

Study on lean thinking among MSMEs in the Machine tool sector in India

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Abstract. In the era of stiff competition and customer expectations, manufacturing organizations across the world are struggling hard to minimize their costs and maximise their performance. Micro, Small and Medium enterprises (MSMEs), who are dependent on large corporate for business and support have a tall task of keeping pace quality in processes and output. They are in the constant vigil to adopt new systems and practices so that they can minimise their cost and maximize the productivity. This study has been conducted in the machine tool sector of Coimbatore, India; which houses more than 9000 companies and offers employment to over one lakh employees. They have a tremendous pressure to use scientific processes to increase their product quality and productivity. While Lean manufacturing has been the thrust to improve the competitiveness among MSMEs in India, this study has attempted to understand their attitude towards lean management and understand the extent to which companies practice lean tools and practices. It has been found that most of the organizations in the study possess a culture of lean thinking and possess the support of top management and employees also towards the initiative. It is also seen that the organizations that incorporated lean in their daily operations have been able to scale up their productivity.

1. Introduction

MSMEs world over struggle to keep pace with competition from local and international players in guarding their business. They are in the constant look out for managing their cost, quality, product variance and operational excellence. According to the World Bank report of 2016, MSMEs contribute about 45% of employment all across the globe and 33% of national income in growing economies. In India, SMEs contribute about 8 % of the country's GDP while they have a potential of making to 50% according the Economics Times report in December 2016.

Industrial clusters which are intense presence of basic and allied industries operate in several parts of

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India. Basically they operate as clusters to share infrastructure, resources, geographical presence, allied industries and suppliers. Industrial clusters also have the benefit of increasing productivity, scaling up innovation and helping in new business formation (www.referenceforbusiness.com › Encyclopaedia of Small Business) With a view to make the traditional industrial businesses profitable, Indian MSMEs have been classified into various clusters so as to increase its competence to grow and gain the economies. Around 50 clusters operate in the manufacturing and allied industries cluster in India, ranging from Auto components to Electronics to Heavy Engineering to Machine tools to Tea to Wood and Wood products. Coimbatore is noted for its entrepreneurial culture and is home to a number of industrial clusters like foundry, textiles, auto-components, engineering, motor & pumps, and machine tools. The study has considered understanding the lean management practices among the machine tool industry, which is considered as backbone of the Make in India movement.

It is interesting to note that Indian machine tool industry ranks 10th in consumption and 13th in production. Indian Machine tool manufacturers association has shown a promising growth rate in Production, Exports, Imports and Consumption of the Machine tool industry over the years 2016 from 2015 which is shown in Table 1. Coimbatore houses one of the largest machine tool clusters in India and accounts for employment to 1.5 lakh people and has an annual turnover of Rs. 20,000 crore.

Table 1. Growth in Production, Imports and Exports in Indian Machine tool Industry

Indian Machine Tool Industry 2014-15 & 2015-16 (INR Crores)			
	2014-15	2015-16	Growth Rate
Production	4230	4727	12%
Exports	281	296	5%
Imports	5318	5945	12%
Consumption	9267	10376	12%

Source: Indian Machine tool manufacturers association

1.1 Lean management in Indian organizations

Lean manufacturing has been the thrust of Indian government to improve the competitiveness of the organizations and the government has brought in number of initiatives and support systems to scale up their performance in the global market. It is seen that the price and customer expectation is constant in such an environment while the only scope of improvement is on cost and improved processes.

Lean manufacturing requires organizations to be focussed on enhancing quality through systematic and scientific processes so that waste is minimized and cost is reduced. Waste minimization in Lean manufacturing is categorized under eight heads namely correction of errors and defects, reduction in movement, waiting time reduction, over-processing, over-production, unwanted motion, transportation that does not add value and unused creativity in employees. To reduce such wastes, organizations use a number of scientific practices and offer employee support that helps them in enhancing productivity.

