Vol. XII & Issue No.10 October - 2019
INDUSTRIAL ENGINEERING JOURNAL

DEVELOPING A LEAN SIX SIGMA CONCEPTUAL MODEL AND ITS IMPLEMENTATION: A CASE STUDY

H. S. Sodhi
D. Singh
B. J. Singh

ABSTRACT:

Purpose of this study is to propose a Lean Six Sigma Model that will be applicable for manufacturing organizations for waste management and the same has been implemented in a foundry SME unit. A Lean manufacturing model has been proposed in with the various phases of Six Sigma, i.e. Define, Measure, Analysis, Improve and Control are reinforced with the tools of Mean Manufacturing. Further the same has been implemented in a machining organization. After the implementation of advanced Lean Six Sigma model, significant improvement in the scrap rate and reduction of reworking has been observed. A unique Lean Sigma model that will be applicable in modern manufacturing organizations for the purpose of waste management.

KEYWORDS: Lean Manufacturing, Six Sigma, Lean Six Sigma, Waste Management Techniques, LSS Model

1. INTRODUCTION

Present study is influenced by the rapidly changing Indian manufacturing SME's, which are considered to the back bone of the national economy. Present contribution of SME's is of 17% of the gross domestic product (GDP) of India. Indian SME's sector is providing employment to nearly 40% of its population. Therefore, the figures show poor condition and performance of manufacturing SME's sector across India. Hence present study is focused upon providing a sustainable model for improvement and providing high-quality possibilities to attempt more modern techno managerial challenges in modern practices and frameworks for the sustainability of the SME's. To remain competitive in present unstable and turbulent industrial environment, industrial organizations needs to keep updated themselves and their systems in order to respond accordingly to the changes. (Yang and Li, 2011). Manufacturing industry over the globe and in India specifically has seen a high level of progress in the past years, which includes changes in management, process innovation, client expectation, supplier attitudes, comparative behavior, etc. (Doordarshi S. 2013). Because of these progressions, Industrial organizations must adjust to advertise weight and contenders' developments rapidly and adequately. These kinds of changes and escalation among the competitors have been captured by number of authors in their research articles (Meredith et al., 1994; Hum and Sim, 1996; Spina et al., 1996; McNamara et al., 2003; Wiggins and Ruefli, 2005; Oberoi et al., 2008; Singh et al., 2013). Rapidly increasing number of manufacturing managers perceive that accomplishing minimal effort and high skill is not sufficient to enhance or manage their manufacturing organizations position in this competitive world for a long time (Lau, 1999). As the market condition keeps on changing progressively, quickly and capriciously, supervisors are progressively focusing on adaptability as an approach to accomplish new types of models and to execute such waste management strategies which are highly dependable in the long run to remain competitive and sustainable. Increased availability in the diversity of the various products, enhanced changes in the market and refined competitive techniques outlines the scenario of present manufacturing world. The fluctuations in demand of products and services respond rapidly to continue to exist towards competitive markets. In the modern manufacturing sector, industries utilize nearly identical manufacturing operations and techniques; henceforth competition isn't constrained to manufacturing technology only. Innovation is diagnosed as a non-stop and in-built procedure in manufacturing industries for regular development (Anuj Singla. 2017). Therefore, after reviewing the relative literature a need has been felt to guide academicians and practitioners in figuring out and prioritizing the relevant critical success factors (CSFs) which are significantly influencing the waste reduction in manufacturing organizations. In the present research work a Lean Six Sigma has been proposed, which is based upon the previous literature survey and the experience of the industrial practitioners further the same model has been implemented in a foundry industry situated at Mohali, India in order to observe the pre an post implementation results of the model.

