Literature Survey

Lean manufacturing was developed by the Japanese automotive industry, principally Toyota, following the challenge to re-build the Japanese economy after World War-II. Until the 1990s it was really only the automotive industry that had adopted lean manufacturing. Since then it has spread to aerospace and general manufacturing, consumer electronics, healthcare, construction and, more recently, to food manufacturing and meat processing.

Every company will have its own set of objectives; however, a study by Hendricks & Singhal (1997), explores the hypotheses that implementing effective total quality management (TQM) programs improves the operating performance of firms.

Peter et al (2003) reveals about twelve key to success, 1. The Six Sigma Efforts to Business Strategy and priorities, 2. Position Six Sigma as an improved way to manage for today; 3. Keep the message simple and clear; 4. Develop your own path to Six Sigma; 5. Focus on Short-Term Results; 6. Focus on Long-term growth and development; 7. Publicise results, admit setbacks, and learn from both; 8. Make an investment to make it happen; 9. Use Six Sigma tools wisely, 10. Link customers, process, data and innovation to build the Six Sigma System, 11. Make top leaders responsible and accountable, 12. Make learning an ongoing activity.

Pries (2010) states that Six Sigma was not the first quality concept introduced to business. It could probably trace the first real attempts to polis processes to Henry Ford at the beginning of the twentieth century. The Ford assembly lines were the product of never-ending attempts to optimize the process. Ford didn't stop with the assembly lines- he also improved the product, sometimes with innovative new substances.

Bhaskaran (2011) study reveals from the technical score and ranking of auto component manufactures, it is found that there is significant increase in technical efficiency of Auto Components Industry (ACI) after the Cluster Development Approach (CDA) when compared to before CDA.

Bhaskaran (2012) reports that there is increase in technical efficiency of not only Chennai auto cluster in general but also Chennai auto components industries in particular.

He did study on ten ACIs. In the first phase, diagnostic study is done and the areas for improvement in each of the cluster member companies are identified. In the second phase, training programs and implementation is done on 5S and other areas. In the third phase auditing is done and found that the lean manufacturing techniques implementation in Aiema Technology Centre-Lean Manufacturing Cluster

(ATC-LMC) is sustainable and successful in every cluster companies, which will not only enhance competitiveness but also decrease cost, time and increase productivity. The technical efficiency of LMC companies also increases significantly.

Shaffie and Shahbazi (2012) reveal that in real terms, the rollout of a Lean Six Sigma (LSS) effort has three distinct phases. In the first phase, the Quality Leader aligns the effort with the company's mission, selects a focus area, and forms the organization. During the second phase, champions are trained, metrics are developed, and projects are identified. In the third and final phase Black and Green Belts are trained and start executing the projects.

Study made by Bhaskaran in 2013, 2014 for inclusive growth and sustainable development reveals that inefficient Automotive Component Cluster (ACC) should increase their turnover and exports, as decrease in no. of enterprises and employment is practically not possible.

He concludes, for inclusive growth and sustainable development, the inefficient Textile Cluster should increase their Sales /turnover and Exports, as decrease in number of enterprises and Employment is practically not possible.

It is also found out that the variables are highly correlated and the inefficient automotive components manufacturing industries should increase their gross output or decrease the fixed assets or employment. Moreover for sustainable development, the cluster should strengthen infrastructure, technology, procurement, production and marketing interrelationships to decrease costs and to increase productivity and efficiency to compete in the indigenous and export market.

According to Ministry of Micro, Small and Medium Enterprises (2013), the two Light Engineering Clusters in India got funds under Lean Manufacturing Competitiveness Scheme which comes under National Manufacturing Competitiveness Programme (NMCP) of Government of India. The Tripartite Agreement is taken place between National Productivity Council (NPC), Consultants and Cluster Units. There is need for study on Lean Six Sigma Implementation in these 2 clusters.

Objective of The Study

The objective is

1. To study on the five distinct problems- innovative solving phases of Lean Six Sigma tools like Define, Measure, Analyze, Improve and Control (DMAIC) for the two Light Engineering Clusters (LEC) in India.

2. To Define (D) the problems of the two Light Engineering Clusters in India.
3. To Measure (M) the problems of the two Light Engineering Clusters in India and also to measure sigma level.
4. To Analyse (A) the problems of the two Light Engineering Clusters in India and also to analyse the sigma level.
5. To Improve (I) the problems of the two Light Engineering Clusters in India.
6. To Control (C) the problems of the two Light Engineering Clusters in India.

