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THE EFFECT OF LEAN MANUFACTURING ON PRODUCT QUALITY AND INDUSTRIAL PRODUCTIVITY: AN EMPIRICAL SURVEY

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Abstract:
This paper presents a methodology for determining the real problem associated with the industries in implementation of Lean Manufacturing (LM) practices by collecting and analyzing the gathered data from 84 small-scale industries situated in Jharkhand, India with the help of a structured questionnaire.

The results of this assessment have been used to identify and customize an implementation plan as well as selection of the required lean tools in the light of company's long term vision, mission and corporate strategy. From an operational management perspective, this survey analysis gives a clear picture and logical impact with justification for the implementing of Lean Manufacturing, in improving the productivity and quality of an organization as a whole.

Key Words: Lean Manufacturing, Product Quality, Productivity

1. INTRODUCTION

In today's competitive marketplace, companies are under increased pressure to produce products that have a low cost and high quality. One aspect that strongly influences both is manufacturing process. Variations exist because no production process is perfect. The effort and resources could be reduced, if the manufacturing processes are well managed through scientific tools and techniques. World-class Companies, such as, Toyota, Porsche, Boeing and Tesco have adopted Lean Manufacturing at the corporate level.

This research is an attempt to present a structured methodology for determining opinions and ground realities about Lean Manufacturing tools and techniques through questionnaire in some of the companies in Jharkhand (India).

2. OBSTACLES IN IMPLEMENTATION OF LEAN MANUFACTURING

Lean Manufacturing is applicable to any industry, whether it is a small or big manufacturing organization. But implementation of lean manufacturing tools and techniques require through understanding of the philosophy and processes to ensure step-by-step application. Many small manufacturers experience difficultly during implementation due to shortage of skilled manpower, lack of resources and training facility etc. Further, small manufacturers are often financially constrained and time constrained as well. This makes implementation of Lean Manufacturing more difficult. Similarly, small manufacturers often face cultural inertia to overcome, which makes it harder to establish the philosophy and culture necessary to support lean manufacturing tools and techniques.

3. THE LEAN MANUFACTURING TOOLS AND TECHNIQUES: A SURVEY

Many tools are readily available to promote continuous improvement in industries, but it has proven that lean manufacturing tools and techniques give superior results. Through the use of statistics, management is better able to gain an understanding and control of the production system, and therefore, make informed decisions in regard to overall improvement. In order to test the viability of Lean Manufacturing tools and techniques in small manufacturing environments a survey questionnaire was developed with the direction from literature reviews [1-35]. The same set of questionnaire was distributed to small manufacturers.

3.1 Background and Survey Sample

Questions from the previously used survey instruments were evaluated to determine their suitability for small manufacturers and for testing the hypotheses of this research. In order to further enhance the validity of the survey instrument, expert help from my guide was taken regarding the selection and development of appropriate questions for measuring Lean Manufacturing practices in a small industry. The main aim of the survey is to determine the effect of lean manufacturing on product quality and productivity related manufacturing environment in engineering industries.

Although no correct specifications exist for labeling N Company as being small or large, most sources use a cutoff point of 250 employees or less to define a small company. This cutoff point was considered, but later abandoned because the environment of a 20-employee company and a 250-employee company are often considerably different. To determine a reasonable cutoff point for this research, a Pareto analysis was performed on all of the companies listed in the Manufacturers Association of India database pertaining to Jharkhand, India. The Pareto analysis revealed that 90% of the manufacturers listed in the database had fewer than 100 employees. In accordance with the 90/10 rules, a determination was made to only include manufacturers having less than 100 employees and conducted the survey conducted with the help of Email reply, Letter Correspondence, Personal contacts and Fill out the survey form. The notations indicated as 1,2,3,4,5,6,7 and 8 represent very excellent to poor choice of company's response received and evaluated accordingly to given feedbacks. The analysis has been presented in the form of bar charts from Figure 1 through Figure 9 and findings have been supplemented through case studies of the companies.

3.2 Survey feedback

The survey feedback forms were sent to different small industries and responses have been received at different frequencies, but within prescribed time limit. Out of 241 survey contacts to the company representatives through emails, fax, or post, only 84 completed feedbacks were received back, yielding to a response rate of 35%. The average number of employee per company is 102. The quality of the received data was further validated through a response bias analysis, which compared the data collected from early respondents to data collected from late respondents, and found no evidence of significant response bias.

3.3 Performance and Multi-skilled workers

The collected data tends to indicate that the performance of small manufacturers has generally improved through application of Lean Manufacturing Tools and Technique during the last three years. The use of multi-skilled workers appears to be widely practiced among small manufacturers. This is not surprising, since workers in a small company are often naturally Multi-skilled because the ratio of the number of process steps to number of employees tends to be much higher at a small manufacturer than at a large manufacturer. The multi skilled workers with categories of '1'Highly excellent, '2' excellent,'3' Very good, '4' good, '5' Average, '6'Below average, '7'Satisfactory, and '8' unsatisfactory is 2.4%, 8.3%, 4.8%, 14.3%, 42.9%, 17.9%, 7.1% and 2.4% respectively. The results obtained are presented in Figure 1 and Figure 2.