2. COMBINED LEAN AND SIX SIGMA: A SUSTAINABLE APPROACH

Lean Six Sigma (LSS) is a methodology that depends on a collaborative effort to improve performance by systematically removing waste. Further lean manufacturing is combined with Six Sigma to eliminate the eight kinds of waste defects i.e. waiting, overproduction, non-utilized talent, transportation, motion, extra-processing inventory etc. LSS is an approach which is highly used in America. Medium and small-scale industries of America utilizing LSS approach are highly benefited from this technique in terms of scrap reduction. The main aim of Lean Six Sigma is growth oriented which includes reduction in cost and improvements in quality and productivity. The integration of Lean and Six Sigma is necessary because in general, Lean aims to create value through scrap elimination while Six Sigma aims to meet quality demands as per customers need. Lean and Six Sigma can be taken into consideration as a powerful tool to aid the conservation of assets, combat global warming and saving energy. Various researchers provide evidence of this as such, businesses should not simplest bear in mind these strategies to manage quality and improve operational performance however additionally meet environmental regulations as well methods to manage quality and improve operational performance but also meet environmental regulations (Chugani 2017). The main advantages of using LSS are that it increases the organization's revenue by streamlining processes. In some cases when work is done on prioritized valued processes, manufacturer's faces problems related to delivery speed. Engineering often places multiple gating, detailed processes through combination of different processes and theories and increased non-value-added designs to reduce the rejections in production or reworking processes. Enhancing the overall design process also improves the throughput speed. To identify the factors responsible for loss of work done on prioritized valued processes, mostly manufacturers faces problems in delivery speed. Engineering often have multiple gating, enhanced and detailed sophisticated processes with the combination of different value-added designs to prevent rejections in production or reworking processes. Fig. no 1 represents the success factors contributing towards the successful implementation of Lean Six Sigma.

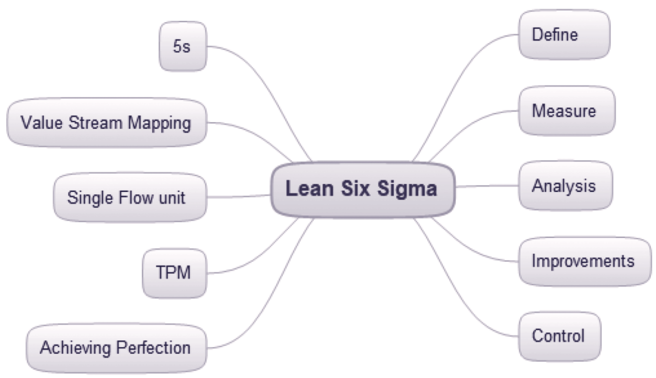

Figure No 1: Lean Six Sigma an Integrated Approach

3. LITERATURE REVIEW

This section of the research work will focus upon the brief discussion about status of SME's, reasons for their sickness and poor performance, various waste management techniques implemented in SME's and Also about the effectiveness of Lean Six Sigma implementation in manufacturing units. Detailed literature review has been carried out to capture the voice of various concerned researchers and their relative works as far as the implementation of waste management techniques in Small and medium enterprises is concerned about. A Categories wise detailed literature review has been enlisted in table no 1 below.

3.1 Critically important factors of Lean Six Sigma

Many research papers focusing upon the critical success factors of Lean Six Sigma were reviewed. Pepper (2010) stated that the integration of lean standards with Six Sigma technique as a coherent technique contributing towards continuous development, and presents a conceptual version for integration of Lean manufacturing with Six Sigma to reap higher fiscal advantages. Albliwi (2013) stated that the crucial failure factors for LSS in manufacturing sectors, consisting of non-consistent production rate, services, higher skilled workers required, and many others. There are 34 failure factors of LSS cited in this paper. There are some common elements for failure, inclusive of a lack of top control dedication and involvement, lack of conversation, loss of training and education, constrained resources and others. Many gaps and barriers are mentioned in this paper and want to be explored in future research. Ren jie (2014) the LSS framework proposed in this paper isn't like other LSS framework based on other initial studies in phrases of the focus of LSS implementation in SMEs industries across nation. This paper contributes closer to the research upon a structured implementation of LSS in SMEs in which it addresses the problems confronted by means of previous works regarding LSS implementation in SMEs. Lande (2016) researched with a motive that to become aware of and list vital Critical Success factors (CSFs) of Lean Six Sigma (LSS) framework affecting and influencing excellent, operational and financial overall performance of small and medium enterprises (SMEs). It also intends to manual researchers and practitioners in selecting suitable set of CSFs for empirical research, developing frameworks and to ensure powerful implementation experience of LSS. Thomas (2013) investigate the migratory nature of Lean Six Sigma (LSS) implementation and adoption in production-based totally SMEs within the United Kingdom. The agencies have been surveyed at two factors over a 5-12 months period. those intervals have been earlier than and after the 2008 recession factor. This being executed so that you can discover the extent of LSS adoption as a result of the tougher financial climate that has prevailed in view that 2008.