Methodology of The Study

The methodology adopted is collection of primary data from two Light Engineering Clusters in India and secondary data from Ministry of Micro, Small and Medium Enterprises (2014). The data were analyzed using Innovative Lean Manufacturing Tools and Techniques according to Ministry of Micro, Small and Medium Enterprises (2014) like 5S; Visual Control, Standard Operating Procedures (SOPs), Just in Time (JIT), KANBAN System, Cellular Layout, Value Stream Mapping, Poka Yoke or Mistake Proofing, Single Minutes Exchange of Dies or Quick Changeover (SMED), Total Productive Maintenance (TPM), Kaizen Blitz or Rapid Improvement Process and Six Sigma.

Lean Six Sigma Implementation

A. Light Engineering Cluster, Malwa, Haryana.

According to Ministry of Micro, Small and Medium Enterprises (2014), the cluster comprised 10 units in Faridabad and was promoted by the SPV named 'Integrated Association of Micro, Small and Medium Enterprise of India' (IamSME of India). They were the manufacturer of sheet metal components, turned components, forging, stators and rotors, etc. and supplier to large industries, OEMs etc.

B. Light Engineering Cluster, Kolkata, West Bengal.

According to Ministry of Micro, Small and Medium Enterprises (2014), the SPV named '10 suppliers of the Neogi group joined together to form a cluster named 'Neogi Group Suppliers Cluster'. The SPV was the manufacturer of Flow Meters, springs, Rotor Head, Non Ferrous Castings etc. and was also engaged with the job work and machining of various components like Nozzle Body, Valve Tops etc. The cluster was supplier to OEMs like IFB, KBM, Neogi Group etc.

The complete Lean Six Sigma Model of 5 steps is given in table II to VII. The structure of the two Light Engineering Cluster are given in table I.

Phase I : Define (D)
The first step of Lean Six Sigma is to define the problems. The problems of Light Engineering Cluster are given in table II.

Phase II : Measure (M)
The Lean tools used for measurement of the problems are given in Table III. Some of the tools used are Kaizen, 5S, Layout Improvement, Brainstorming, Visual Management, SMED and Pareto Analysis.

Phase III : Analyse (A)
The problems were analysed and given in the table IV. 5S stands for Sort, Set in order, Shine, Standardize & Sustain. The figure 2 shows implementation of 5S before and after the application of Lean Manufacturing techniques.

Phase IV- Improve (I)
The improvement made for the two Light Engineering Clusters in India are given in table V. Mostly 5 S is implemented in the two Light Engineering Clusters in India and the other tools like Kaizen, 5S, Layout Improvement, Brainstorming, Visual Management, SMED and Pareto Analysis are also implemented.

Phase V: Control (C)
The tools used for control of two Light Engineering Clusters in India are given in table VI. After improvement the process were controlled and standardized. There were savings in each of the MTMIs after the implementation of Lean Manufacturing Techniques. The cycle time is also reduced considerably.

The overall benefits obtained by all the two Light Engineering Clusters in India are given in table VII. The Voice of Proprietor / Managing Director / Chief Executive Officer of two MTMIs are also given in table 7 according to Lean Manufacturing Competitiveness Scheme, success stories to share (2014). The unit 1 has 4.6 sigma levels and 5.0 sigma level, unit 2 has 4.1 sigma level and 4.4 sigma level, before and after implementation of Lean Six Sigma level respectively. These units are very near to 6 sigma level and they should reach it at 6 sigma level. The calculation of sigma level for unit 2 is given in table VIII.

Table VIII: Six Sigma Calculation

DPMO= (Total Defects / Total Opportunities)* 1,000,000
DPMO- Defects per Million Opportunities

Before Lean Six Sigma Implementation	After Lean Six Sigma Implementation
Units = 1,000,000	Units= 1,000,000
Total number of defects=960	Total number of defects= 230
DPMO= (960 / 1,000,000)* 1,000,000=	DPMO= (230 / 1,000,000)* 1,000,000= 230
Z score (using Z table) = 4.6 sigma	Z Score (using Z table) = 5.0 sigma

