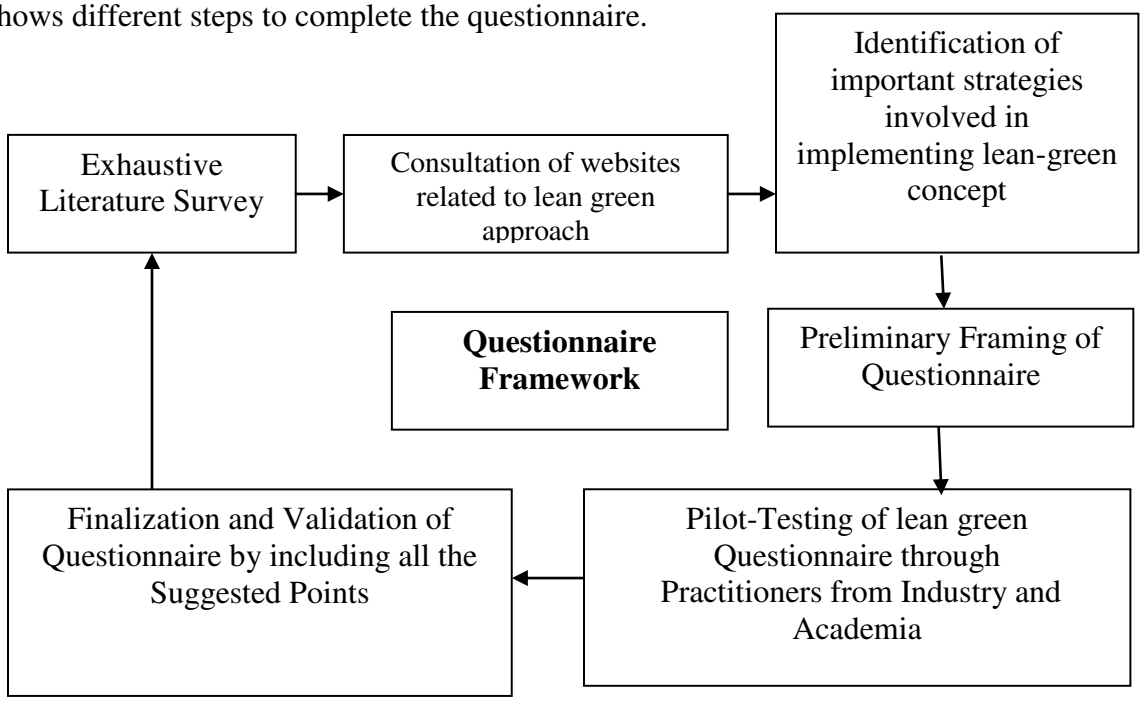

Figure 5 Framing of Lean-Green Questionnaire

The measurement of other sections consists of five point likert scale (Lean and Green tools on five point: 5= To an extremely large extent, 4= To a large extent, 3= To a moderate extent , 2= To small extent, 1=Not at all important; Impact of TPM on 5= To an extremely large extent, 4= To a large extent, 3= To a moderate extent , 2= To small extent, 1=Not at all important; and benefits for organizational sustainability on 5= To an extremely large extent, 4= To a large extent, 3= To a moderate extent , 2= To small extent, 1=Not at all benefits. A total of 160 industries are surveyed including Industries manufacturing auto parts, multi-products, sheet metal components, billets and blooms, tractor parts, rods, bars, fasteners and cycle parts. The respondent designations include managing directors, partners, head of departments, managers, assistant managers, senior engineers, and engineers from different departments.

4. Results and Discussion

4.1 Reliability Statistics

The loading of 0.5 has been used while calculating cronbach's alpha (reliability statistics) using online calculator. Reliability statistics of all variables is adequate for operations management research {cronbach's alpha=0.65(Singh and Khamba, 2009)}. Table 1 shows the values of cronbach's alpha for different constructs.