3.2 Status of SME's across globe

Chih-hung (2017) studied that it is becoming tougher for small and medium-sized firms (SMEs) to achieve sustainable organizations, as scarcity of resources is a common feature for most SMEs. Therefore, SMEs must correctly utilize their limited resources and prioritize their overall performance factors in terms of a balanced scorecard (BSC) approach in elaborating their sustainability development. MertGünerergin (2012) aimed to explore the difficulties and advantages of Turkish SMEs for sustainability and on the light of the effects, it discusses the strategic managerial implications important for sustainability. AlManei (2017) aims at the most prominent waste management strategies frameworks has been discussed, below the prism of the desires of SMEs.

3.3 Exiting Waste Management Techniques

Romdhane (2016) focuses at the success of some of the applied waste management strategies including Six Sigma, however such tactics remains reserved frequently for massive firms as it calls for significant financial assets and the intervention of Black Belt experts. Consequently, such waste management techniques are needed to be changed as in step with the requirements of SME's. Ambe J.Njoh (2017) reviews the usage of the Strengths-Weaknesses-opportunities-Threats (SWOT) version inside the strength sector. Some of the models based upon Lean Six Sigma reviewed for this study are mentioned below.

Quality Techniques	Author	Model/ Brief Description
Lean Six Sigma	Jeyaraman et al. (2010)	Implemented a LSS model in a Food industry, which adopts Lean & Six Sigma initiatives mainly to increase productivity and to reduce costs and inventory.
	Hussain et al. (2011)	Proposed LSS concepts for sustainable construction and improved quality.
	Pocha et al. (2013)	Implemented a LSS model in health care industries located in USA.
	McAdam et al. (2014)	Demonstrated a LSS model underlying the routines for Knowledge absorption processes. Propositions are defined relating the characteristics of SMEs for LSS implementation
	Cheng et al., (2015)	Conducted a case study using LSS Model for Projects in non-profit organizations.
	Hilton et al. (2016)	Proposed a conceptual LSS model for the successful deployment of Lean Six Sigma in an air conditioner industry.
	Antony et al. (2017)	Worked in the field of proposing ds an integrated Model for LSS application in the airline industry.
	Timans et al. (2018)	Projects of LSS in small-and medium-sized manufacturing enterprises in the Netherlands for use and usefulness of LSS-tools.

4. PROBLEM FORMULATION

After reviewing the literature and survey conducted during our study, it has been noticed that the SME manufacturing sector across India is falling sick as far as its contribution towards the Indian GDP is concerned. The main reason noticed during our study is that most of the SME organizations are facing a huge problem related to the waste management. Readily enhancing rate in the scrap is putting the financial conditions of most of the SME's in the alarming state. The major problem noticed in this is, the waste management technique used in those organizations is not effective enough to provide the adequate results as far as waste reduction is concerned. Because of this delegation in the implementation of waste management technique in Indian SME's may cause serious consequences. Therefore, it becomes important to introduce an adequate waste management technique in such industrial organizations. Many of them are using some of the waste management techniques such as Lean Manufacturing, Six Sigma, Total Productive management, 5s, KIZEN, Lean Six Sigma etc, but due to the inadequate implementation these techniques are also not performing up to the mark. Form the survey it has been noticed that during the SWOT analysis of many of the waste management techniques Lean Six Sigma has been found to be the one of the best techniques among all others. Therefore, there is a need to evaluate and analyses the various Critical success factors of the Lean Six Sigma so that a systematic approach for the proper implementation of LSS can be proposed.

5. OBJECTIVE OF STUDY

This study has been done with an objective of proposing and implementing a Lean Six Sigma model for the manufacturing organizations in order to reduce the heavy scrap produced in these organizations. Due to heavy scrap rate these organizations are facing heavy financial losses. This study will assists managers to reduce scrap and enhance their profitability by reducing scrap by a systematic manner through implementing the proposed model as recommended in this study.