Source: Computed Data, Developed by Researcher

Table I: Structure of the Machine Tools Manufacturing Industries		
MTMIs	**Light Engineering Cluster, Faridabad, Haryana**	**Light Engineering Cluster, West Bengal**
Light Engineering Cluster	The unit is a leader in manufacturing of Deep Draw Parts, Sheet Metal Components, Spring Steel Components, Furnace Brazed Components, Deep Draw Components, Bracket, Wire Forming Components etc. in India. 	The unit is mainly dealing with the machining jobs. The unit started with only one conventional lathe machine and was doing job work for only one company with very less volume of production. The unit adopted progressive approach and has grown over the last few years in terms of its production capacity and turnover. At present, the unit is having 3 CNC machines along with old machines.  
Established	1987	1985
Type of Unit	Small	Micro
No. of Workers	40	19
Turnover Rs. In crores	3.76	0.40
Certification	ISO / TS 16949: 2009	
Vendors of	Its major clients are Padmini VNA Mechatronics Pvt. Ltd, Hella India Electronics Pvt. Ltd, Senior India Pvt. Ltd., Keihin Fie Pvt. Ltd., Clutch Auto Ltd., Glen Appliances etc.	The unit is supplier to OEMs like IFB, KBM and Neogi Group.

Source: Primary data and Secondary data from Ministry of Micro, Small and Medium Enterprises (2014).

Table II: Phase I: Define (D)	
Light Engineering Cluster, Faridabad, Haryana	**Light Engineering Cluster, West Bengal**
Lean Journey: During the diagnostic study the Lean team identified cycle time reduction to be of prime concern as it was a continuously affecting productivity.	Lean Journey: During Diagnostic study, the Lean team realised that there was no concept of improvement and unit lacked good manufacturing practices. The Lean project was initiated with awareness programme on concepts of Lean for staff and workmen to make them understand that CHANGE is required in their work environment and work process in order to cope up with the changing market scenario and demands of customer.
Table III: Phase II: Measure (M)	
Lean Tools Used 1. 5S 2. Cycle time reduction. 3. TPM.	Lean Tools Used 1. 5S 2. Kaizen 3. Brainstorming.

Source: Primary data and Secondary data from Ministry of Micro, Small and Medium Enterprises (2014).

Table IV: Phase III: Analyse (M)			
Light Engineering Cluster, Faridabad, Haryana		**Light Engineering Cluster, West Bengal**	
The unit formed a Lean Implementation Team headed by a Lean Coordinator. The team started with implementing 5S as a start-up exercise and divided the plant into 5 zones. 1-S to 5-S was implemented in each of the zones during the various phases while also improving the visual management of the workplace. As a first step towards practicing Total Productive Maintenance (TPM), the unit started with an initiative called 'my-home-my-machine' under autonomous maintenance. Basic training on topics e.g. about the machines and tools, maintenance of equipment history card, assessing condition and preparation of PM checklist was imparted to the Lean team followed by horizontal deployment to all the workforce.		5S implementation was started in the entire unit with the involvement of unit head as the team leader. Unwanted and unnecessary items were removed from the shopfloor, office area, store area etc followed by systematic and organized arrangement of required / necessary items. A place was fixed for everything and people were trained to keep everything in its proper place. This approach led to improved workplace and better working conditions.	
BEFORE 5S SCORE	**AFTER 5S SCORE**	**BEFORE 5S SCORE**	**AFTER 5S SCORE**
 Pattern Storage Yard.	 Pattern Storage Yard.	 No place for fork lift.	 Designated place for placing fork lift.
21 on 100 scale.	62 on 100 scale.	28 on 100 scale.	89 on 100 scale.
Figure 2: Implementation of 5S			

Source: Computed Primary data and Secondary data from Ministry of Micro, Small and Medium Enterprises (2014).

Discussion

The objective of the two Light Engineering Clusters in India is reducing manufacturing cycle time by innovative methods. Innovative Lean principles have helped to identify the following areas of 7 wastes to be eliminated for all the 4 Industries.

1) *Defects*: Any nonconformance that leads to redoing, reworking, recontacting, or reviewing. The defects were identified and rectified in all 4 Industries.

2) *Waiting:* Any time during which work is not being performed on the customer request. Waiting time of parts manufactured was identified.

3) *Over Production*: Producing more than required more than a process step has the capacity to handle, resulting in the building of inventory. Here the inventory is reduced in all the four industries.

4) *Unnecessary Transportation*: Movement of raw materials, process and finished goods. With every movement, the risk of loss or delays in processing is identified.

5) *Inventory:* Work-in-process, representing unrecognized potential revenue. Parts waiting for processing are identified.

6) *Over processing*: Doing more than is required from a customer's perspective and over processing is controlled.

7) *Motion*: Movement to transport automotive components. Inefficient process layout is identified.

The five distinct problems solving phases of Six Sigma like Define, Measure, Analyze, Improve and Control. (DMAIC) for the Machine Tools Manufacturing Industries (MTMI) in India using Lean Six Sigma Tools were studied using innovative methods and the following results were obtained.