3.4 Relations with suppliers and Lot size

Small manufacturers also tended to indicate that they develop long-term, cooperative relationships with suppliers. This may be a natural result of the environment of small manufacturers. The findings are given in Figure 3.

The data collected indicates that small manufacturers tend to have small batch sizes. Again, this result is not surprising since the volume in which small manufacturers produce a job tend to be small as per requirement. Many of the companies who participated in the survey use a make to order approach to production. Because of their make to order production methodology, it makes sense that these companies would naturally have small batch sizes. The results are presented in Figure 4.

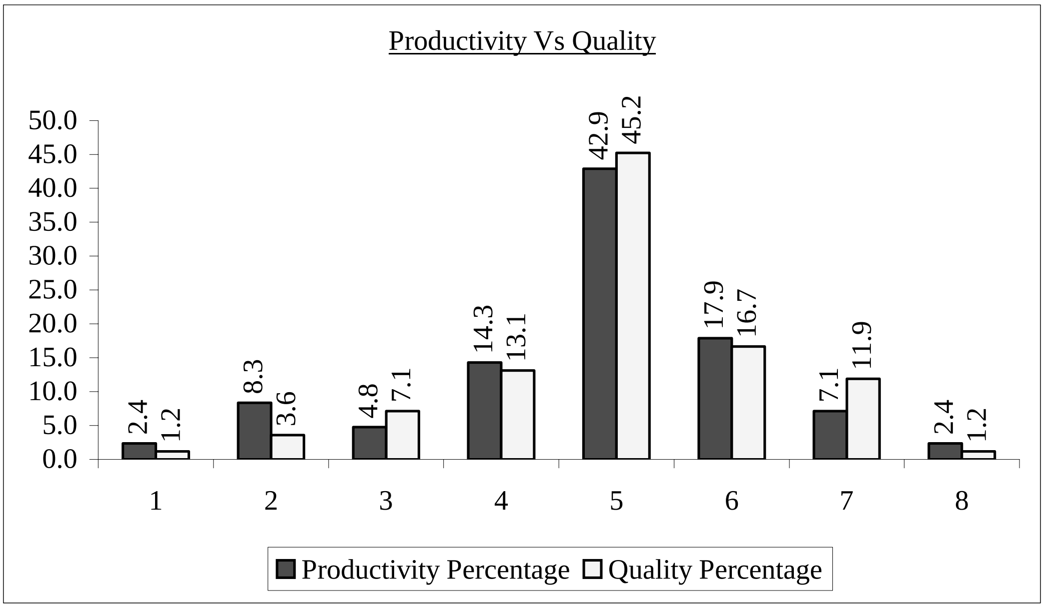

Figure 1: Impact on productivity vs. quality.

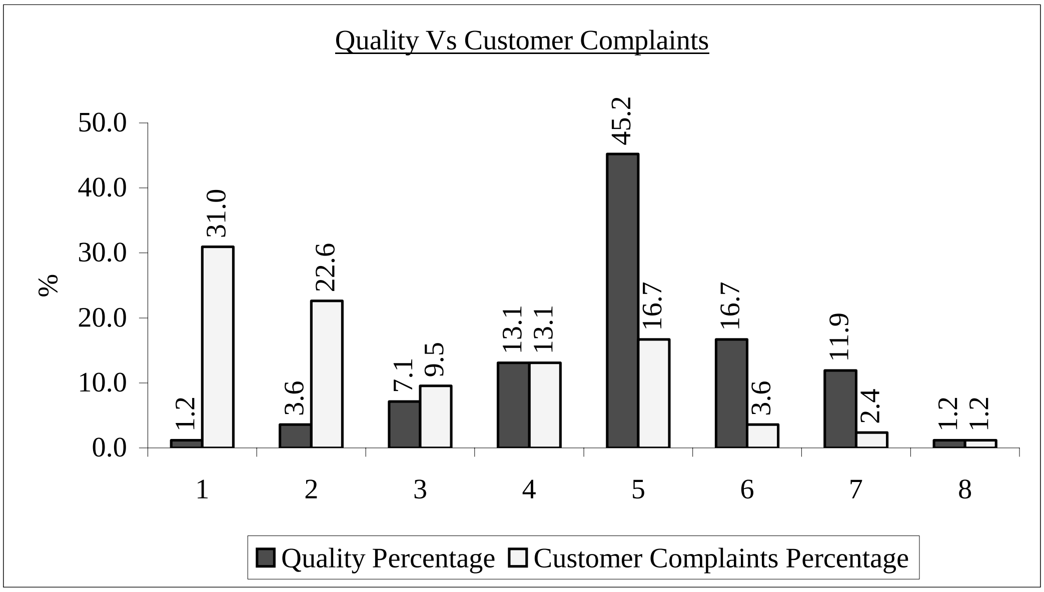

Figure 2: Impact on quality vs. customer complaints.