1.2 Lean thinking in MSMEs

The key to implementing lean practices in organizations, whether large corporate or MSMEs is lean management. It is the people and the spirit with which it is practiced that matters to the success of the implementation. More than what is done, the sustainability of the practice requires the top management support and the culture built in the organization in appreciating and making it happen [1]. It so happens that most of the SMEs are dependent on the buyers who place orders with them and their products are skewed to their specifications. But those organizations that have a vision and leadership drive to pull out the efforts would matter immensely to its implementation and sustainability [2]. Statistical concurrence to quality, achieving compliance to customer expectations is important, but driving people to abide with a hard intent to practice lean is primary to its implementation. Short term benefits like driving towards profit at the cost of a long term plan and vision would collapse the organization. Lean management is a low risk change management strategy in contrast to the big bang

theory which brings in strategic change to organizations at the macro level. The core of Lean management is continuous improvement and a constant vigil to imbibe a need to change. Visionary leadership and systems thinking would drive even a micro level organization to success and build a strong culture that can sustain the effects of lean implementation [3] [4]. Among the two types of leadership: transformational and transactional leadership, the former style instils employee engagement towards continuous improvement. It drives a “burning platform” or a compelling vision to implement and imbibe the practice and overcome the barriers to change in the form of people, process and technology. It is seen that such leadership practices present constructive people behaviour that would offer breakthrough profits and customer satisfaction [5].

1.3 Use of Lean tools in MSMEs

While increasing productivity is a key to organizational success, constraints- management in terms of eliminating lean *Muda* (wastes) supports it. *Muda* in organizations in the form of waiting time, over production, over processing, increased defects, excess motion, unwanted transportation, holding inventory and unused creativity in people present constraints in lower productivity in organizations. It is imperative to create systems and practices that curb these constraints and *Muda* [6].

It is reinforced multiple times that practice of lean tools like Kanban, JIT, VSM, TPM have a positive relationship with Business performance. Business performances in terms of sales, customer satisfaction, productivity and quality have a positive relationship with Lean practices and systems that are implemented in organizations [7] [8][28].

The choice of organizational metrics would phenomenally aid organizations in implementing lean. Lean metrics may be of types: inventory efficiency, takt time, and cycle time, average cost per unit, non-productive capacity and sales per employee. These would guide the organization to sufficiently keep track of organizational focus towards lean practices like 5S, Kanban, and JIT. The key would be to map the practices and systems to the metrics so that any faltering would highlight the gaps and aid in its correction. MSME have to inherently create systems and controls that present clarity to the inadequacies and lack of correlation between them [9].

2. Objectives of the study

The key objectives of the study is to

- Analyse the factors facilitating lean thinking among SMEs in the machine tool sector
- Usage of lean tools and the impact on organizational productivity

3. Methodology

A detailed questionnaire was created keep in mind important aspects like conducive culture to promote lean practices, employee orientation and training and application of appropriate lean tools. Respondents were SMEs in the machine tool sector, having inception from the year 1971 to 2013, of which 48% of them possessing ISO certifications or TUV certifications; their employee strength ranging from 5 employees to 200 employees. Detailed discussions were conducted with them to understand their attitude towards lean thinking. There were 23 items to assess the attitude towards lean thinking, apart from questions that focus on understanding the usage of specific lean tools and practices.

Table 2. Reliability Statistics

Cronbach's Alpha	No. of Items
0.798	23

Table 3. Reliability Statistics

Cronbach's Alpha	No. of Items
0.840	19

The reliability of the scale developed to assess the attitude towards lean thinking is 0.798 as shown in Table 2. Based on Cronbach's alpha scores and item-total correlation for individual items, items related to “Decisions related to values and beliefs” and “long term beliefs” and “Profit more than

customer value” and “Variations in Employee workload” were removed. Hence the Cronbach’s alpha score improved to 0.840 as shown in Table 3.

The Item total statistics, individual item-total correlation and Cronbach’s alpha scores are shown in Table 4.

4. Key factors that facilitate lean thinking

Lean thinking is essentially a culture instilled in organizations among employees, through systems and practices and using various scientific tools towards waste minimization.

It is seen that the following are the prominent factors towards the same:

- Organizational culture
- Employee training and orientation
- Quality management practices
- Practice of lean tools

