Lean Implementation in Indian Foundry Industries: A Quantitative Survey

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***Abstract*—The implementation of Lean and the deciding parameters are elaborately studied by surveying the Indian Foundry industry workers. The study conducted in the domain of various demographical factors of age, firm size, education background, gender and years of experience shows cluttering of the data indicating the reasons, benefits and barriers of Lean implementation in Indian sub-continent. 28 Foundry Industries in the state of Karnataka are surveyed with a total of 204 workers providing the input for the intricate questionnaire designed for them. The results indicate that the factors like overall equipment effectiveness, plan-do-check-act, total productive maintenance, bottleneck analysis, continuous flow manufacturing, poka yoke, and standardized work are the most effective categories of Lean. The same is also evident from the standard deviation values obtained from chi-square distribution.**

Keywords*—*Lean, Lean Implementation, LMS, JIT

I. INTRODUCTION

Lean is a systematic process approach to identify and eliminate waste (non-value-added activities) through continuous improvement by owing the product at the pull of the customer in the pursuit of perfection. The central core idea of Lean is to maximize customer value while minimizing waste. In simpler context, Lean means creating more value for customers with fewer resources and thus offering a economical and competent solution. A Lean adopted industry understands customer value and focuses its resources to satisfy the same. Lean in the era of batch production provides a detailed index itinerary for the corresponding actions that needed to be undertaken. It is recommended that the executives & managers following Lean transformations emphasizes on the three aspects i.e., Purpose, Process, and People issues [1],[2] that shall pave the path to transformation of the entire organization .

The term `Lean' was initially proposed based on the Toyota Production System (TPS) [3],[4]. Further details [1],[2] report Lean as a multi-faceted concept that was coined to describe the effectiveness of the `Japanese Way of Working' that led to their radical competitiveness. Lean organizations understand core customer value and focus its key processes to continuously increase it.

Components of the `Lean idea' included operations like Zero inventory [5], Just in time (JIT) [6], and small lot sizes. The underpinning of robust quality procedures, exemplified by Total Quality Management (TQM), Total productive maintenance (TPM) and encouragement of empowered employee participation revamps the old over-bureaucracy and top-down oriented approach of the organizational structures that dominated many business since dozen of decades [7]. Lean is an opposing concept to mass production approach. In mass production, the competitive advantage is derived and explored through cost benefits via economies of scale (e.g. large batch runs) which however produce significant inefficiencies between production functions as there is reduced scope of any customization or changes. Lean challenges the mass production and focuses on the reduction of waste (any activity that occurs in the manufacturing cycle that doesn't add any value to customers).

A. Lean Manufacturing Systems (LMS)

LMS was an alternative approach to the production systems with the elimination of waste with continuous improvement [8]. In simpler words LMS as an sustainable approach, utilizes the least to produce the most [9]. On an overview, it is a holistic strategy that delivers quality products and services which satisfy the customers' expectations (the required quantity at the right time and at the right price) [2]. LMS however, is totally dependent on quick availability of the supply chain and its corresponding participation [10]. Furthermore, it is a continuously evolving process stressing on employee skill enhancement, knowledge & empowerment, productivity, customer satisfaction, and long-term vision [9].

In earlier literature [11] for Lean tools implementation, four primary-constructs were chosen which are workplace organization practices, management practices, inventory control practices, and industrial manufacturing and quality improvement practices. This helps in endorsing the sustainable development and improving productivity and business performance measures, within the foundry. Here, 25 tools were considered for the preparing questionnaire. Other tools are identified in the literature [12] like 7R - Reduce, Recycle, Re-use, Remove, Renewable, Revenue (can waste be sold), and Read (encourage the employees). As per the existing literature, LMS can be subdivided into many tools. However, based on the frequency of occurrence of these tools [13],[14] and the industrial & auditing experience of the author, LMS in this study is broadly categorized into 25 major Lean tools, which are analysed later in details in this study, as listed below:

1. 5S: Organize the work area
2. Andon visual feedback system
3. Bottleneck analysis

4. Continuous flow management
5. Gemba
6. Heijunka
7. Hoshin Kanri
8. Jidoka
9. Just-In-Time (JIT)
10. Kaizen
11. Kanban
12. KPI
13. Muda
14. Overall Equipment Effectiveness (OEE)
15. PDCA (Plan, Do, Check, Act)
16. Poka-Yoke (Error Proofing)
17. Root Cause Analysis
18. Single-Minute Exchange of Dies (SMED)
19. Six Big Losses
20. SMART Goals
21. Standardized Work
22. Takt Time
23. Total Productive Maintenance (TPM)
24. Value Stream Mapping (VSM)
25. Visual Factory

II. RESULTS & DISCUSSION

A. Estimation of Sample size for the study

According to the survey report in Karnataka state, the district wise major quality foundry units (A grade) distribution are as follows: Belagavi 14, Bengaluru 12,Davanagere 2, Bellary 4, Kolar 6, Dharwad 10, and shivamogga 12 [15]. This study focuses on foundry sector located in Karnataka. The size of the sample-space based on the parameters like confidence level, standard deviation, Z value based on the confidence level and margin of error (ε), is shown in Equation-1 [16]

$$m = \frac{Z^2 p(1-p)}{\varepsilon^2} \quad (1)$$

where m is the estimated sample size, p is preliminary estimation of success percentage (95% for the present case), ε is assumed a reasonable 5%, Z=1.64 for confidence level of 90%.

For the present study, the sample size for the number of foundry SMEs are calculated using the approach (Equation-2)

$$n = \frac{m}{1+\frac{m-1}{n}} \quad (2)$$

where p=0.95 (95% accuracy), n=modified sample size based on actual population and N=population size=60, m is obtained from Equation-1[16]. The n value is found to be 27.93 rounded off to 28. Thus, the foundry type SMEs surveyed is 28 consisting of 204 workers.