Table 1: Reliability statistics for different constructs

Constructs	Cronbach's Alpha
Lean strategies	
Removal of waste	0.736
Waste Segregation	
Proper utilization of space	
KAIZEN	
5S	
Design of Environment	
Integration of energy and material flows	
Kanban system	
Single Minute Exchange of Die	
Supply chain involvement	
Technology Modification	
Continuous optimization	
Process Integration	
Green Strategies	
Green purchasing	

Environmental Management System	0.846
Material Diversity	
Recycling	
Green Scheduling	
Impact of TPM	
Unplanned events	0.698
Understanding of the problem	
Less intervention	
Environmental Performance	
Use of natural resources	0.723
Environmental Management	
Pollution Prevention	
Social benefits	
Improved Standard of living	0.626
Awareness of education	
Equal opportunity to all	
Economic performance	
Profit enhancement	0.862
Economic Growth of the company	
Research and Development	
Saving in cost	

4.2 Correlation between Lean- Green strategies and performance parameters

Karl Pearson coefficient is calculated between lean green strategies and performance parameters. Correlation coefficient is tested using single factor ANOVA for its significance towards performance improvement. Table 2 shows values of Pearson correlation measured using MS Excel 2007 and Table 3 shows values calculated in single factor ANOVA.

Table 2 Correlation coefficient between lean green strategies and performance parameters

	EP	SB	ECONP
Lean Strategies	0.2216*	0.0588*	0.1386*
Green Strategies	0.2267*	0.1316*	0.2081*
*Correlation is significant at 5% level			

Table 3: Validation of correlation with single factor ANOVA

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
3.428571	159	547.0714	3.440701	0.049613
3.4	159	513.2	3.227673	0.1329

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.607779	1	3.607779	39.53443	1.07E-09	3.871054
Within Groups	28.83709	316	0.091257			
Total	32.44487	317				

4.2.1 Results Discussion of correlation analysis

Since the calculated value of F using single factor ANOVA is more than critical F, the null hypothesis (There is no significant correlation between lean green strategies before implementing them) is rejected. All correlations are significant at 5% level. Results suggests that Lean manufacturing strategies significantly aimed at improving environmental performance (r=0.2216) followed by improved economic performance (r=0.1386) and attaining social benefits (r=0.0588); Green manufacturing strategies significantly aimed at improving environmental performance (r=0.2267) followed by improved economic performance (r=0.2081) and attaining social benefits (r=0.1316). Waste elimination strategies are highly helpful in getting cost benefits; environmental waste elimination strategies also aimed at improving economic performance of manufacturing system processes.

4.3 Importance of different variables

In order to find out important lean green strategies, and benefits of implementing these strategies, z test has been applied in Microsoft Excel 2007. Null hypothesis is taken as mean of initial population (five point likert scale have been applied and half of it is 2.5 which is taken as hypothezed mean) Table 4 shows z test applied to all variables.

Table 4: z-test applied to all variables

Variables	Mean	Std. Deviation	z-stat
Lean Strategies			
Removal of waste	3.1125	0.513803	15.07889*
Waste Segregation	3.375	0.601361	18.40487*
Proper utilization of space	3.55625	0.557926	23.94694*
KAIZEN	3.73625	0.640331	23.82829*
5S	3.59375	0.694062	19.93333*
Design of Environment	2.95	0.750681	7.582581*
Integration of energy and material flows	3.50625	0.593432	21.44839*
Kanban system	3.56875	0.60002	22.53049*
Single Minute Exchange of Die	3.64375	0.666794	21.69697*
Supply chain involvement	3.24375	0.621895	15.1276*
Technology Modification	3.475	0.603449	20.43732*
Continuous optimization	3.7125	0.565101	27.14034*
Process Integration	3.48125	0.75212	16.50261*
Green Strategies			
Green purchasing	3.1875	0.595449	14.60454*
Environmental Management System	3.0375	0.559509	12.15154*
Material Diversity	3.31875	0.628184	16.48635*
Recycling	3.28125	0.584623	16.90339*
Green Scheduling	3.3187	0.712617	14.533*

Environmental Performance			
Use of natural resources	3.1125	0.560632	13.81937*
Environmental Management	3.2875	0.730189	13.64191*
Pollution Prevention	3.425	0.649625	18.01105*
Social Benefits			
Improved Standard of living	3.09375	0.569639	13.1845*
Awareness of education	3.3	0.680362	14.87338*
Equal opportunity to all	3.25	0.777029	12.20912*
Economic Performance			
Profit enhancement	3.6	0.528437	26.33054*
Economic Growth of the company	3.3625	0.639256	17.0665*
Research and Development	3.2	0.767254	11.54034*
Saving in cost	4.15	0.626461	33.3158*
Z critical (0.05) = 1.96			*Significant at 5% level