Table 4. Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Decisions made on long-term benefit	69.3226	63.559	.328	.831
Complete utilization of machines	68.1613	63.406	.444	.832
Completion of customer orders in	68.3548	67.103	.368	.835
Employees trained to identify defects	68.3226	63.092	.434	.833
Defects identified and acted upon	68.0645	67.062	.230	.842
Standardising of work processes &	68.2903	65.080	.576	.828
Employees discretion to redesign	68.6452	64.303	.503	.829
Visuals used to indicate current	68.8065	58.295	.543	.828
Shop floors clutter free	68.2903	65.680	.284	.831
latest tech usage	68.6452	64.570	.592	.827
Preference of internal promotions	70.3871	67.512	.312	.837
Grooming internal employees for	70.1935	64.361	.564	.827
Promotion of employee participation	68.6452	69.637	.291	.839
Employees’ actions sync with org	68.7742	66.314	.580	.830
Customers and suppliers practice	68.8387	65.340	.668	.827
Root cause of problems identified	68.2903	68.346	.217	.821
Employee participation in continuous	68.2258	62.314	.504	.828
Top management support quality	67.8710	64.716	.482	.830
Use of employee creative ideas	68.5806	60.985	.632	.822

In this paper, the following aspects measure the factors specified:

Organizational culture is assessed through Belief in long term benefits for long term decisions, Belief in long term benefits while making day-to-day decisions, Organizational decisions based on its values and beliefs, Importance of customer value than profit making, Organizational support for employee participation and teamwork, Organizational support for implementing employee suggestions, Use of Creative ideas of employees, Preference of internal employees for higher level positions and Top management support to implement quality initiatives.

Employee training and orientation to quality and lean management is pertinent and is measured through Employees actions and behaviours' synchronising with the company's culture (values and beliefs), Internal employees groomed to take higher level responsibilities and positions, Employees' discretion to redesign and manage the work processes in the organization, Internal employees groomed to take higher level responsibilities and positions and Employees' participation in continuous improvement initiatives.

Lean management initiatives that were assessment for their practice were Standardisation of work processes and procedures, Full utilization of machines, Reduction in rework, Reduction in defects, Identification of defects and correction, Managing variations in employee workload, Use of latest technology, Clutter-free shop floor, Use of visuals to indicate the current status of an order, Identification of root-cause of problem and Practice of quality management practices by business partners.

The practice of lean tools were assessed such as 5S, Batch production, Reduction in change over time, Single piece production, Just-in-time, Continuous improvement initiatives, Kanban, Elimination of waste, Total productive maintenance, Value Stream mapping and Standardization of work

5. Analysis and Discussion

5.1 Vision and decision making in organizations:

Most of the organizations (55%) have commitment to long term vision and consider any major decisions with a long-term perspective even they feel they would be at a disadvantage; while some organizations evaluate the issue but do not compromise whenever they take any major decisions, as shown in Figure 1. This is a prominent factor in being vision oriented so that they gain sustainable advantage for their organizations [10], [11]. This attitude in the organizations further keep them well integrated with larger corporate who may be their buyers and with other suppliers.