B. Design of questionnaire

The study used survey questionnaire method to gather data from different foundry industries located in and around Bengaluru, Belgaum, Dharwad, and Shivamogga. The questionnaire was designed in three parts; Part A- related to basic demography; Part B- related to reasons, benefits and barriers to Lean implementation; Part C-related to individual Lean components and its implementation.

The Lean study categorized into five constructs namely Demographic approach, reasons to choose Lean adaptation, Lean benefits, barriers to Lean implementation, and Lean tools impact & effectiveness (LI). In Demographic study, the following parameters are selected: Location, Age, Designation (role of the job), the Number of employees, Academic qualification, years of experience, salary, gender, plant capacity, ISO certified or not, export and non-export nature of industry details.

In the evaluation of benefits of Lean, [17] suggests that by considering the push vs. pull approach, management synergies and firm performance, the supply chain perception, and competitive advantage and growth. A management integrated model was developed and concludes highly positive outcomes. In other studies, [18] it is stated that this helps to identify critical success factors(CSFs) for quality and productivity improvement using Lean Six Sigma (LSS).

Research [19] emphasizes that the barriers of LMS are experience, right resources, employee quality, financial issues, conflicts, knowledge and lastly management are in the increasing order (around 2.94 to 3.93 scale range). It is claimed [20] that the barriers are of three types, i.e., people issue, process issue, and sustainability issue.

In the present work questionnaire used is taken from the available literature of similar surveys [21], and the questions are discussed as their results come into explanation. template is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

C. Demography

The survey is performed by dividing the workers into the following demographic regimes and the distribution is shown in Table-I with number of workers in each category.

Categories	Demographic factors	Numbers
Gender	Male	192
	Female	12
Cost of the project	26-50 lakhs	33
	51 lakhs-1crore	171
Number of Employees	02-10	19
	11-25	60
	26-50	35
	51-100	88
	>100	2

Years of experience	<10years	97
	11-20years	49
	21-30years	54
	31-40years	4
Job profile	Technical	161
	Non-technical	43
Education Levels	ITI	12
	Diploma	92
	Graduation	50
	Post-graduation	45
	Others (non-technical)	5
Monthly salary grade (in INR)	<10K	142
	11-20K	52
	>20K	10
ISO certification	ISO certified	172
	Non-ISO	32
Nature of industries	Export	117
	Non-export	87

Table I. Demographic distribution and factors for the surveyed 204 workers

D. Reasons for Lean implementation

The Lean implementation is studied by measuring the reasons, benefits and the barriers of Lean implementation. This involves a simple YES or NO answer to the questionnaire prepared for all the three categories. The questionnaire for reasons of Lean implementation is as follows:

1. Stream lines the company's process
2. Lean can build team commitment
3. Quality- TQM, TQC
4. Stabilizing the work environment
5. To reduce the overall processing time of the production line
6. Reduction of waste
7. Value creation, understanding customer value
8. Globally competitive products
9. To reduce non value activities present in any form
10. To increase the overall Efficiency

The literature signifies the Lean implementation and its benefits and the suitable reasons for moving in that direction. However, a first person account of the workers can add more insight to the same. The survey as discussed above envelops their response to the individual questions which is plotted and depicted in Fig-1. It can be well observed that the individual contributions from the questionnaire may vary (mostly over 50%), the average is well suited to add credibility to the questionnaire put forward. It is observed that with the latter half of the questionnaire from 8-10, the percentage contribution of the reasons falls down. These questions involved the Lean reasons on `Globally competitive products', 'To reduce non value activities present in any form', 'To increase the overall Efficiency' which are more of a management related decisions which the surveyed workers are not confident enough in answering.

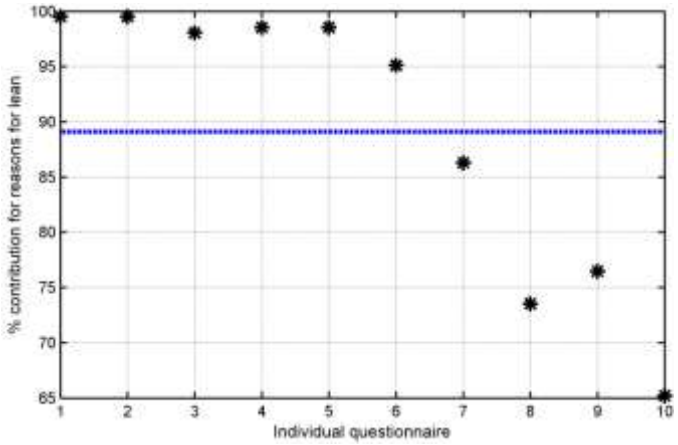

Fig1. Reasons of Lean survey with average and individual contributions from questionnaire. The dotted blue line indicates the average

E. Benefits of Lean implementation

Separate questionnaire is also formulated for noticing the benefits of Lean implementation, which is listed as follows:

1. Quality performance, fewer defects and rework (in house and at customer)
2. Fewer machine and process breakdowns
3. Lower levels of Inventory
4. Greater levels of Stock turnover
5. Less space required
6. Higher efficiencies, more output per man hour
7. Improved delivery performance
8. Faster development
9. Greater Customer Satisfaction
10. Improved employee morale and involvement
11. Improved supplier relations
12. Higher profits
13. Increased business

The workers in survey are queried carefully to note the benefits of Lean implementation and the questionnaire response is plotted in Fig-2. It can be seen that the average consensus about the benefits lie and however over 70%, though individual questionnaire responses may vary. Again, it is observed that on question number 8 and 12 the contribution or consent of workers for the barriers is less. These questions involve 'Faster Development' and 'Higher Profits' which are to be better assessed by the top management than the workers overall. Thus, except these two questions every other question response is validated around over 60%, the average consent to these reasons lies almost at 75% which is a reasonable amount judging by the 204 number of workers surveyed.