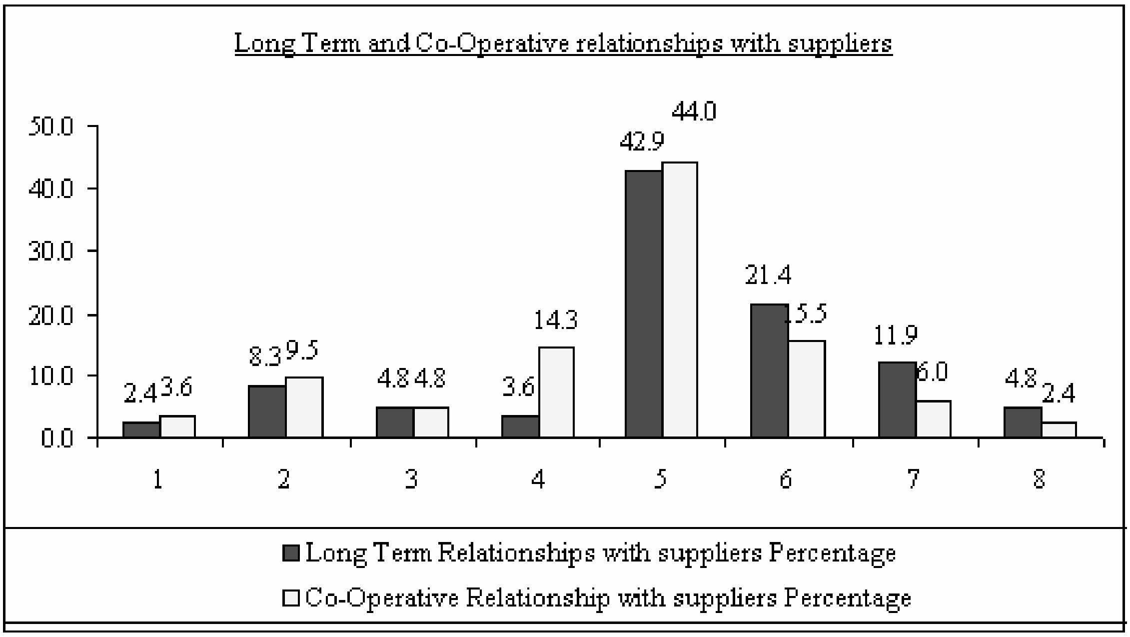

Figure 3: Impact on long term & co-operative relationship with suppliers.

3.5 Lot size reduction vs. setup reduction

The lack of a relationship between lot size reduction and setup reduction was surprising. Regrettably, large lot sizes have the effect of decreasing flexibility and increasing required inventory buffers. By reducing setup times fixed costs are reduced and smaller lot size production is possible, with the advantages of increased flexibility and decreased required inventory levels. Unfortunately, from the responses to the questions regarding setup time reduction and lot size reduction, it appears that the linkage between setup times and lot size is not well understood. The results obtained are given in Figure 5.

3.6 Inventory reduction vs. problem solving

The response to question about inventory reduction suggests that many companies actively pursue the practice. Implementation of best practices such as inventory reduction without understanding the philosophy of Lean Manufacturing leads to disappointing results. From the collected survey data, it appears that many companies strive to reduce inventory, but fail to eliminate the problems. The results are depicted in Figure 6.

3.7 Lot size reduction vs. flexibility

Although vast majority of the survey participants responded that they strive to increase flexibility of their operations, very few of them appear to pursue lot size reduction. This suggests disconnection between the desired result (increased flexibility) and the means to achieve it (lot size reduction). The basic principle of one of the Lean Tool (JIT) is that reduction in lot size reduces lead-time and increases flexibility. Lot size reduction not only increases flexibility but it allows smooth material flow. It also encourages the selection and development of flexible processes, capable for small lot size production. The results are presented in Figure 7.