6. METHODOLOGY ADOPTED

Thorough literature survey based upon Lean manufacturing, six sigma and Lean Six Sigma has been carried out. Few key factors contributing towards the successful implementation of these waste management strategies has been pointed out. Afterwards a conceptual modified Lean Six Sigma model of implementation has been proposed after the synergy of Lean and Six Sigma. In this model tools having higher level of significance of Lean manufacturing are enforced in the DMAIC approach of Six Sigma. After that the implementation of the proposed conceptual model has been done in a foundry based manufacturing SME and the pre and post implementation results of Lean Six Sigma strategy has been analyzed.

As illustrated in figure no 2, there are four critical aspects related to the management of waste in the manufacturing organization.

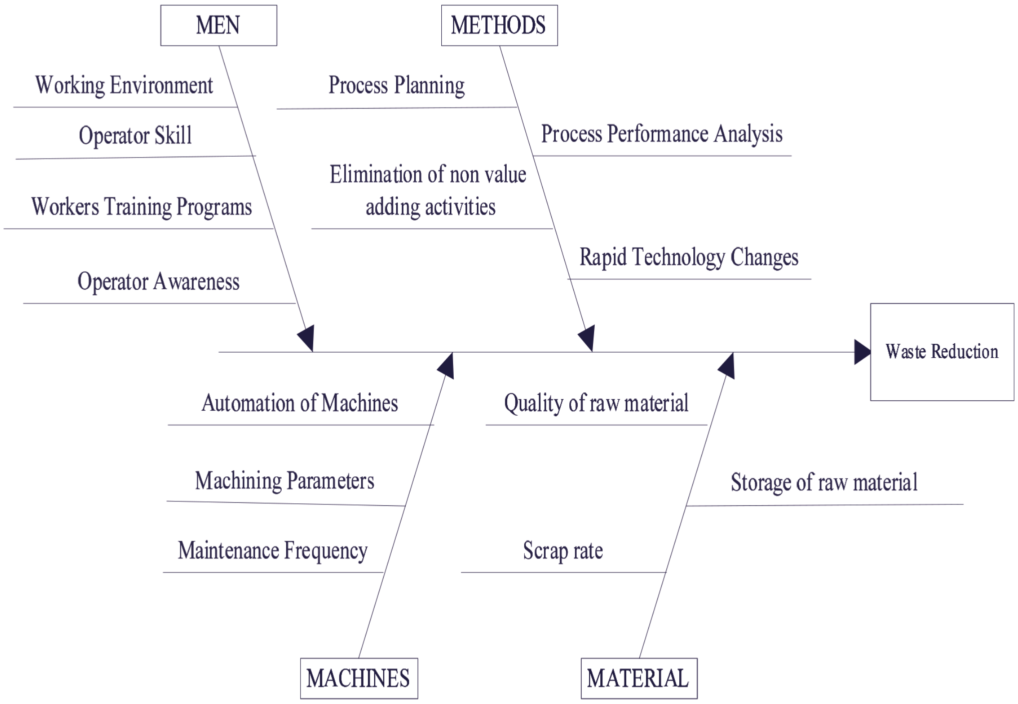

Figure no 2. Fish Bone diagram for process improvement

A thorough information has been collected related to these aspects form previous literature and the survey. Management of waste in any manufacturing organization revolves around controlling these four critical parameters of any organization i.e men, methods, machines and material.

Table no 1 points out the significance of workforce, manufacturing processes followed, materials used, machinery/ equipment's available and the probable customers for a manufacturing organization. here in table no 1 the frequency has been rated in the range of very high to low, based upon the weightage shown in the previous research papers frequency of each parameter has been fixed.