F. Barriers of Lean implementation

The barriers for Lean implementation that is restricting the industries into going full fledged application in that domain are checked by the questionnaire below:

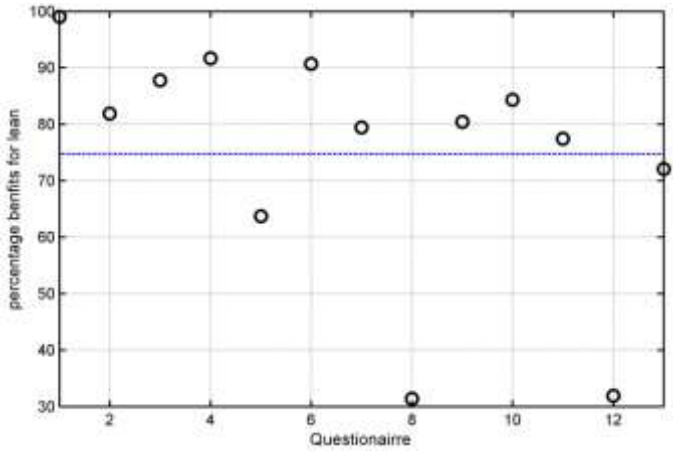

Fig2. Benefits of Lean survey results with average & individual contributions from questionnaire. The dotted blue line indicates the average

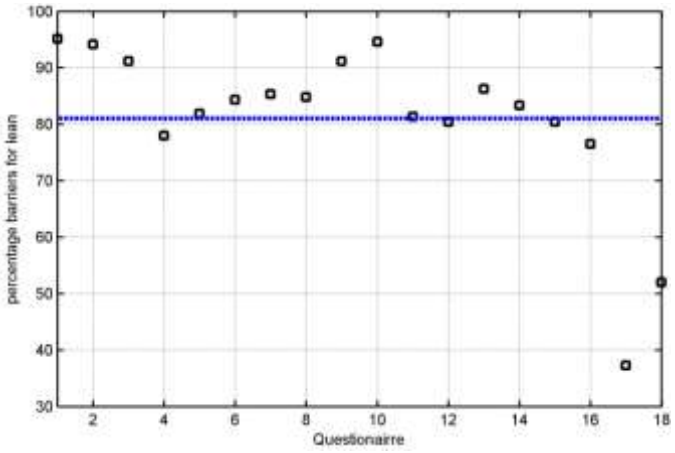

Fig3. Barriers of Lean implementation survey results with average and individual contributions from questionnaire. The dotted blue line indicates the average

1. Nature of the Industry
2. Extensive use of sub contractors
3. Delay in decision making
4. Materials scarcity
5. Delay in materials delivery
6. Inadequate pre planning
7. Poor project definition
8. Lack of culture from users
9. Lack of Management support
10. Lack of relevant (required) training
11. Lack of understanding (need of Lean)
12. Lack of adequate Equipments
13. Worker's attitude
14. Social interactions between workers
15. Lack of internal commitment from the top managers
16. Lack of technological up-gradation
17. Pressure from the Head quarters
18. Insecurity feeling of workers of loosing job

In all the literature the Lean is shown to be effective and beneficial to the industry, yet the implementation of the same has not been too widespread. This indicates there are some barriers and limitations to the application and implementation involved. The workers under survey are asked about the same in the detailed questionnaire as mentioned above, the barriers to the Lean implementations were made clear. The credibility and the consensus to the questionnaire is well depicted by the over 80% average values (see Fig-3). Here, the observation is other than the question 17, 18 every other barriers is well predicted with certainty around 80%. These questions are `Pressure from the Head quarters' and `Insecurity feeling of workers of loosing job' where there is no coherency of consent as there is deviation in answering these questions as the response may vary from person to person. The insecurity feeling and pressure can vary from one to another foundry unit and thus no certain consensus can be achieved through these two questions.

The predicted barriers fare well with experimental and field out from the surveys except a couple of exceptions where the asked questions were either beyond the scope of expertise of the workers or were industry dependent.

G. Lean implementation levels

Depending upon the kind of foundry industry and its scale, the workers consent about the Lean implementation does vary. The number of workers of the industry affects on their readiness for the Lean implementation and much specific to the tools in questions. Thus, the kind of demographic distribution shall play a significant role in the results obtained. In the Indian Foundry domain, in the Karnataka state the impact of Lean implementation with the contribution of individual Lean components based on firm size (capital wise), export & non-export and ISO certification is studied. This study demarcates the most significant Lean tools with their ease and readiness to be implemented in the Industry first. This is obtained by performing χ^2 analysis of various Lean components in the survey with the null hypothesis mentioned below and the survey results with the statistical χ^2 distribution and standard deviation or 'p' values are tabulated for the cost of project with various Lean tools in Table-II. It is to be noted that the relationship between the considered parameters is significant when the value of $p<0.5$. Thus, for the columns with 'p' values more than 0.5, the parameters are 'Not Significant' (NS). The degree of freedom (DF) is number of rows of the category minus one. The χ^2 tabulated values depend on the DF and thus, are same for the number of categories of the variables.