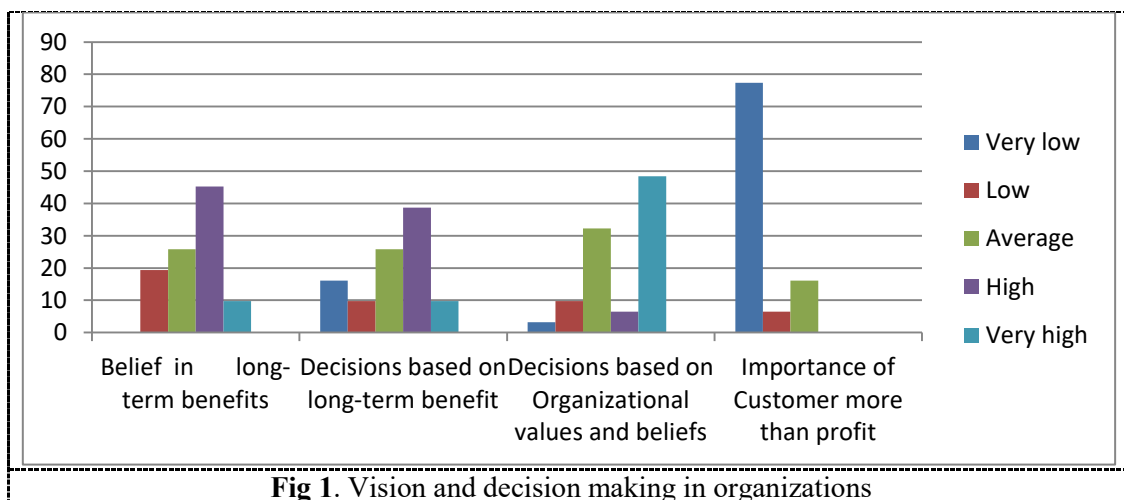


Fig 1. Vision and decision making in organizations

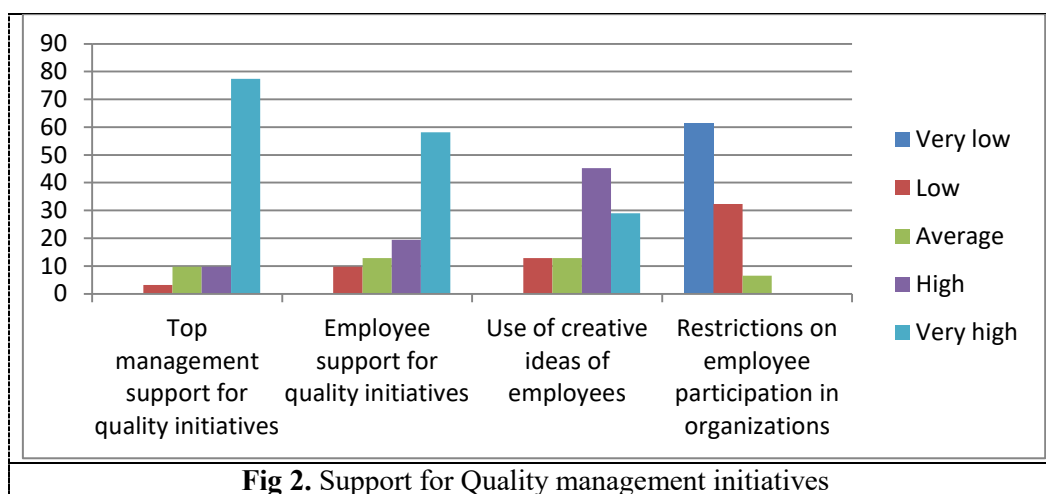
It is also seen that while making short-term decisions they do not much keep in mind the long term benefits. It is understood that SMEs have outstanding accounts and have regular fire-fighting issues.

Issues of manpower, financial support and irregular customer requirements deter their short-term decisions and they may have to make decisions without having a long-term perspective.

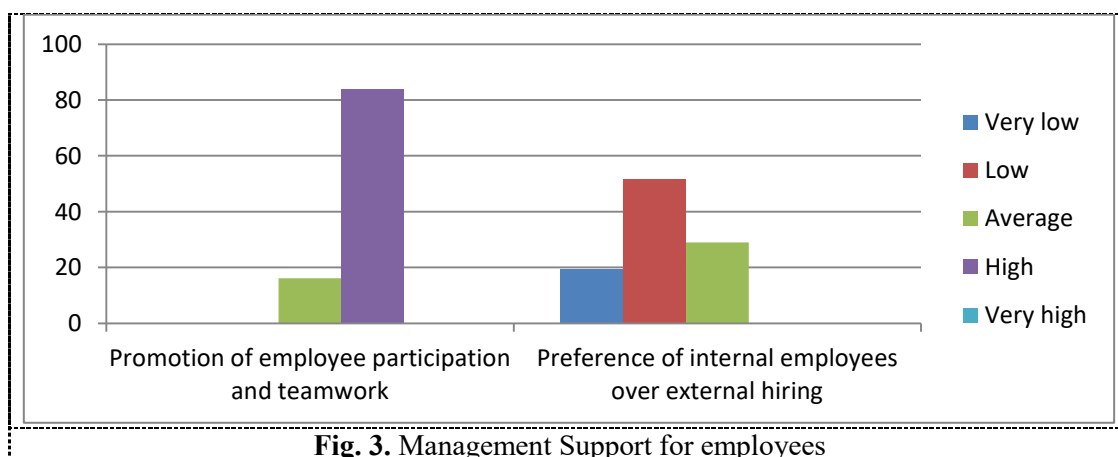
It is understood that while most organizations (87%) place much importance on their values and beliefs whenever they take decisions. It is also interesting to note that most of the organizations (84%) place more on customer benefit than profit accruing to the organization as shown in Figure 1.

5.2 Support for Quality management initiatives:

The analysis reveals that there is strong support from top management and employees for any quality management initiatives. 78% of the organizations have expressed strong participation of employees in quality management initiatives, while 87% of them have shown significant support for such initiatives from among the top management as shown in Figure 2. It is a very promising to note that when such an attitude is prevalent among management and employees, any such initiative would be successfully implemented and would have sustainability tool [12], [13], [14], [15].