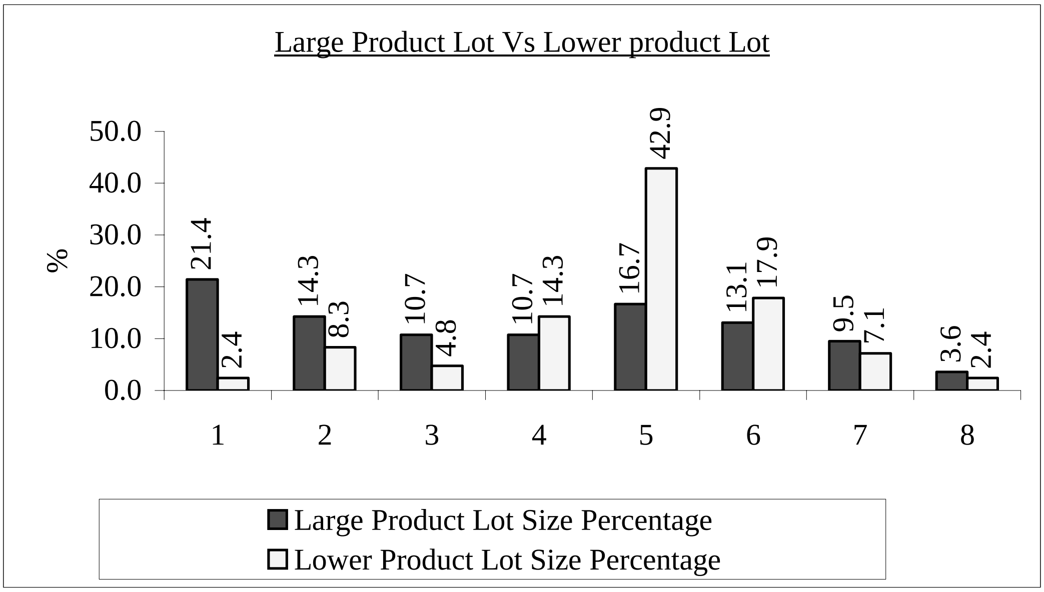

Figure 4: Concept of large lot size and lower lot size.

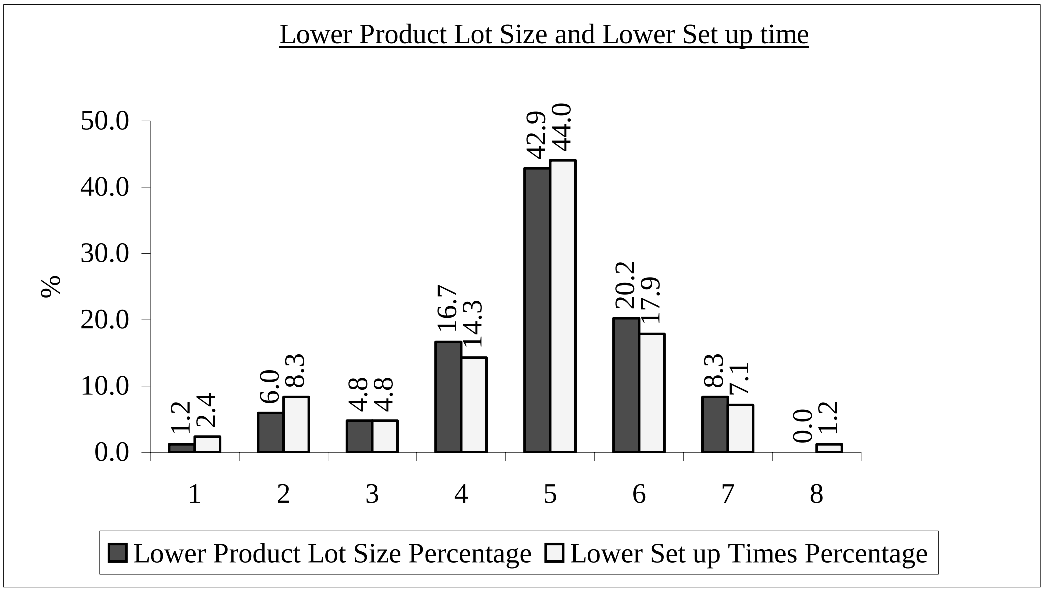

Figure 5: Lower products lot size vs. lower set up percentage time.

3.8 Barrier analysis applying Pareto chart

Finally, the survey allows for an insightful Pareto chart analysis to study different barriers, which might have been encountered while implementing Lean Manufacturing practices in small industries. To perform the Pareto chart analysis, comments from the various respondents were grouped into logical categories, which were then plotted to form the Pareto chart. From the chart many conclusions can be drawn with respect to the challenges facing small manufacturers during the implementation process. The barriers are shown with their respective scores in Figure 8.