1. Hypothesis $H_0 1_a$: There is no relationship between the cost of the project and 5S (organize the work area) of the Lean implementation
2. Hypothesis $H_0 1_b$: There is no relationship between the cost of the project and Andon visual feedback system of the Lean implementation
3. Hypothesis $H_0 1_c$: There is no relationship between the cost of the project and bottleneck analysis of the Lean implementation
4. Hypothesis $H_0 1_d$: There is no relationship between the cost of the project and continuous flow of the Lean implementation

5. Hypothesis H_01_e: There is no relationship between the cost of the project and Gemba of the Lean implementation
6. Hypothesis H_01_f: There is no relationship between the cost of the project and Heijunka of the Lean implementation
7. Hypothesis H_01_g: There is no relationship between the cost of the project and Hoshin Kanri (policy deployment) of the Lean implementation
8. Hypothesis H_01_h: There is no relationship between the cost of the project and Jidoka (autonomation) of the Lean implementation
9. Hypothesis H_01_i: There is no relationship between the cost of the project and JIT of the Lean implementation
10. Hypothesis H_01_j: There is no relationship between the cost of the project and Kaizen of the Lean implementation
11. Hypothesis H_01_k: There is no relationship between the cost of the project and Kanban of the Lean implementation
12. Hypothesis H_01_l: There is no relationship between the cost of the project and KPI of the Lean implementation
13. Hypothesis H_01_m: There is no relationship between the cost of the project and Muda of the Lean implementation
14. Hypothesis H_01_n: There is no relationship between the cost of the project and OEE of the Lean implementation
15. Hypothesis H_01_o: There is no relationship between the cost of the project and PDCA of the Lean implementation
16. Hypothesis H_01_p: There is no relationship between the cost of the project and Poka Yoke of the Lean implementation
17. Hypothesis H_01_q: There is no relationship between the cost of the project and Root cause analysis of the Lean implementation
18. Hypothesis H_01_r: There is no relationship between the cost of the project and SMED of the Lean implementation
19. Hypothesis H_01_s: There is no relationship between the cost of the project and six big losses of the Lean implementation
20. Hypothesis H_01_t: There is no relationship between the cost of the project and SMART goals of the Lean implementation
21. Hypothesis H_01_u: There is no relationship between the cost of the project and Standardized work of the Lean implementation
22. Hypothesis H_01_v: There is no relationship between the cost of the project and Takt time of the Lean implementation
23. Hypothesis H_01_w: There is no relationship between the cost of the project and TPM of the Lean implementation
24. Hypothesis H_01_x: There is no relationship between the cost of the project and VSM of the Lean implementation
25. Hypothesis H_01_y: There is no relationship between the cost of the project and Visual factory of the Lean implementation

The total implementation of the Lean with respect to cost of project is shown in ascending order as shown in Fig-4. This shows the corresponding contribution of the Lean components and its ease of implementation from the workers point of view. The representation is made in fractional percentage contribution to various Lean tools thus showing its impact with implementation and non-implementation. It can be observed in Fig-4 that the Six breakdown losses and SMART goals, as Lean tools, have detrimental effect on the industries in 26-50 lakh scale.

Similar observations are also drawn by plotting the 'p' values from the relationship between the cost of the project and various Lean components in Fig-5 obtained from the Table-II. This only shows the total relationship with cost of project and not by subdividing into various cost groups. However, this is important to mention that lesser the 'p' values more the relationship. In other words higher 'p' values mean less relationship between the parameters. Thus, the preference order should be from lesser 'p' values to higher 'p' values. It can be seen that as observed in Fig-4 components like breakdown losses and SMART goals are not even present in the 'p' values of Fig-5 as there is no relation and that's why the demarcation happens in Fig-4.

Lean tool	Cost of the project	Imple-mented	Not imple-mented	DF	χ^2 table	χ^2 calcu-lated	p value	Signi-ficance
5S	26-50 lakhs	33	0	1	3.84	0.194	NA	NS
	51lakhs-1 crore	170	1					
Andon	26-50 lakhs	32	1	1	3.84	2.675	.102	S
	51lakhs-1 crore	149	22					
Bottle neck Analysis	26-50 lakhs	33	0	1	3.84	7.054	NA	NS
	51lakhs-1 crore	171	0					
Continu-ous Flow	26-50 lakhs	33	0	1	3.84	7.054	NA	NS
	51lakhs-1 crore	171	0					
Gemba	26-50 lakhs	33	0	1	3.84	7.054	.008	S
	51lakhs-1 crore	140	31					
Heijunka	26-50 lakhs	33	0	1	3.84	9.902	.002	S
	51lakhs-1 crore	130	41					
Hoshin Kanri	26-50 lakhs	23	10	1	3.84	.006	.937	NS
	51lakhs-1crore	118	53					
Jidoka	26-50 lakhs	11	22	1	3.84	7.397	.007	S
	51lakhs-1crore	101	70					
JIT	26-50 lakhs	12	21	1	3.84	0.542	.462	S

	51lakhs-1crore	74	97					
Kaizen	26-50 lakhs	33	0	1	3.84	0.39	NA	NS
	51lakhs-1crore	169	2					
Kanban	26-50 lakhs	32	1	1	3.84	.019	.89	NS
	51lakhs-1crore	165	6					
KPI	26-50 lakhs	33	0	1	3.84	5.249	.022	S
	51lakhs-1crore	147	24					
Muda	26-50 lakhs	33	0	1	3.84	0.989	NA	NS
	51lakhs-1crore	166	5					
OEE	26-50 lakhs	33	0	1	3.84	0.194	NA	NS
	51lakhs-1crore	170	1					
PDCA	26-50 lakhs	33	0	1	3.84	0.194	NA	NS
	51lakhs-1crore	170	1					
Poka Yoke	26-50 lakhs	33	0	1	3.84	0.194	NA	NS
	51lakhs-1crore	170	1					
Root cause analysis	26-50 lakhs	33	0	1	3.84	0.39	NA	NS
	51lakhs-1crore	169	2					
SMED	26-50 lakhs	33	0	1	3.84	27.56	0	S
	51lakhs-1crore	87	84					
Six big losses	26-50 lakhs	22	11	1	3.84	29.4	0	S
	51lakhs-1crore	164	7					
SMART goals	26-50 lakhs	22	11	1	3.84	60.25	0	S
	51lakhs-1crore	171	0					
Standardized work	26-50 lakhs	33	0	1	3.84	0.194	NA	NS
	51lakhs-1crore	171	0					
Takt time	26-50 lakhs	33	0	1	3.84	0.39	NA	NS
	51lakhs-1crore	169	2					
TPM	26-50 lakhs	33	0	1	3.84	0.194	NA	NS
	51lakhs-1crore	170	1					
VSM	26-50 lakhs	32	1	1	3.84	0.083	.773	NS
	51lakhs-1crore	164	7					
Visual factory	26-50 lakhs	23	10	1	3.84	36.51	0	S
	51lakhs-1crore	32	139					

Table II. Relationship between cost of the project and Lean tools of LI

Here, the important inference is that for 'p' value around 0.5 which is achieved by JIT (0.462), the shift of influence travels towards lesser 'p' values. The same is also noted from Fig-4 where JIT and Jidoka mark the line over which the total implementation of Lean components is effective. This is interesting as similar conclusions are drawn for the Lean parameters through both direct and statistical quantities analysis.