Table no 1: Lean Six Sigma dimensions and its factors

S.no	Dimensions	Factor	Frequency
1	Men (Workforce)	Workforce Skill	25(VH)
		Workforce Development Programs	13(L)
		Workforce Involvement	6(VL)
2	Methods (Manufacturing Processes)	Define	20(VH)
		Measure	16(H)
		Analysis	13(L)
		Improve	18(H)
		Control	19(H)
		TPM	15(H)
		5S	13(L)
		Value Stream Mapping	7(VL)
		Single Flow Unit	16(H)
		Achieving Perfection	15(H)
3	Material	Availability of raw material	20(VH)
		Quality of raw material	21(VH)
		Material inventory	22(VH)

4	Machinery	Automation of Machinery	23(VH)
		Up gradation of machines	20(VH)
		Maintenance Frequency	16(H)
5	Consumer	Customer satisfaction	19(H)
		Customer service	10(L)

Frequency scale: 1 to 7 = Very Low (VL); 8 to 13 = Low (L); 14 to 19 = High (H); 20 to 25 = Very High (VH)

7. DEVELOPMENT OF THE CONCEPTUAL LEAN SIX SIGMA MODEL

Generally, the manufacturing system is an Input-output model. The system receives the input elements and then later undergoes a few processes in the transformation stage. Finally, the desired product is produced in the output stage. Quality and cost of the final output rely heavily on the factors that affect or control the system during the transformation process. The goal is to produce the right product at the right time and with the right cost in order to gain profitability and stay competitive by continuing the sales growth. Figure no 3 illustrated is consisting of Six Sigma Strategy's Define, Measure, Analysis, Improve and Control phases reinforced with the tools used in Lean Manufacturing approach. This strategy leads to the building a new LSS model for the purpose of achieving an effective approach towards the waste management.