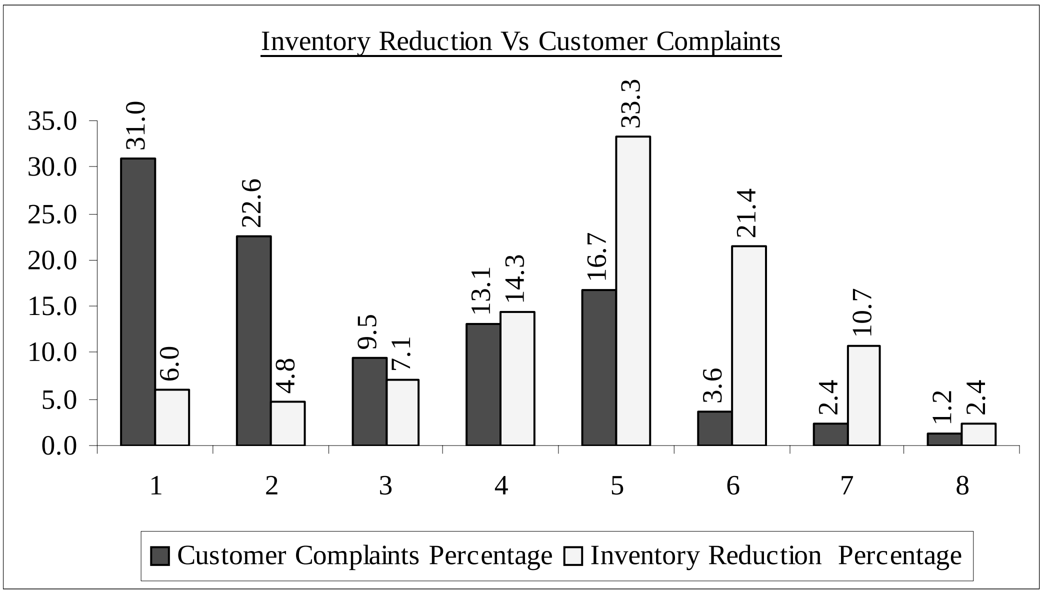

Figure 6: Inventory reduction vs. customer complaints.

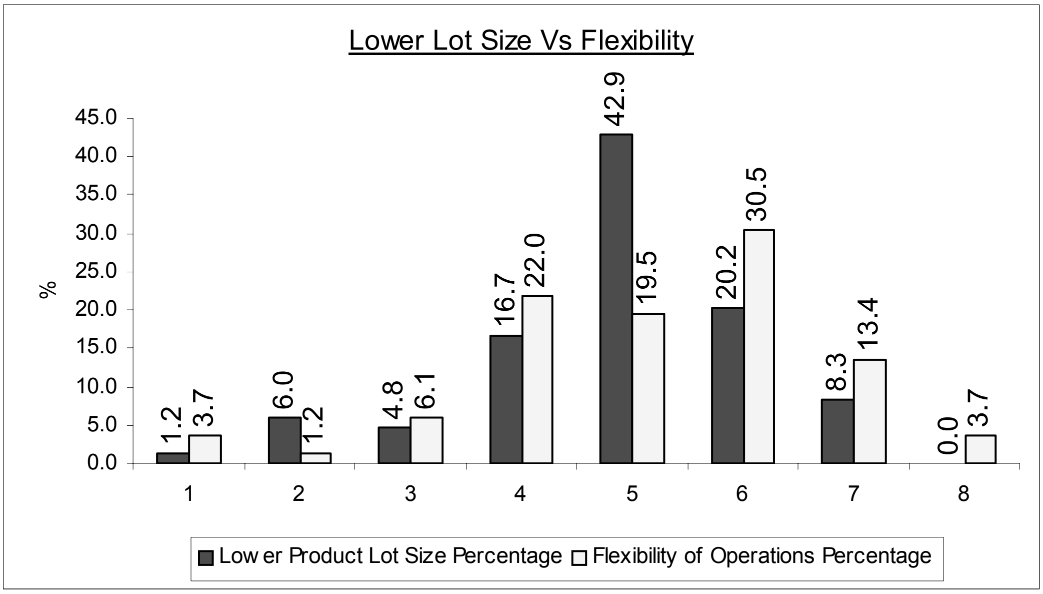

Figure 7: Lower lot size vs. flexibility of operation.

4. SURVEY RESPONSES

The responses were analyzed and grouped into Cultural mindset, Human resources, financial constraints, Time constraints and Nature of Industry. The details of findings are given below.

4.1 Cultural mindset and Human resources

Cultural inertia was the most common barriers as revealed by the survey responses. The commented responses are as follow.

1. It is an exercise to breaking down old habits and Most tools and techniques are old-style management philosophies.
2. Employee's resistance to small batch sizes and quality at the source.

3. Inflexibility to change.
4. Change is difficult for people ; Strong "old school" mentality and No one likes to change.
5. Same mindset exists causing major difficulty in implementing productive change.
6. Resistance to change at every level and also from line supervisors.
7. Stagnant Inertia.
8. Because of union, it is more difficult to implement some of the methods.
9. Corporate culture in a small family-owned business is difficult to overcome.

Like wise, It is also revealed from the below responses that HR related issues were also common barriers to the implementation of LM practices. The responses related to HR are as follows:

1. Poor work ethics.
2. Difficult to find the appropriate time to conduct training and can’t be given additional assignment to conduct these programs with normal jobs.
3. People’s lack of interest in trying to finish and or understand Systems.
4. Can’t be given additional assignment to conduct these programs with normal jobs.
5. Tightness of personnel management.
6. Lack of manpower, time and capital resources.
7. It is always a personal challenges.
8. Trying to find out qualified employees and Unavailability of experts to train others.
9. Funding for implementation of better practices or Lean tools.