The relationship between the nature of industry (export/non-export) to the Lean implementation is carried out with χ^2 analysis with the following hypothesis and the survey results with the statistical χ^2 distribution and 'p' values are tabulated for the cost of project with various Lean tools in Table-III.

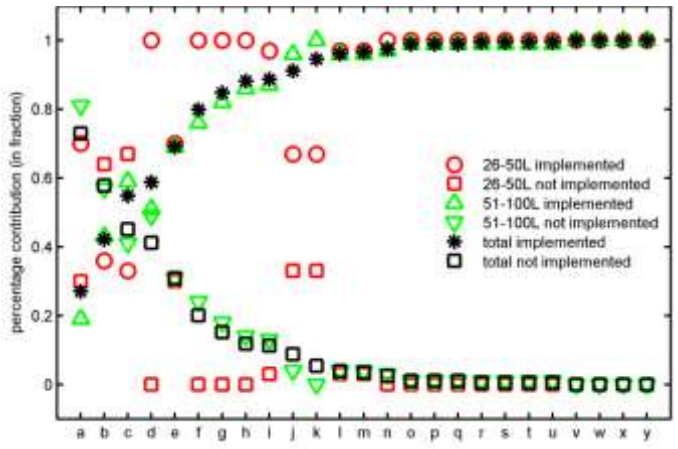

Fig4. Lean implementation percentage contribution with Lean tool index with 26-50 Lakh and 51-101 Lakh cost industries. X axis marks a=visual factory, b=JIT, c=Jidoka, d=SMED, e=Hoshin Kanri, f=Heijunka, g=Gemba, h=KPI, i=Andon, j=Six big losses, k=SMART goals, l=VSM, m=Kanban, n=Muda, o=Kaizen, p=Root cause analysis, q=Takt time, r=5S, s=OEE, t=PDCA, u=TPM, v=Bottleneck analysis, w=Continuous flow manufacturing, x=Poka Yoke, y=Standardized work

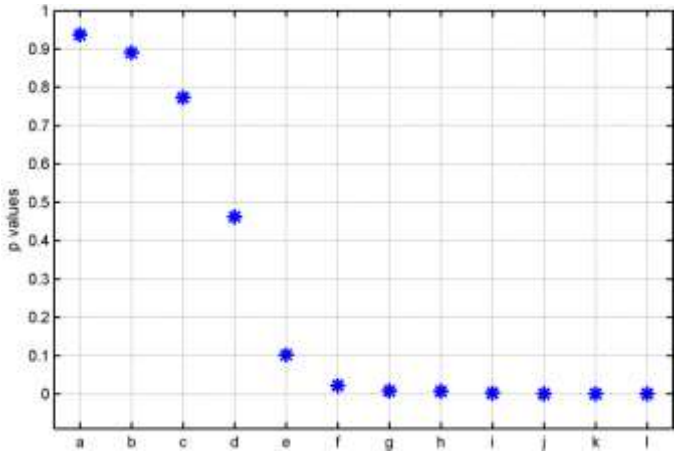

Fig5. Relationship between cost of project and Lean components based on 'p' values where the x index is as follows: a-Hoshin Kanri, b-Kanban,c-VSM, d-JIT, e-Andon, f-KPI, g-Gemba, h-Jidoka, i-Heijunka, j-SMED, k-Six big losses, l-visual factory

1. Hypothesis $H_0 2_a$: There is no relationship between the export and 5S (organize the work area) of the Lean implementation
2. Hypothesis $H_0 2_b$: There is no relationship between the export and Andon visual feedback system of the Lean implementation

3. Hypothesis H_02_c: There is no relationship between the export and bottleneck analysis of the Lean implementation
4. Hypothesis H_02_d: There is no relationship between the export and continuous flow of the Lean implementation
5. Hypothesis H_02_e: There is no relationship between the export and Gemba of the Lean implementation
6. Hypothesis H_02_f: There is no relationship between the export and Heijunka of the Lean implementation
7. Hypothesis H_02_g: There is no relationship between the export and Hoshin Kanri (policy deployment) of the Lean implementation
8. Hypothesis H_02_h: There is no relationship between the export and Jidoka (autonomation) of the Lean implementation
9. Hypothesis H_02_i: There is no relationship between the export and JIT of the Lean implementation
10. Hypothesis H_02_j: There is no relationship between the export and Kaizen of the Lean implementation
11. Hypothesis H_02_k: There is no relationship between the export and Kanban of the Lean implementation
12. Hypothesis H_02_l: There is no relationship between the export and KPI of the Lean implementation
13. Hypothesis H_02_m: There is no relationship between the export and Muda of the Lean implementation
14. Hypothesis H_02_n: There is no relationship between the export and OEE of the Lean implementation
15. Hypothesis H_02_o: There is no relationship between the export and PDCA of the Lean implementation
16. Hypothesis H_02_p: There is no relationship between the export and Poka Yoke of the Lean implementation
17. Hypothesis H_02_q: There is no relationship between the export and Root cause analysis of the Lean implementation
18. Hypothesis H_02_r: There is no relationship between the export and SMED of the Lean implementation
19. Hypothesis H_02_s: There is no relationship between the export and six big losses of the Lean implementation
20. Hypothesis H_02_t: There is no relationship between the export and SMART goals of the Lean implementation
21. Hypothesis H_02_u: There is no relationship between the export and standardized work of the Lean implementation
22. Hypothesis H_02_v: There is no relationship between the export and Takt time of the Lean implementation
23. Hypothesis H_02_w: There is no relationship between the export and TPM of the Lean implementation
24. Hypothesis H_02_x: There is no relationship between the export and VSM of the Lean implementation
25. Hypothesis H_02_y: There is no relationship between the export and visual factory of the Lean implementation