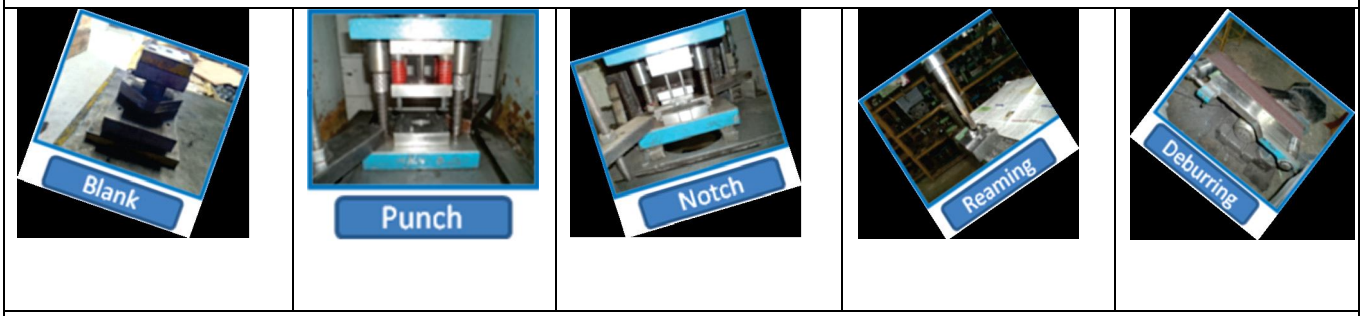
Table V: Phase IV: Improve (I)	
Light Engineering Cluster, Faridabad, Haryana	**Light Engineering Cluster, West Bengal**
Subsequently, the unit started a productivity improvement initiative and identified the following parts based on criteria e.g., high volume part involving frequent tool maintenance, heavy rejections etc. The team did brainstorming, built Fish Bone Diagram and developed ideas (kaizen) which were then checked and validated for feasibility to be implemented one by one. A progressive tool was designed and developed for processing the Armature Plate in which 4 operations (Blanking, Punching, Notching and Reaming) were combined. Also to increase the productivity, instead of single cavity the tool was made with two cavity that ensured double production and less lead time.	During the discussions with the unit head it was mentioned that the unit was having high demand for Aluminum 805 Base but it failed to achieve 100% delivery compliance. Due to this the unit was almost on the verge of losing business as the delivery compliance for the product was just 54%. The Lean team decided to take up this issue and adopted the following approach for improvement: Based on the Customer demand, Takt time per piece was calculated. The cycle time for each operation (in the manufacturing of Aluminum 805 Base) was recorded. The operations having high cycle time (Pre Matching, CNC Machining, Tool Searching) were identified for detailed study and analysis. Brainstorming by the Lean team along with shop floor team was done to identify the reasons for high cycle time for the identified processes.

Source: Primary data and Secondary data from Ministry of Micro, Small and Medium Enterprises (2014).

1) *Define*: The problem Statement, the goal, and the financial benefits are defined using the diagnostic study.

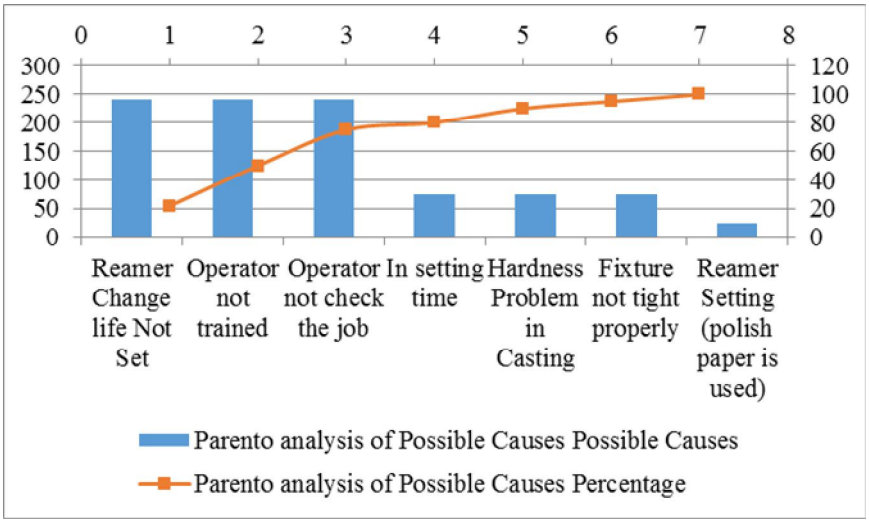
2) *Measure:* The current performance of the process and required data are collected.