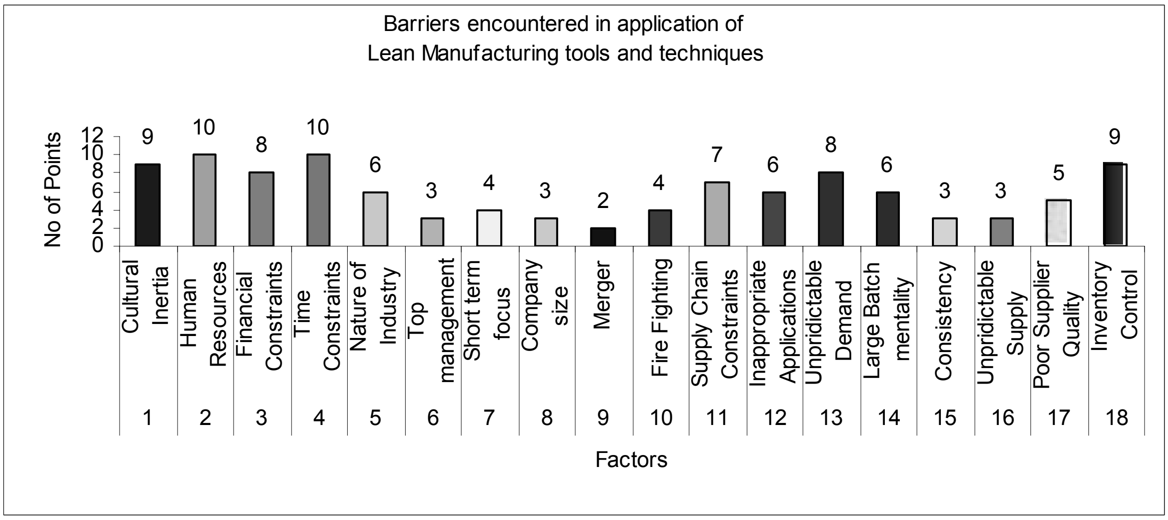

Figure 8: Barriers encountered in application of Lean Manufacturing Tools and Techniques.

4.2 Financial constraints and Time constraints

It can be seen from the frequency of the responses that financial constraints are also a major obstacle for small companies.

1. The main barrier is management commitment to spend the money
2. Lack of capital and a small business can’t afford it
3. Lack of resources to drive the 5-S and Lean Thinking efforts
4. Financial restraints specially ; Lack of Rupee and Resources
5. Company has to be willing to dedicate money and resources to making it happen
6. Insufficient capital and Resource constraints of a small company.

In the same way, many respondents also mentioned barriers relating to time constraints. Their comments may indicate the presence of “fire fighting i.e. fulfilment of day to day activities”. The responses were like:

1. Difficult to find the appropriate time to conduct training and implement programs.

2. Manpower and Time / Resources.
3. Time to explain and implement them.
4. Not enough time to implement. Just busy trying to get the work done!
5. Time and resource constraints of a small company.
6. Lack of time is similar to the problem to that of lack of capital.

4.3 Nature of industry

The related responses and comments by many respondents made indicating Lean Manufacturing were:

1. Contract Manufacturing dictates the size of lots instead of quality or production issues.
2. We are a job shop and our jobs are non repeating.
3. We are in a job shop environment. We depend on large projects.
4. We are a prototype shop. Not Production.
5. This survey is not a good fit for our company. Items listed do not apply to our processes.
6. We are an engineering development company and do not have large production runs.
7. Our plant is job shop. Each item is unique and requires exclusive set up for manufacturing.
8. The form is for a larger company and asks about programs, which are not applicable to us.

5. HYPOTHESES TESTS AND CORRELATION ANALYSIS

The statistical tests and data analyses were done using the statistical tools like Correlation analysis, ANOVA, Sample t-tests and f-tests, etc. and the relationships between the performance of the Lean Manufacturing and characteristics of organizations were established.

5.1 Mathematical modeling for analysis of variance (ANOVA) test

To apply analysis of variance test the survey data were grouped into two groups X and Y according to their number of employees irrespective of its turnover per annum in solving industrial engineering problem. Companies having less than 90 employees were put in-group X and above 90 in Group Y. Then Pareto analysis was done and it is shown in Figure 9.

Based on the Pareto analysis the survey feedbacks were classified into three classes coded as Sx_1, Sx_2 and Sx_3 for group X and Sy_1, Sy_2 and Sy_3 for group Y. If the score of company was between 20-35 it was put under Sx_1 and Sy_1. Similarly, scores having 36-50 were put Sx_2 and Sy_2, scores having 51–70 were put under Sx_3 and Sy_3. The following data has been obtained from the Pareto Analysis.