The net result of the type of industry is plotted in Fig-6 in a similar fashion and way of representation as in Fig-4. It is observed that when it comes to export type industry (Fig-6, the Lean tools key performance indicator (KPI) and Andon visual feedback is detrimental. Similar observations can be drawn out of Fig-7 obtained from the Table-III, where it can be seen that other than 5S, bottleneck analysis, continuous flow management and Kaizen every other Lean components shows statistical 'p' values (relationship) with the export nature of industries and thus show a more dominant relationship with Lean components unlike the cost of project as in Fig-5. Even in this case higher 'p' values come from visual factory thus, it does not contribute (value addition) much to the Lean implementation with respect to export nature of industry. Evidently the same is also shown in Fig-6 where Visual factory shows the least amount of contribution to export industries.

Lean tool	Nature of industry	Imple-mented	Not imple-mented	DF	χ^2 table	χ^2 calcu-lated	p value	Signi-ficance
5S	Export	116	1	1	3.84	0.747	NA	NS
	Non export	87	0					
Andon	Export	94	23	1	3.84	19.28	0	S
	Non export	87	0					
Bottle neck analysis	Export	116	1	1	3.84	0.747	NA	NS
	Non export	87	0					
Continu-ous flow	Export	116	1	1	3.84	0.747	NA	NS
	Non export	87	0					
Gemba	Export	106	11	1	3.84	7.148	.008	S
	Non export	67	20					
Heijunka	Export	97	20	1	3.84	1.542	.214	S
	Non export	66	21					
Hoshin Kanri	Export	94	23	1	3.84	16.19	0	S
	Non export	47	40					
Jidoka	Export	76	41	1	3.84	11.20	.001	S
	Non export	36	51					
JIT	Export	60	57	1	3.84	9.368	.002	S
	Non export	26	61					
Kaizen	Export	115	2	1	3.84	1.502	NA	NS
	Non export	87	0					
Kanban	Export	110	7	1	3.84	92.35	0	S
	Non export	26	61					
KPI	Export	93	24	1	3.84	50.51	0	S
	Non export	26	61					
Muda	Export	112	5	1	3.84	98.84	0	S
	Non export	26	61					
OEE	Export	116	1	1	3.84	113.1	0	S
	Non export	26	61					
PDCA	Export	116	1	1	3.84	113.1	0	S
	Non export	26	61					
Poka Yoke	Export	117	0	1	3.84	117	0	S
	Non export	26	61					
Root cause analysis	Export	115	2	1	3.84	109.4	0	S
	Non export	26	61					
SMED	Export	59	58	1	3.84	7.99	.005	S
	Non export	26	61					
Six big	Export	110	7	1	3.8	2.75	.097	S

losses	Non export	76	11		4	2		
SMART goals	Export	117	0	1	3.84	15.64	0	S
	Non export	76	11					
Standardized work	Export	117	0	1	3.84	117	0	S
	Non export	26	61					
Takt time	Export	115	2	1	3.84	109.4	0	S
	Non export	26	61					
TPM	Export	116	1	1	3.84	113.1	0	S
	Non export	26	61					
VSM	Export	109	8	1	3.84	89.26	0	S
	Non export	26	61					
Visual factory	Export	33	84	1	3.84	0.216	.642	NS
	Non export	22	65					

Table III. Relationship between nature of the industries (export/non-export) and Lean tools of LI

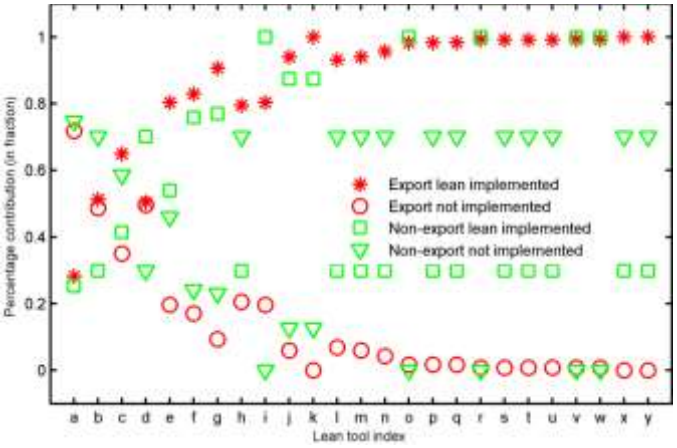

Fig6. Lean implementation percentage contribution with Lean tool index for export and non-export industries. X axis marks a=visual factory, b=JIT, c=Jidoka, d=SMED, e=Hoshin Kanri, f=Heijunka, g=Gemba, h=KPI, i=Andon, j=Six big losses, k=SSMART goals, l=VSM, m=KANBAN, n=Muda, o=Kaizen, p=Rootcause analysis, q=Takt time, r=5S, s=OEE, t=PDCA, u=TPM, v=Bottleneck analysis, w=Continuous flow manufacturing, x=Poka Yoke, y=Standardized work