It is interesting to note that the high percentages (about 70%) of employees' creative ideas are used by the organizations. Employees are encouraged to offer suggestions and improve processes so that the organization benefits in the long-run. Most of the organizations (94%) encourage employees to offer suggestions and do not impose any restrictions towards the same, as shown in Figure 3. It is seen that employees are much valued in their organizations. They are encouraged to work in teams and motivated to offer their participation in work improvement and improving customer services.



While more than 90% of them have a team working and worker participation culture, they are not able to support in grooming them for higher positions in their organizations. They are not offered much support to groom them to take up higher responsibilities as resources for grooming employees in organizations are low and hence about 85% of organizations do not groom employees for higher level positions.

5.3 Employee training and Orientation

It is seen that most of the SMEs (74%) have a culture of orienting employees' behaviours with organizational values and beliefs. It is important to see to it that the right type of employees is inducted into the organizations by ensuring the induction of employees from similar organizations to be inducted or encourage promoting internal talent to higher positions.

MSMEs and large corporate consider it important to ensure that employees are encouraged to participate in Continuous improvement initiatives and participate in relevant training and development sessions helpful in lean implementation [16],[17]. In this study it is found that most organizations do not groom them for higher positions, do not scale up higher level positions in the organizations. This is due to the fact that employees lack enough competence to scale-up higher responsibilities.

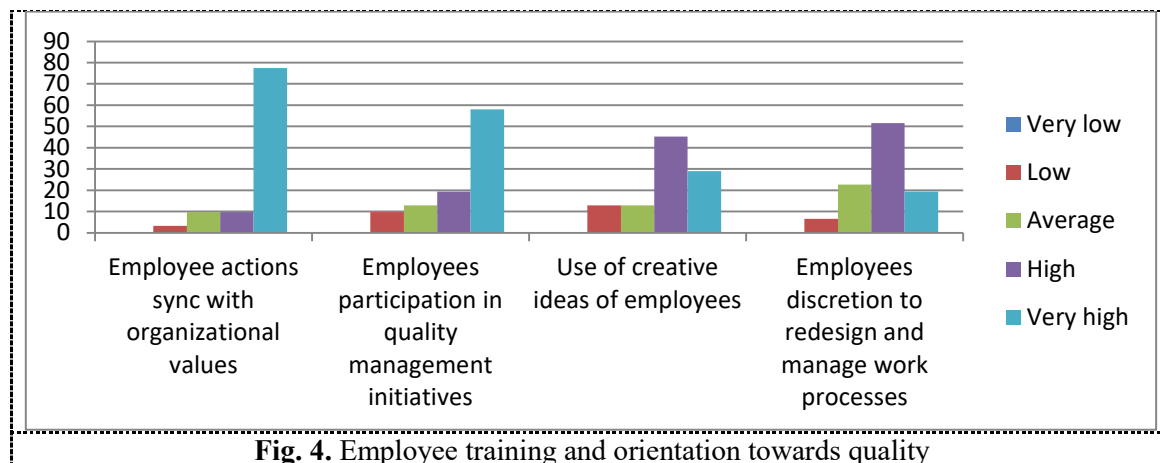


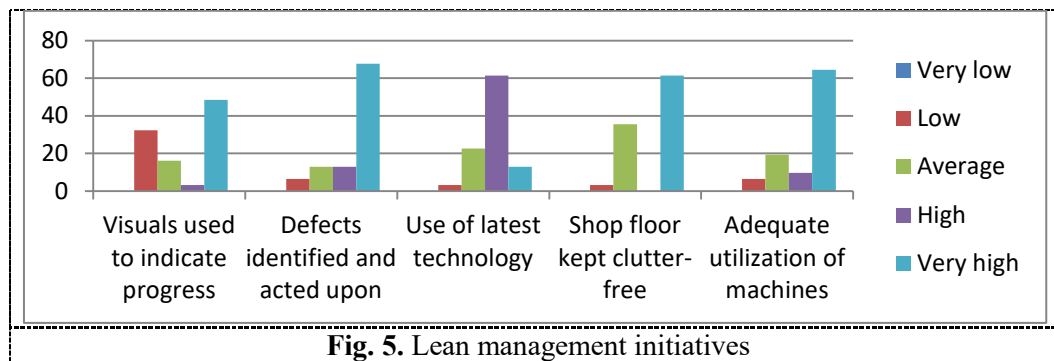
Fig. 4. Employee training and orientation towards quality

However it is observed that 70% of the organizations are confident of the employees' expertise in their roles and hence they encourage them to redesign and manage the work processes to facilitate organizational productivity as shown in Figure 4.