Sx_1, Sx_2 and Sx_3 = 20, 22 and 12, Similarly, Sy_1, Sy_2 and Sy_3 = 12, 10 and 8

$\bar{x}$ = Mean value of Sx_1, Sx_2 and Sx_3 = $\frac{20+22+12}{3} = 18$,

$\bar{y}$ = Mean value of Sy_1, Sy_2 and Sy_3 = $\frac{12+10+8}{3} = 10$

Mean of above means $\bar{x}$ and $\bar{y}$ = $(x\,y)_{mean}$ = $\frac{20+22+12+12+10+8}{6} = 14$

Now, Δsm = Deviation of properties of each sample from its mean,

$\Delta^2 sm$ = Square of deviation of each sample from its mean

δ = Deviation of mean property of each sample from the mean property of both the samples [$\bar{x}$ -$(x\,y)_{mean}$, $\bar{y}$ - $(x\,y)_{mean}$]

δ^2 = Square of deviation of each sample from the mean property of both the samples

n_b = The degree of freedom between the number of groups
n_w = The degree of freedom within the groups

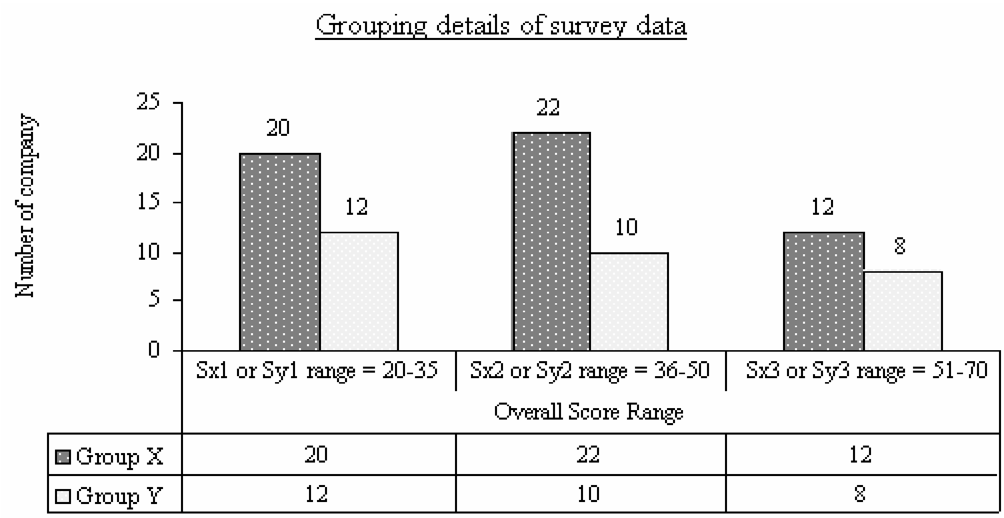

Figure 9: Pareto analyses for grouping of survey data.

The calculated data required for ANOVA analysis have been tabulated in Table I. Now, Product of Sum of squares of deviation of both groups of samples and no. of sample in each group = 32 x 3 = 96. The degree of freedom for

n_b = (r-1) = (2-1) = 1 and, n_w = r (n-1) = 2(3-1) = 4,

Where *r* is the number of groups and *n* is the number of samples in each group. Referring to the statistical table for 5% level of significance of the F distribution,

$$\text{For } n_b = 1 \text{ and } n_w = 4, \quad \text{the corresponding value of F} = 7.71 \tag{1}$$

From the Table II, the value of test statistic (TS) is thus,

$$TS = \frac{Variance \ \ between \ \ groups}{Variance \ \ within \ \ groups} = \frac{V_b}{V_w} = F = \frac{96}{16} = 6 \tag{2}$$

We see that the value of test static 6 [equation 1] does not exceed 7.71 [equation 2], we cannot, at the 5% level of significance, reject the null hypothesis that the questionnaire received equal treatment.

5.2 Mathematical modelling for correlation test of company locations and lean manufacturing

The survey data were classified into two groups for conducting correlation coefficient according to location. The groups were coded as Group A and Group B. Eight different locations have been assigned to each group and the correlation co-efficient was calculated to test and find effective relation of lean manufacturing tools and techniques with location of the companies.