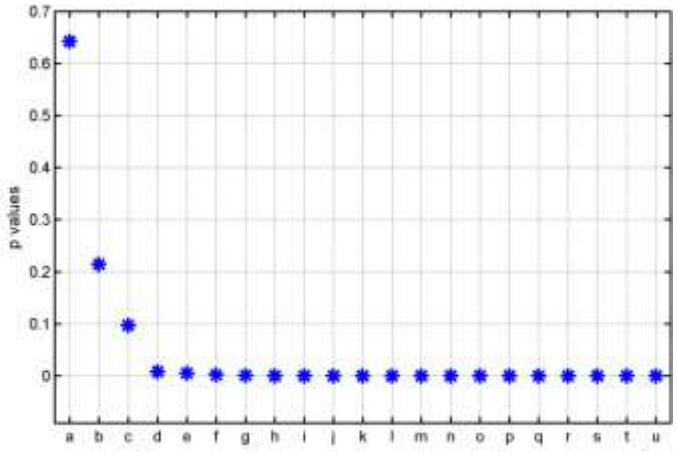

Fig7. Relationship between export type nature of industry and Lean components based on 'p' values where the x index is as follows: a-visual factory, b-Heijunka,c-Six big losses, d-Gemba, e-SMED, f-JIT, g-Jidoka, h-Andon, i-Hoshin Kanri, j-Kanban, k-KPI, l-Muda

Similar approach is followed for the analysis of the ISO certification and various Lean components with the following hypothesis and the results are finally tabulated in Table-IV and plotted in Fig-8

1. Hypothesis H_03_a: There is no relationship between the ISO and 5S (organize the work area) of the Lean implementation
2. Hypothesis H_03_b: There is no relationship between the ISO and Andon visual feedback system of the Lean implementation
3. Hypothesis H_03_c: There is no relationship between the ISO and bottleneck analysis of the Lean implementation
4. Hypothesis H_03_d: There is no relationship between the ISO and continuous flow of the Lean implementation
5. Hypothesis H_03_e: There is no relationship between the ISO and Gemba of the Lean implementation
6. Hypothesis H_03_f: There is no relationship between the ISO and Heijunka of the Lean implementation
7. Hypothesis H_03_g: There is no relationship between the ISO and Hoshin Kanri (policy deployment) of the Lean implementation
8. Hypothesis H_03_h: There is no relationship between the ISO and Jidoka (autonomation) of the Lean implementation
9. Hypothesis H_03_i: There is no relationship between the ISO and JIT of the Lean implementation
10. Hypothesis H_03_j: There is no relationship between the ISO and Kaizen of the Lean implementation
11. Hypothesis H_03_k: There is no relationship between the ISO and Kanben of the Lean implementation
12. Hypothesis H_03_l: There is no relationship between the ISO and KPI of the Lean implementation
13. Hypothesis H_03_m: There is no relationship between the ISO and Muda of the Lean implementation
14. Hypothesis H_03_n: There is no relationship between the ISO and OEE of the Lean implementation
15. Hypothesis H_03_o: There is no relationship between the ISO and PDCA of the Lean implementation
16. Hypothesis H_03_p: There is no relationship between the ISO and Poka Yoke of the Lean implementation
17. Hypothesis H_03_q: There is no relationship between the ISO and Root cause analysis of the Lean implementation
18. Hypothesis H_03_r: There is no relationship between the ISO and SMED of the Lean implementation
19. Hypothesis H_03_s: There is no relationship between the ISO and Six big losses of the Lean implementation
20. Hypothesis H_03_t: There is no relationship between the ISO and SMART goals of the Lean implementation
21. Hypothesis H_03_u: There is no relationship between the ISO and Standardized work of the Lean implementation
22. Hypothesis H_03_v: There is no relationship between the ISO and Takt time of the Lean implementation
23. Hypothesis H_03_w: There is no relationship between the ISO and TPM of the Lean implementation
24. Hypothesis H_03_x: There is no relationship between the ISO and VSM of the Lean implementation

25. Hypothesis $H_0 3_y$: There is no relationship between the ISO and visual factory of the Lean implementation

It is observed that in terms of ISO certification (Fig-8, six big losses and SMART goals are again the low impact Lean tools as was the case for the cost of project scenario (Fig-4). In Fig-9 obtained from the Table-IV the 'p' values are plotted for ISO certification vs Lean components where the lower 'p' values shows more relationships and higher 'p' values show low relationship. For ISO certification all values are less than 0.5 showing higher extent of relationships. The p-distribution however does not show the variation for Lean implementation in non ISO certified units. That part is well shown in Fig-8 for Lean implementation with components for both ISO and non ISO industries.

Lean tool	Nature of industry	Imple-mented	Not imple-mented	DF	χ^2 table	χ^2 calcu-lated	P Value	Signi-ficance
5S	ISO	172	0	1	3.84	5.401	NA	NS
	Non ISO	31	1					
Andon	ISO	149	23	1	3.84	4.823	.028	S
	Non ISO	32	0					
Bottle neck analysis	ISO	172	0	1	3.84	5.401	NA	NS
	Non ISO	32	0					
Continu-ous flow	ISO	172	0	1	3.84	5.401	NA	NS
	Non ISO	32	0					
Gemba	ISO	141	31	1	3.84	6.801	.009	S
	Non ISO	32	0					
Heijunka	ISO	131	41	1	3.84	9.547	.002	S
	Non ISO	32	0					
Hoshin Kanri	ISO	129	43	1	3.84	17.77	0	S
	Non ISO	12	20					
Jidoka	ISO	110	62	1	3.84	36.28	0	S
	Non ISO	2	30					
JIT	ISO	84	88	1	3.84	20.07	0	S
	Non ISO	2	30					
Kaizen	ISO	172	0	1	3.84	10.86	NA	NS
	Non ISO	30	2					
Kanban	ISO	165	7	1	3.84	1.349	.246	S
	Non ISO	32	0					
KPI	ISO	149	23	1	3.84	4.675	.031	S
	Non ISO	31	1					
Muda	ISO	167	5	1	3.84	0.954	NA	NS
	Non ISO	32	0					
OEE	ISO	171	1	1	3.84	0.187	NA	NS
	Non ISO	32	0					
PDCA	ISO	171	1	1	3.84	0.187	NA	NS
	Non ISO	32	0					
Poka Yoke	ISO	172	0	1	3.84	5.401	NA	NS
	Non ISO	32	0					
Root cause analysis	ISO	172	0	1	3.84	10.86	NA	NS
	Non ISO	30	2					
SMED	ISO	88	84	1	3.84	26.57	0	S
	Non ISO	32	0					
Six big losses	ISO	165	7	1	3.84	30.8	.0	S
	Non ISO	21	11					
SMART goals	ISO	172	0	1	3.84	62.49	0	S
	Non ISO	21	11					
Standar dized work	ISO	172	0	1	3.84	5.401	NA	NS
	Non ISO	32	0					
Takt time	ISO	171	1	1	3.84	1.798	NA	NS
	Non ISO	31	1					
TPM	ISO	172	0	1	3.8	5.40	NA	NS
	Non ISO	31	1		4	1		
VSM	ISO	164	8	1	3.84	1.549	.213	S
	Non ISO	32	0					
Visual factory	ISO	42	130	1	3.84	3.599	.058	S
	Non ISO	13	19					