5.4 Lean management initiatives

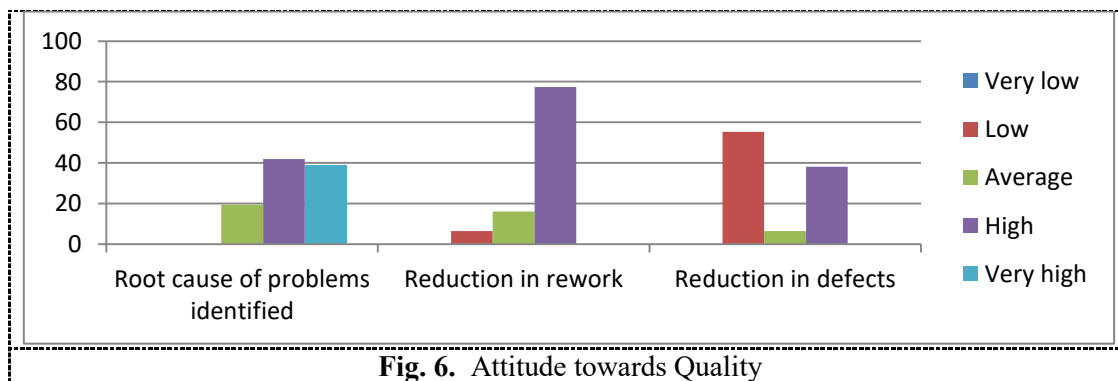
Lean manufacturing in organizations is a scientific phenomenon, by which number of systematic processes and practices are introduced to aid waste minimization. Towards this, the following are the common practices that are used in SMEs in this study as shown in Figure 5.

Standardization of work processes is a much widely practiced practice in organizations, where about 94% of the SMEs practice them extensively. It is seen that they make use of the machines extensively (74%) and keep them occupied, whereby defects are identified and acted upon to a larger extent (80%). It is encouraging to know that latest technology is used (74%), systems implemented to keep the shop floor clutter free (97%), visuals used to indicate current progress (53%).



It is found that variations in employee workload are high (45%), which can be attributed to irregular orders, variations in employee competence and are also due to high attrition among employees.

It is interesting to note that root cause of problems are identified extensively (81%) and defects are acted upon and corrected at the right time (80%). As a resultant of these practices, it is obvious that there is extensive reduction in rework (94%) though the reduction in defects is still low at 55%, as shown in Figure 6. These good practices are reinforced by the practice of good quality and lean management practices by various business partners (customers and suppliers) (68%).



5.5 Practice of Lean tools:

SMEs in manufacturing domain are suppliers to larger corporates who have enormous emphasis on quality and focus on customer excellence [18], [19]. The study shows that about 50% of the SMEs have quality certifications like ISO 9000, ISO 9001, ISO 2008 and TUV. To keep pace with the expectations of the buyers and customer expectations, the SMEs have placed emphasis on the practice of number of lean tools. Table 5 shows the extent of their practice of Lean tools by various organizations.

It is also important to note that organizations that practiced various lean tools had increase in productivity of above 10%. SMEs have placed more emphasis on Standardization of work, Total productive maintenance, and Continuous improvement and Batch production. It is also seen that organizations have extensively benefited in helping to increase their productivity above 10% by 39%, 39%, 42% and 39% respectively using these tools. [20], [21], [22], [23], [24], [25], [26], [27]

Table 5. Extent of Lean tools usage

Lean tool	Percentage of companies who do not practice	Percentage of companies who practice	Increase in productivity	
			10% - 20%	Greater than 20%
5S	55%	45%	25.8%	6.5%
Batch production	42%	58%	32.3%	6.5%
Single piece production	55%	45%	19.4%	6.5%
Just-in-time	45%	55%	22.6%	9.7%
Continuous improvement	45%	55%	22.6%	19.4%
Kanban	68%	32%	12.9%	16.1%
Total productive Maintenance	34%	66%	29.0%	9.7%
Value Stream Mapping	64%	36%	12.9%	9.7%
Standardization of work	34%	66%	25.8%	12.9%

5.6 Factors affecting completion of customer orders

As is known, SMEs face number of challenges in completion of customer orders in time. Effective planning, efficient use of resources, right technology and quality orientation are the prime factors in ensuring the completion of customer orders in time. It is worth noting that role of employees play a vital role in fulfilling customer requirements as shown in Table 6. Employees training to identify defects in the first time and use of employees' creative ideas influence the same.