Light Engineering Cluster, Faridabad, Haryana



BEFORE KAIZEN

AFTER KAIZEN

Table VI: Phase V: Control (C)	
Light Engineering Cluster, Faridabad, Haryana	**Light Engineering Cluster, West Bengal**
The processing time came down to 2.5 secs/ piece from 25 secs / piece and the productivity increased by 800%. There was a saving of 2 operators and 3 machines with a calculated saving of Rs.165,000/- per year. Similar exercise was carried out for the other two parts also. The unit achieved a WIP reduction of 40% production increase of 14% and PPM reduction upto 170 PPM.	Video shoot was conducted for VMC Machine Change over. Real time analysis was done with the identified project team to evaluate total elapsed time and elementary time used to carry out all the activities during changeover as per standard format. While calculating the elementary time, only those activities were considered, which were necessary for die change. The project team reviewed all the activities performed to decide internal and external setup activities. Some quick win kaizens were evolved which on implementation, reduction / eliminated waste activities involved; for example a changeover trolley containing the necessary tools and equipment's was designed for streamlining the internal changeover activities. 

Source: Primary data and Secondary data from Ministry of Micro, Small and Medium Enterprises (2014).

3) *Analyze*: The root cause of the problem are analyzed using innovative Lean Tools.

4) *Improve*: The process to eliminate errors and instability and to improve the process is identified.

5) *Control*: The performance of the process are controlled and ensured that the improvements are sustained.

The Key Deliverables of SIX SIGMA Implementation in two Light Engineering Cluster in India are

1) *Improved Service reliability*: Consistency of performance and delivered the service right the first time.

2) *Improved responsiveness:* Timeliness of the response and readiness provided to the service when the customer wants it.

3) *Improved assurance:* Created trust and confidence in the customer's base.

4) *Reduced expenses:* Improved the effectiveness and accuracy of business processes.

5) *Increased revenue:* Understood what their customer wants, when they want it and what the right price is.

Table VII: LEAN SIX SIGMA- (DMAIC)-Overall Benefits

Light Engineering Cluster, Faridabad, Haryana		**Light Engineering Cluster, West Bengal**	
➢ 5S Levels – 60% ➢ Productivity Improvement-30% ➢ Quality Improvement- 30% ➢ Manufacturing Cost Reduction-10% ➢ Reduction in Inventory-10% ➢ Annual Savings- Rs.5 lakhs. The voice of the proprietor of the company is "Implementing Lean has not only given us enormous monetary savings but also transformed our capability."		• 5S Score- 16% to 64% (100% scale) • Customer Quality Rejection-5000 ppm to 2214 ppm. • Internal Quality Rejection- 35000 ppm to 18257 ppm. • Savings in Change over time 67%. The voice of the proprietor of the company is "The scheme has helped us in war against the wastes and has boosted our confidence to new heights. 5S project has enabled us to take up customer visits at any time. Our changeover time, travelling time has reduced considerably. New techniques learnt and knowledge sharing under this project has enhanced our productivity and profitability."	
DPMO Before	**DPMO After**	**DPMO Before**	**DPMO After**
960 ppm 4.6 sigma.	230 ppm 5.0 sigma.	4660 ppm 4.1 sigma.	1860 ppm 4.4 sigma.

Source: Computed Primary data and Secondary data from Ministry of Micro, Small and Medium Enterprises (2014).

The main deliverables on the implementation of Lean in two Light Engineering Cluster are:

1) Reduction in work in process (WIP), or the backlog.
2) Increased productivity.
3) Increased process capacity.

4) Improved area and / or organizational layouts for optimization.
5) Standardized operations and processes.

Conclusion

The dynamism of two Light Engineering Cluster in India participation has been mainly responsible for the success and sustainability of Lean Six Sigma Implementation. The participatory initiatives by the Ministry of Micro, Small and Medium Enterprises, National Productivity Council and Lean Manufacturing Consultant has changed the innovation, and quality of these two Light Engineering Clusters in India. The Productivity has been improved considerably after implementation of Lean Six Sigma Manufacturing Techniques. The initiatives are sustainable and can be replicated in other two Light Engineering Cluster in India for sustainable development of two Light Engineering Cluster in India. The Lean Six Sigma Model helped two Light Engineering Cluster in India to manufacture less defective parts and also improves sigma levels. If this trend continues, the two Light Engineering Cluster in India will reach six sigma levels in near future. Lean Six Sigma implementation could pave way for Quality Management and Innovation, a necessary condition for sustainable development of two Light Engineering Cluster in India.

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