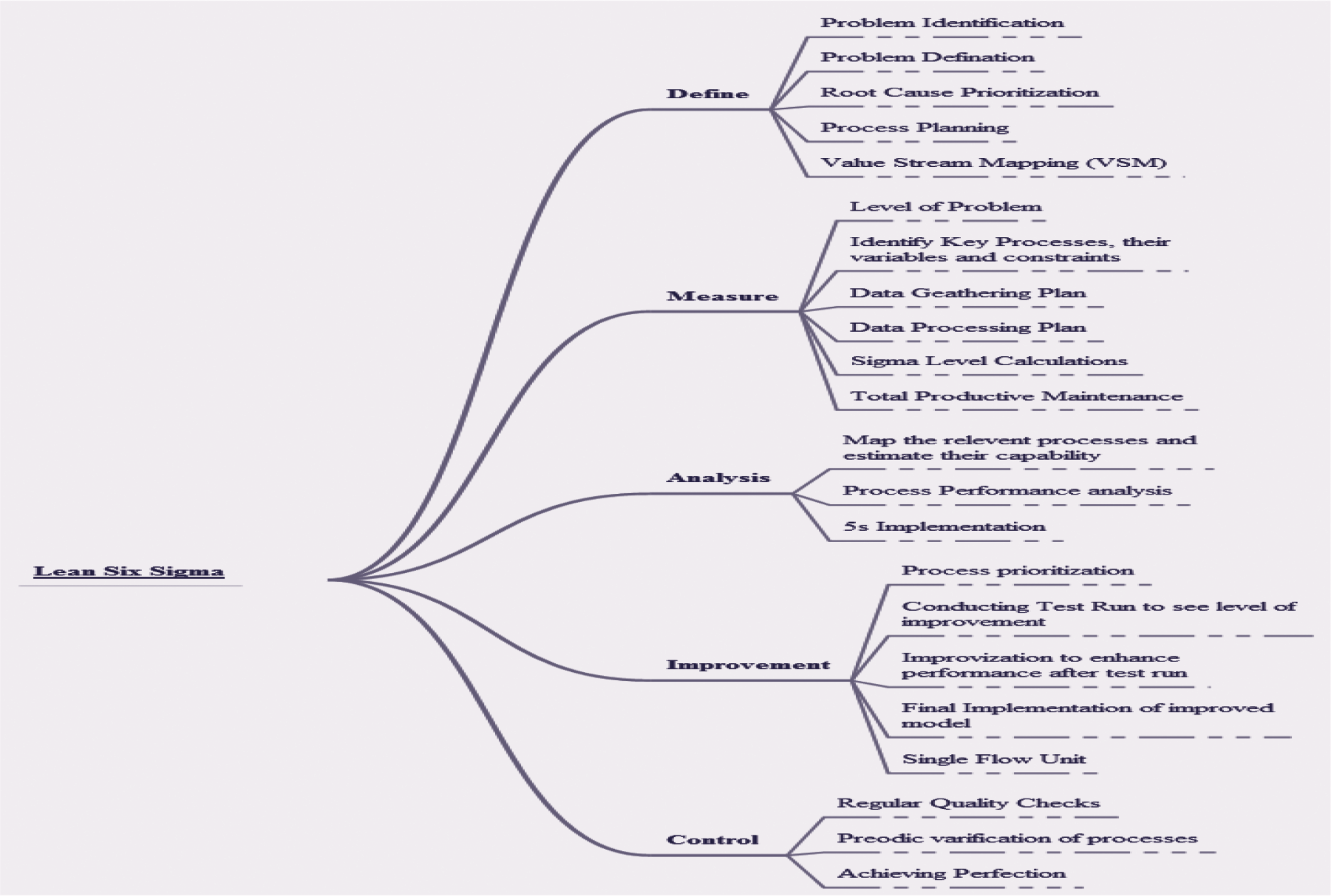

Figure no 3 : Improved Lean Six Sigma Model

8. CASE STUDY

A case study has been conducted at a bath fitting manufacturing organization situated in Mohali Punjab, along with its sister concerns is in the business of manufacturing and trading of Chrome Plated fittings. The organization is a leading manufacturer of C.P. fittings and manufactures almost every kind of C.P. fittings. The organization is having a work force of around 200 workers with annual turnover around Rs 40 Crores. The organization is ISO 19001 certified and is spread in an area of 2000 square yards.

After having a joint meeting with the engineers of that organization, it has been observed that the organization is facing the following problems in the manufacturing of some of its components Organization was having a burning problem of high rejection & rework in one of their products called "Wallmixer". Data was collected to benchmark the situation.

8.1 Nature of Problem

During this visit we deliberated on various systems/processes going on in the organization, following problems have been notified through our observation and after discussing with the engineers and the management of the organization.

1. Higher rate of scrap due to rejection during final inspection.
2. Higher reworking requirement resulting in wastage of resources
3. Saving of raw materials.

8.2 Corrective Actions

In the corrective action for the above-mentioned problems of the organization it has been recommended to the management that lean Six Sigma approach should be implemented in the industrial organization in order to reduce the scrap / reworking and to save the raw material. At the same time, it has been suggested that the number of cores produced per day can also be improved by the implementation of Lean Six Sigma approach in their organization. A fish bone diagram as shown in fig no 1 representing the four M indicates the proper utilization of Men, Machines, Methods and Materials in order to achieve perfection in the processes conducted in their organizations for the purpose of ensuring the sustainability in the present competitive world.

8.3 Implementation of Lean Six Sigma Model

Present study focuses upon the reinforcement of Lean manufacturing tools and techniques in Six Sigma in order to propose a new Lean Six Sigma model for the manufacturing industries across India. Stepwise implementation of Proposed Lean Six Sigma model has been done in the organization. Table no 2 represents the Lean Six Sigma DMAIC framework.

Table no 2: Lean Six Sigma DMAIC framework

Phase	Objectives	Key Activities
Define	Study the problems and processes in detail	Defining the Problem
		Team Formulation and assigning duties
		Designing SIPOC and Process map
		Identification of Critical to Quality Characteristics
		Identification of Key Process Output Variable
		Value Stream Mapping
Measure	Data collection for measuring process performance	Measure and analyse Key Process Output Variable
		Determine baselines and project character
Analyse	Identification of Root causes	Brainstorm and prioritize root causes
		Identify Key process Input Variables
Improve	Implementation of Prioritize Solutions	Prioritize solutions
		Validate solutions
Control	System Monitoring	Update the process control plan.
		Monitor the process for long-term affect.

Step 1

In the first step of implementation the whole process is defined in detail. It has been observed that defects like Blow holes, shrinkage, gas porosity, sand wash etc. are generated at casting stage (Shown in Fig 3). They were partially visible only after machining of part. This was the first step in which the problem is identifies and the brain storming is done in order to find out the root cause for the problem. Photographical presentation of reasons of problem can make problem more understandable and less chance of communication gap is left behind. Chance of misunderstanding and misconception regarding the current problem is highly reduced after inspection at this stage defective parts were either rejected or reworked wherever possible.