4.3.1 Result Discussion of z test

All z values are significant at 5% level (95% confidence interval). Results claimed that KAIZEN is rated most important (mean=3.73625) in terms of lean strategies followed by Continuous Optimization (mean=3.7125), Single Minute Exchange of Die (mean=3.64375), 5S (mean=3.59375), Kanban System (mean=3.56875), Proper utilization of space (mean=3.55625), Integration of energy and material flows (mean=3.50625), Process Integration (mean=3.48125), Technology Modification (mean= 3.475), Waste Segregation(mean= 3.375), Supply chain involvement(mean= 3.24375), Removal of waste(mean=3.1125), Design of Environment(mean=2.95); Material Diversity and Green Scheduling are rated most important(mean =3.31875) in terms of Green Strategies followed by Recycling (mean = 3.28125), Green purchasing (mean = 3.1875), and Environmental Management System (mean = 3.0375); Pollution Prevention (mean = 3.425) in rated most important environmental benefit followed by Environmental Management (mean= 3.2875), and Use of natural resources(mean=

3.1125); Awareness of Education (mean= 3.3) is rated most in terms of social benefits followed by Equal opportunity to all(mean= 3.25) and Improved Standard of living(mean= 3.09375); Saving in cost is rated most important (mean= 3.09375) in terms of Economic Performance followed by Profit enhancement(mean=3.6), Economic Growth of the Company(mean = 3.3625) and Research and Development (mean= 3.2).

4.4 Importance of main variables

The z-stat has been calculated for main variables by taking mean of all variables and preparing an array. This array has been used to measure mean, standard deviation and z-statistics. Table 5 shows values of z test applied to the main variable.

Table 5. Importance of main variables (z-test)

Main variable	Mean	Std. Deviation	z-stat
Lean Strategies	3.440625	0.22204	53.58519*
Green Strategies	3.22875	0.363662	25.34783*
Environmental Performance	3.275	0.452572	21.66076*
Social Benefits	3.214583	0.465958	19.39842*
Economic Performance	3.578125	0.38156	35.74101*
Z critical (0.05) = 1.96			*Significant at 5% level

4.4.1 Results Discussion of importance of main variables

All the respondents are confident (95% confidence level) in answering the main variables. Results signifies that lean manufacturing strategies are more important (mean= 3.440625) than green strategies (mean = 3.22875); Economic performance is rated most important benefit (mean =3.578125) followed by Environmental Performance (mean =3.275) and social benefits (mean=3.214583).

4.5 Moderator effect of TPM between LM, GS and Benefits (Hierarchical Regression)

The moderator effect of impact of TPM between Lean Green strategies and benefits including performance parameters viz. economic performance, social benefits and environmental performance (Figure 6) has been measured using hierarchical regression and expert analysis. The hierarchical regression and cluster procedure, by using SPSS 21v software have been performed. Analysis has been performed for both the performance parameter (ECONP and EVMTLPERF). Then, main independent variables, i.e. Lean and Green dimensions (LM) and Green Strategies (GS) – were introduced as a block followed by the centralizing these variables (ECONP and EVMTLPERF), product

of these centralized variables (ECONP and EVMTLPERF) and Impact of TPM as a moderator variable.

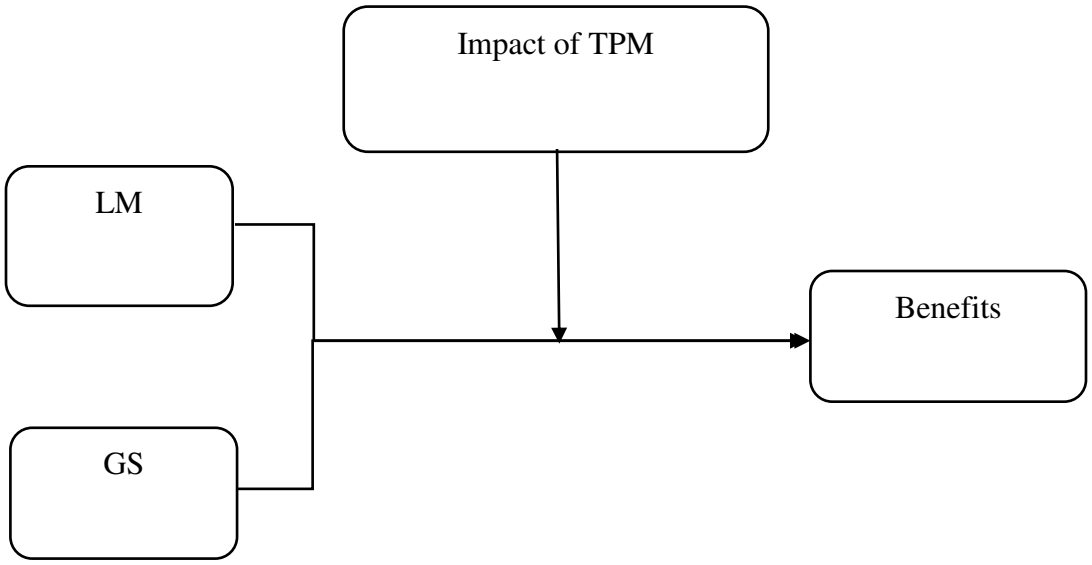

Figure 6 Moderator Model for measuring impact of TPM

Table 6 and Table 7 shows the comparison between initial multiple regression and final hierarchical regression.