Table IV. Relationship between ISO certification and Lean tools of LI

III. CONCLUSIONS

Based on the data from the demography survey as discussed in the introduction, the distribution of workers their education level and their income is clearly demarcated. Furthermore, from the Lean questionnaire, the impact of Lean implementation is further subdivided into 25 categories and the effect or the contribution is not the same for all. Separate subdivisions have different impact or effect on the effectiveness of Lean implementation. It is very clear that the certain categories have more augmentative effects on Lean implementation and vice versa. It is to be noticed that the factors helping in Lean implementation in ascending order are visual factory, JIT, Jidoka, SMED, Hoshin Kanri, Heijunka, Gemba, KPI, Andon, six big losses, SMART goals, VSM, Kanban, Muda, Kaizen, Root cause analysis, Takt time, 5S, OEE, PDCA, TPM, bottleneck analysis, continuous flow manufacturing, Poka yoke, and Standardized work. Here, the lowest belongs to visual factory and JIT with effectiveness as low as 0.27 to 1 from continuous improvement onwards, as seen in Fig-4. Furthermore, this variation is favourable to the industries in the 26-50 lakhs bracket than the ones with 51-100 lakhs bracket. The interesting observation is for the 26-50 lakhs bracket, the factors like six big losses and SMART goals prove to be a hindrance in Lean implementation. This serves as a demarcation in the list of factors as below this the Lean implementation is not suitable to either of the two kinds of industries or both. Hence, any category in the ascending list over this two is beneficial as the implementation of Lean with these categories in mind is worth focussing on. However, the demarcating parameter for export non export shifts back to KPI and Andon (see Fig-6) whereas for ISO the detrimental parameter remains unchanged (Fig-8).

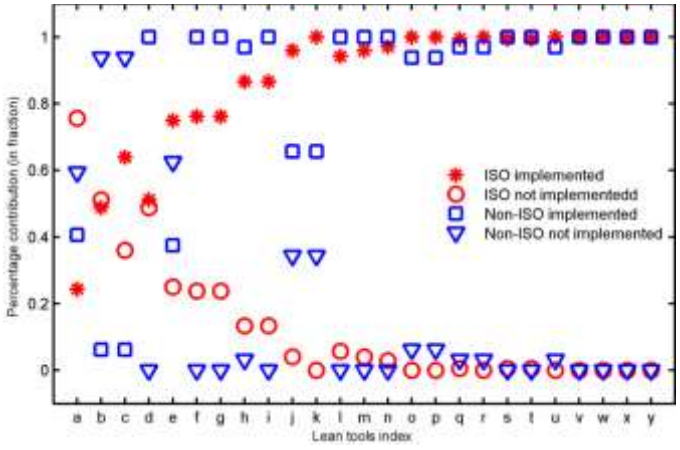

Fig8. Lean implementation percentage contribution with Lean tool index for ISO and non-ISO industries. X axis marks a=visual factory, b=JIT, c=Jidoka, d=SMED, e=Hoshin Kanri, f=Heijunka, g=Gemba, h=KPI, i=Andon, j=Six big losses, k=SMART goals, l=VSM, m=KANBAN, n=Muda, o=Kaizen, p=Rootcause analysis, q=Takt time, r=5S, s=OEE, t=PDCA, u=TPM,

v=Bottleneck analysis, w=Continuous flow manufacturing, x=Poka Yoke, y=Standardized work

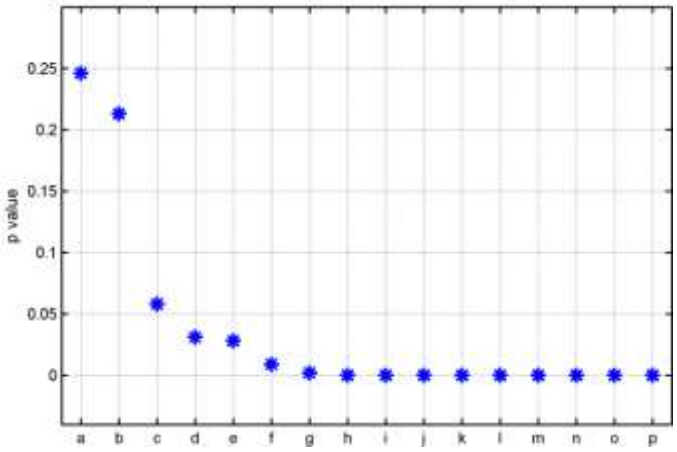

Fig9. Relationship between ISO certification and Lean components based on 'p' values where the x index is as follows: a-Kanban, b-VSM,c-Visual factory, d-KPI, e-Andon, f-Gemba, g-Heijunka, h-Hoshin Kanri, i-Jidoka, j-JIT, k-SMED, l-Six big losses, m-SMART goals, n-standardized work, o-Takt time, p-TPM

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