Table 6. Factors affecting completion of customer orders

Correlations			
		Percentage use of employee creative ideas	Completion of customer orders in time
Percentage use of employee creative ideas	Pearson Correlation	1	.375*
	Sig. (2-tailed)		.037
	N	31	31
Completion of customer orders in time	Pearson Correlation	.375*	1
	Sig. (2-tailed)	.037	
	N	31	31
*. Correlation is significant at the 0.05 level (2-tailed)			

Table 6 shows the correlation between completion of customer orders and use of employees' creative ideas significant.

5.7 Factors influencing productivity in organizations

One of the prominent goals of any SME is to increase its productivity with the use of its resources and through other scientific and managerial measures. Among various factors that affect productivity, it is found that the use of latest and up-to-date technology, participation of employees in continuous

improvement initiatives and Employees actions and behaviours synchronising with the organization's culture and values play an important role as shown in Table 7.

Table 7 shows that the correlation between latest technology used, participation of employees in continuous improvement initiatives and Employees sync with organizational values and culture is correlated at 0.05 level of significance.

Table 7. Factors affecting Productivity increase

		Productivity increase	latest tech usage	Employee participation in continuous improvement initiatives	Employee actions sync with org values and culture
Productivity increase	Pearson Correlation	1	.414*	.434*	.389*
	Sig. (2-tailed)		.021	.015	.030
	N	31	31	31	31
latest tech usage	Pearson Correlation	.414*	1	.436*	.509**
	Sig. (2-tailed)	.021		.014	.003
	N	31	31	31	31
Emp partn in cont imprvt initiatives	Pearson Correlation	.434*	.436*	1	.570**
	Sig. (2-tailed)	.015	.014		.001
	N	31	31	31	31
Emp actions sync with org values and culture	Pearson Correlation	.389*	.509**	.570**	1
	Sig. (2-tailed)	.030	.003	.001	
	N	31	31	31	31
* Correlation is significant at the 0.05 level (2-tailed).					
**. Correlation is significant at the 0.01 level (2-tailed).					

6. Conclusion

The study shows that MSMEs have a keen interest in conducting their organizations based on long-term values and beliefs and placing high value on customer value than profits. The top management in the organizations support quality initiatives and promote a culture of employee participation and support. However the support offered to groom for higher level responsibilities and work on new technology has to be enhanced so that extent of defects is reduced. MSMEs have practiced Lean tools to increase their productivity which is correlated when employee participation and alignment to organizational culture. It is found that organizational productivity is related to employees' participation in continuous improvement activities and when they make good use of latest technology. In this context, it would be important to align productivity metrics with lean systems and practices, so that gaps that arise in realizing the metrics may be addressed.

7. References

- [1] Trenkner, Małgorzata, 2016 "Implementation of Lean leadership" *Management*, 20 129-142
- [2] Marynell, Tianna M, 2013, "Leadership for success with lean manufacturing: The relationship between style and successful implementation", *ProQuest Dissertations Publishing*
- [3] Li, Benbo; Nahm, Abraham Y.; Wyland, Rebecca; Ke, Jian-Yu; Yan, Wei, 2015, "Reassessing the

role of Chinese workers in problem solving: a study of transformational leadership, trust and security in 'lean' manufacturing" *Asia Pacific Business Review*, 21 463 - 484

[4] Pakdil, Fatma; Leonard, Karen Moustafa, 2015 "The effect of organizational culture on implementing and sustaining lean processes", *Journal of Manufacturing Technology Management*, 26 725-743

[5] Testani, M V and S. Ramakrishnan, S, 2010, "The Role of Leadership in Sustaining a Lean Transformation," *Proceedings of the 2010 Industrial Engineering Research Conference* A. Johnson and J. Miller, eds.