Table 6 Results of initial regression and final hierarchical regression (ECONP)

Initial Multiple Regression			Final Hierarchical Regression		
R Square	R Square Adjusted	t value	R Square	R Square Adjusted	t value
0.025	-0.060	LM- -0.031 GS- - 0.143 Constant- 3.604	0.258	0.257	LM-0.075 GS- --0.449 Moderator – 2.628* Constant- 3.5
*Significant at 5%level					

Table 7. Results of initial regression and final hierarchical regression (EVMTLPERF)

Initial Multiple Regression			Final Hierarchical Regression		
R Square	R Square Adjusted	t value	R Square	R Square Adjusted	t value
0.065	0.004	LM- 0.205 GS- - 0.143 Constant- 2.891	0.350	0.261	LM-0.548 GS- --0.523 Moderator – 3.421* Constant- 2.8
*Significant at 5%level					

4.5.1 Result Discussion of Hierarchical Regression

Results of investigation demonstrated that there is a significant increase in percentage contribution of LM and GS on ECONP by moderator variable (Impact of TPM). This implies that economic performance of the companies has been significantly improved by centralization of independent variables. Moderator effect is also significant in case of EVMTLPERF which also signifies that environmental performance has also been improved by centralized effect of independent variables. Economic effect has been increased by 29.7% and environment performance has been increased by 26.5%. Further results indicated that positive R square values indicate positive relationship between independent and dependent variables. All the *t* values are significant at 5% level, which justify that all claims holds good statistical stability. Moreover, TPM shows moderator level to very high extent, which signifies that economic benefits have been occurred after implementing lean manufacturing and green strategies by using TPM as moderator variable in manufacturing organizations of India.

5. Conclusions, Limitations and Practical Implications

Results indicated that small incremental improvement (KAIZEN) strategies are of high importance for reducing wastes in systematic manner. In order to ensure manufacturing excellence, organization must utilize all the lean and green strategies as these have high level of importance as described by the proposed research. Cost related benefits are significantly obtained after implementing lean and green strategies. Diversity in materials and Green Scheduling are highly important green strategies for profit enhancement. Total Productive Maintenance (as a moderator) improves the economic effect by a factor 29.7% and improves environmental stability by a factor by 26.5%. Economic and Environmental benefits are obtained by taking impact of total productive maintenance as

moderator variable. Lean manufacturing strategies are utilized and highly important as compared to green strategies to these manufacturing organizations. Convenience sampling has been utilized that contains different limitations. Possibility of variance is there as respondents are met on basis of snowball sampling technique. The difficulty in implementing lean green strategies is other limitation of the study that can be taken into account. The results of survey can by synthesized with case study to attain the practical benefits. The practical significance of this study includes role of green strategies towards organizational sustainability by achieving different benefits. Industrial Professionals will come to know the lean green benefits and ways to implement these strategies in their organizations for sustainable development.

References

1. Aminuddin, A. S. A., Nawawi, M. K. M., and Mohamed, N. M. Z. N. (2013), "Analytic Network Process Model For Sustainable Lean And Green Manufacturing Performance Indicator", *AIP Conference Proceedings*, Vol. 32, pp. 32-38.
2. Balan, K. (2008), "Introduction to Green Manufacturing", *The Shot Peener*, Vol. 22., No. 3, pp 4-6.
3. Bhattacharya, A., Nand, A. and Castka, P. (2019), "Lean-green integration and its impact on sustainability performance: A critical review", *Journal of Cleaner Production*, Vol. 236, No. 11, pp.76-97.
4. Bouazza, Y., Lajjam, A. and Dkhissi, B. (2021), "The impact of lean manufacturing on environmental performance in Moroccan automotive industry", *Management Systems in Production Engineering,* Vol. 29, No. 3, pp.184-192.
5. Chen, C. M. and Delmas, M. (2011), "Measuring corporate social performance: An efficiency perspective", *Production and Operations Management*, Vol. 20, No. 6, pp.789–804.
6. Choi, T. M. and Yongjian, L. (2015), "Sustainability in Fashion Business Operations", *Sustainability*, Vol. 7, No. 11, pp. 400-406.
7. Christopher, M., Lowson, R. and Peck, H.(2004), "Creating Agile Supply Chains in the Fashion Industry", *International Journal of Retail Distribution Management*, Vol. 32, No. 1, pp. 367–376.
8. Darlington, R., Staikos, T. and Rahimifard, S. (2009) , "Analytical methods for waste minimization in the convenience food industry", *Waste Management*, Vol. 29, No. 12, pp.12-31.
9. Deif, A. M.(2011) "A system model for Green manufacturing," *Journal of Cleaner Production*, Vol. 19, No. 14, pp. 1553-1559, 2011.
10. Gaikwad, G. and Sunnapwar, A. (2020), "The Role of Lean Manufacturing Practices in Greener Production: A Way to Reach Sustainability", *International*