Let, Group A = X and, Group B = Y, The location wise average scores were tabulated in the Table III. The calculated values of X, Y, X^2, $Y^2$and X^2 *Y^2 are tabulated in Table IV.
Now, correlation analysis by Karl Pearson's method has been done.

$$r(X,Y) = \frac{Cov\ (X,Y)}{\sigma_x \sigma_y} \tag{3}$$

Where, $r(X,Y) = Correlation \ between \ two \ random \ variables \ X \ and \ Y$

$\sigma_x = Correlation\ coefficient\ of\ X$ and $\sigma_y = Correlation\ coefficient\ of\ Y$

Now, by putting the calculated values from the table we have,

$$r(X,Y) = \frac{\frac{1}{n}\sum(XY - \overline{XY})}{\sqrt{(\frac{1}{n}\sum(X^2 - \overline{X}^2)\ (\frac{1}{n}\sum(Y^2 - \overline{Y}^2)}} = \frac{\frac{1}{8}x37560 - 68x69}{\sqrt{\{\frac{37028}{8} - (68)^2\}\{\frac{38132}{8} - (69)^2\}}} = 0.603$$

According to the property of Karl Pearson’s correlation the common factor tested here is Lean Manufacturing, and if the relation does not exist then the correlation coefficient must be zero. From the equation 3, it is evident that the calculated values of correlation coefficient as 0.603 proves that location influence exist with both the groups X and Y. It means that application of lean tools and techniques have location influence. This finding reveals the normal tendency of the companies.

Table I: Tabulation of survey data for the ANOVA analysis.

Group	Sample	Scores	$\overline{x}$ or $\overline{y}$	Δsm	$\Delta^2 sm$	δ	δ^2
X	Sx_1	20	18	+2	4	4	16
	Sx_2	22		+4	16		
	Sx_3	12		-6	36		
Y	Sy_1	12	10	4	16	-4	16
	Sy_2	10		0	0		
	Sy_3	8		4	16		
					∑ 64		∑32

Next, the table of ANOVA analysis is the formulated and presented in Table II.

Table II: Formulation of ANOVA analysis table.

Case	Sum of Squares of Deviation (a)	Degree of Freedom (b)	Mean square of Variance (a/ b)
Within groups	64	4	16
Between groups	96	1	96

6. CASE STUDIES OF TWO COMPANIES

In order to strengthen the results and to overcome this weakness by allowing a more detailed understanding of the individual practices and philosophies, case studies have been conducted, selecting two companies naming them as M Company and N Company to maintain confidentiality about the companies, because some of the information contained within the case studies is of sensitive nature.

6.1 Description of “M Company”

“M Company” manufactures Trailer’s component. The Trailer’s components produced by “M Company” have become very popular among certain market segments, resulting to very rapid growth of the company. The high demand had forced the company to concentrate on meeting the demands irrespective of considering the wastes generated in the process or thinking for other lean manufacturing tools.

Lean Manufacturing has yet to be formally pursued at “M Company”. The Trailer’s components produced are large and bulky, which makes it difficult to store large amounts of work in process inventory. As a result, work in process inventories are low and Trailer’s component move through the production system in single piece flow. Obviously, though inventory reduction and single piece flow is two key components of Lean manufacturing.

Due to lack of information, knowledge and planning, the company failed to be fully benefited from the practices. Further, the Company failed to be fully benefited from inventory reduction and single piece flow, because of other supporting Lean Manufacturing practices such as Total Productive Maintenance, 5-S, Cellular Manufacturing, Mistake Proofing, etc. have not been implemented.

6.2 Description of “N Company”

Earlier the “N Company” was producing large composite cylinders. The company has switched over to new improved products within a development time of 45 days. The Company has used a differentiation strategy, using its process capabilities, to compete with others.

Many Lean Manufacturing practices occur naturally at “N Company” as a result of their make to order production system, pull production and smooth process flow. Management was not knowing the different terms used in lean manufacturing, but they believe in many of the underlying philosophies of Lean Manufacturing, Bur they have not formally implemented a Lean Manufacturing program. We find that training in Lean Manufacturing would be very much beneficial to a company, since they already believe in many of the underlying philosophies of Lean Manufacturing.

The underlying philosophies of quality were present in the company, but the individual quality techniques were not often in use. Quality practices could be improved greatly, if a formal implementing program is adopted.

Table IV: Calculated values of X, Y, X^2, $Y^2$and X^2 *Y^2.

X	Y	X^2	Y^2	X^2 *Y^2
1	2	3	4	5
65	67	4225	4489	4355
66	68	4356	4624	4488
67	65	4489	4225	4355
67	68	4489	4624	4556
68	72	4624	5184	4896
69	72	4761	5184	4968
70	69	4900	4761	4830
72	71	5184	5041	5112
∑544	∑ 552	∑ 37028	∑ 38132	∑37560
$\overline{X}$ = 68	$\overline{Y}$ = 69			

7. CONCLUSIONS

From this analytical study, it is clear that LM practices have positive impact on the product quality and productivity. The following conclusions can be drawn:

1. Lean Manufacturing practices have a positive impact on the operations and performance of small manufacturers.
2. The management should come forward through clear understanding; and correct underlying philosophies and principles to support Lean Manufacturing practices.

3. Product Quality and Productivity can be improved through application of lean manufacturing tools and techniques in engineering industries. It requires sincere continual effort.

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