[6] Taj, Saharam and Lismar, Berro, 2006, "Application of constrained management and lean manufacturing in developing best practices for productivity improvement in an auto-assembly plant", *International Journal of Productivity and Performance Management*, 55, 332-345

[7] Nawanir, G, Teong, L K and Othman, S N, 2013, "Impact of lean practices on operations performance and business performance," *Journal of Manufacturing Technology Management*, 24, 1019–1050

[8] Fullerton, R R, Kennedy, F A and Widener, S K, 2013, "Management accounting and control practices in a lean manufacturing environment," *Accounting, Organ. Soc.*, 38, 50–71

[9] Mehmet, C, David, A and E. Daniel, E, 2011, "Lean Production Practices : Crandon Production System , A Case Study," *Cost Management*, 25, 34-38

[10] Marksberry, Phillip W, 2010, "A new approach in analyzing social-technical roles at Toyota: the team leader", *International Journal of Human Resources Development & Management*. 10 395-412

[11] Ghobadian A, Gallea, D N, 1996, Total quality management in SMEs, *Omega*, 24 83-106

[12] Assarlind, Marcus and Gremyr, Ida "Critical factors for quality management initiatives in small- and medium-sized enterprises", *Total Quality Management & Business Excellence*, 2014, 25 397-411

[13] Salaheldin, S.I, 2009, "Critical success factors for TQM implementation and their impact on performance of SMEs" *International Journal of Productivity and Performance Management*, 58 215-237

[14] Saraph, J.V., Benson, P.G., & Schroeder, R.G. 1989, "An instrument for measuring the critical factors of quality", *Decision Sciences*, 20 210-229

[15] Sathish Kumar, V R, Priyadharshini, R G, 2011, "Roadmap to TQM implementation among Indian SMEs", *Indian Journal of Technical Education*, 34

[16] Kabst, Rüdiger; Larsen, Henrik Holt; Bramming, Pia. 1996, "How do lean management organizations behave regarding training and development?", *International Journal of Human Resource Management*. 7 618-639

[17] Panwar, Avinash; Jain, Rakesh; Rathore, A. P. S, 2015, "Lean implementation in Indian process industries - some empirical evidence", *Journal of Manufacturing Technology Management*, 26 131-160

- [18] Islam, M. & Karim, A., 2011, "Manufacturing practices and performance: Comparison among small-medium and large industries", *International Journal of Quality & Reliability Management*, 28 43-61
- [19] Karim, M. A., Smith, A. J. R., Halgamuge, S. K. & Islam, M. M., 2008, "A comparative study of manufacturing practices and performance variables" *International Journal of Production Economics*, 112 841-859
- [20] Lyons, A. C., K. Vidamour, R. Jain, and M. Sutherland, 2013 "Developing an Understanding of Lean Thinking in Process Industries." *Production Planning & Control*, 24, 475–494.
- [21] Fullerton, R. R., and C. S. McWatters, 2001, "The Production Performance Benefits from JIT Implementation." *Journal of Operations Management*, 19, 81–96.
- [22] Wang, B. J. 2008, "Analysis of Efficiency of Lean Production Implemented in Multi-National Optic Enterprises." *International Journal of Technology Management*, 43 304-319
- [23] Hallgren, M., and J. Olhager. 2009, "Lean and Agile Manufacturing: External and Internal Drivers and Performance Outcomes," *International Journal of Operations & Production Management*, 29 976–999
- [24] Marin-Garcia, Juan A.; Bonavia, Tomas, 2015, "Relationship between employee involvement and lean manufacturing and its effect on performance in a rigid continuous process industry" *International Journal of Production Research*, 53, 3260-3275
- [25] Chay, TickFei; Xu, YuChun; Tiwari, Ashutosh; Chay, FooSoon, 2015, "Towards lean transformation: the analysis of lean implementation frameworks" *Journal of Manufacturing Technology Management*. 2015, 26 1031-1052
- [26] Davidson, Staci, 2008 "Going Lean", *Manufacturing Today*", 8 82-83
- [27] Fullerton, Rosemary R.; Wempe, William F, 2009, "Lean manufacturing, non-financial performance measures and financial performance" *International Journal of Operations & Production Management*, 29 214-240
- [28] Sathish Kumar V. R., Anbuudayasankar S. P. and Thennarasu M., 2016, Design and development of simulation based model to rank flow strategies, *ARPJ Journal of Engineering and Applied Sciences*, 11.