Journal of Industrial and Manufacturing Systems Engineering, Vol. 5, No. 1, pp. 1-5.

11. Gotschol, A., Giovanni, P. D. and Vinzi, V. E. (2014), "Is Environmental Management an Economically Sustainable Business?", *Journal of Environment Management*, Vol. 144, No. 2, pp.73–82.
12. Hallam, C. R. A. and Contreras, C. (2016), "The Interrelation of Lean and Green Manufacturing Practices: A Case of Push or Pull in Implementation", 2016 *Proceedings of PICMET '16: Technology Management for Social Innovation*, pp. 1815-1823.
13. Hosseini, H. M. and Kaneko, S. (2012),"Causality between pillars of sustainable development: Global stylized facts or regional phenomena?" *Ecological Indicators*, Vol. 14, No. 1, pp. 197-201.
14. Jasti N. V. K. and Kodali, R.(2014), "Lean Production: Literature Review and Trends", *International Journal of Production Research*, Vol. 53, No. 2, pp. 867–885.
15. Ji, Y., Huang, G. H. and Sun, W.(2015) , "Risk assessment of hydropower stations through an integrated fuzzy entropy-weight multiple criteria decision making method: A case study of the Xiangxi River", *Expert Systems with Applications,* Vol. 42, No. 12, pp. 5380-5389.
16. Kaczmarek, M. J. (2014), "Integrating Lean and Green Paradigms in Maintenance Management", *Preprints of the 19th World Congress, the International Federation of Automatic Control,* Cape Town, South Africa. August 24-29, 2014, pp. 4471-4476.
17. Kumar, N., Mathiyazhagan, K., Mathivathanan, D. (2020), " Modeling the interrelationship between factors for adoption of sustainable lean manufacturing: a business case from the Indian automobile industry", *International Journal of Sustainable Engineering*, Vol. 13, No. 2, pp. 93-107.
18. Mohan, J., Rathi, R., Kaswan, M.S, and Nain, S. S. (2022), "Green lean six sigma journey: Conceptualization and realization", *Materials Today: Proceedings*, Vol. 6, No. 2, pp. 10-17.
19. Rosen, M. A. and Kishawy, H. A. (2012), "Sustainable Manufacturing and Design: Concept, Practices and Needs", *Sustainability*, Vol. 5, No. 2, pp 154-174.
20. Rusinko, C.A. (2021), "Green manufacturing: an evaluation of environmentally sustainable manufacturing practices and their impact on competitive outcomes", *IEEE Transactions on Engineering Management*, Vol. 54, No. 3, pp. 445-454.
21. Sabadka, D. (2014), "Innovation lean principles in automotive lean manufacturing", *Acta Logistica - International Scientific Journal*, Vol. 1, No. 4, pp. 23-37.
22. Savitz, A. W. and Weber, K. (2006), *The Triple Bottom Line; Jossey-Bass: San Francisco*, NC, USA.

23. Shah, R. and Ward, P. T. (2003), "Lean manufacturing: context, practice bundles, and performance", *Journal of Operations Management*, Vol. 21, No. 2, pp. 129-149.
24. Singh, C., Singh, D. and Khamba, J. S.(2022), "Understanding the key performance parameters of green lean performance in manufacturing industries", *Materials Today: Proceedings* , Vol. 16, No. 4, pp. 12-17.
25. Singh, H. and Singh, J. S. (2009), "Evolving the barriers for enhancing the utilization level of advanced manufacturing technologies (AMTs) in Indian manufacturing industry", *International Journal of Advanced Operations Management*, Vol. 1, No. 2/3, pp. 135-150.