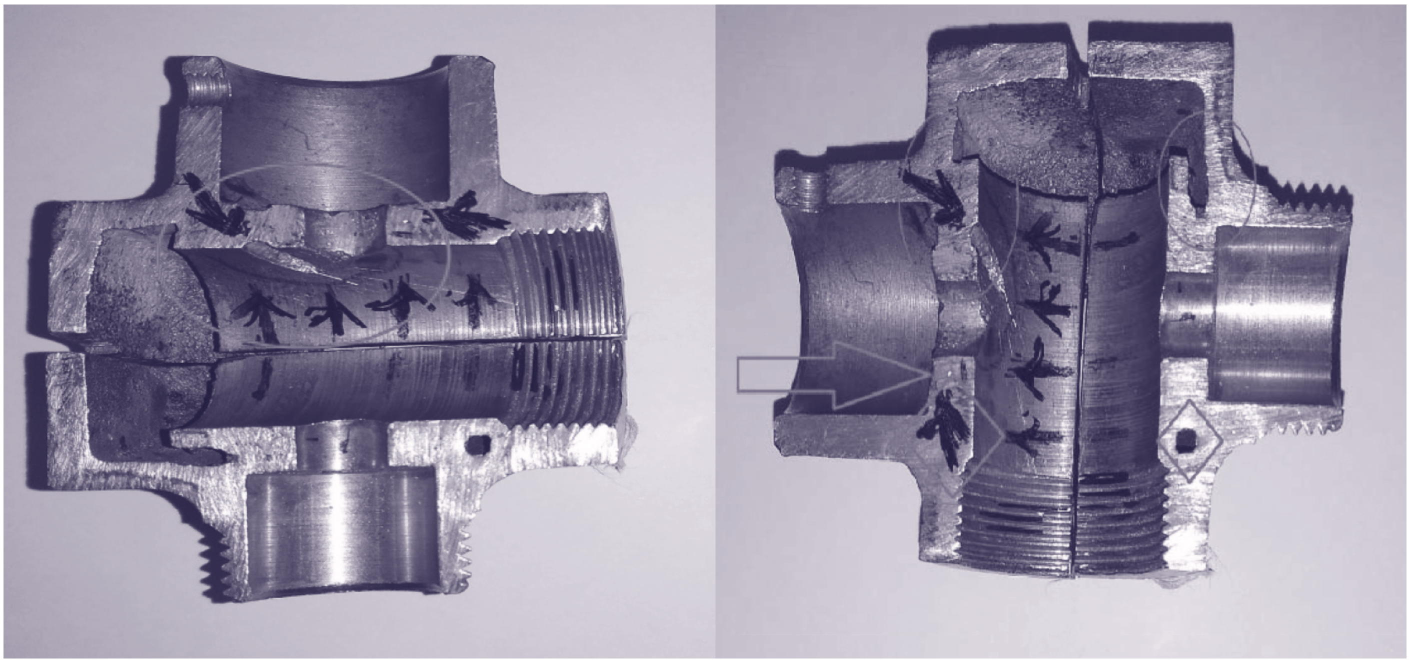

Figure 3. Cut section of Defective Part

From the define phase of the investigation it has been identified that the problem seems to have been in the casting phase of the overall process of the foundry, therefore a supplier-Input-Process-Output-Customer (SIPOC) diagram has been prepared. Table no 3 (a & b) represents the SIPOC of melting and molding processes of the present study.

Table 3 (a): SIPOC of Melting

SIPOC for Melting				
Supplier	**Input**	**Process**	**Output**	**Customer**
Supplier of Copper, Zinc and brass	Scrap Metal	Moving of Charge and Material in the furnace	Final Molten Metal/Alloy	Casting Department
	Internal return	Melting of Metal/ Alloy		
	Water			
	Electricity			

Table 3 (b): SIPOC of Moulding

SIPOC for Moulding				
Supplier	**Input**	**Process**	**Output**	**Customer**
Sand Dept.	Greensand	Transferring Molten Metal into moulds	Casting	Inspection Section
Melting Department	Cores & filters	Solidification of Molten Metal in mould	Sand Return	
	Molten Metal	Removal of Cores		
		Cleaning of Final Casting		

Afterwards Value Stream mapping of the various activities of the manufacturing unit has been done. Fig no 4 shows the Value Stream Mapping proposed.

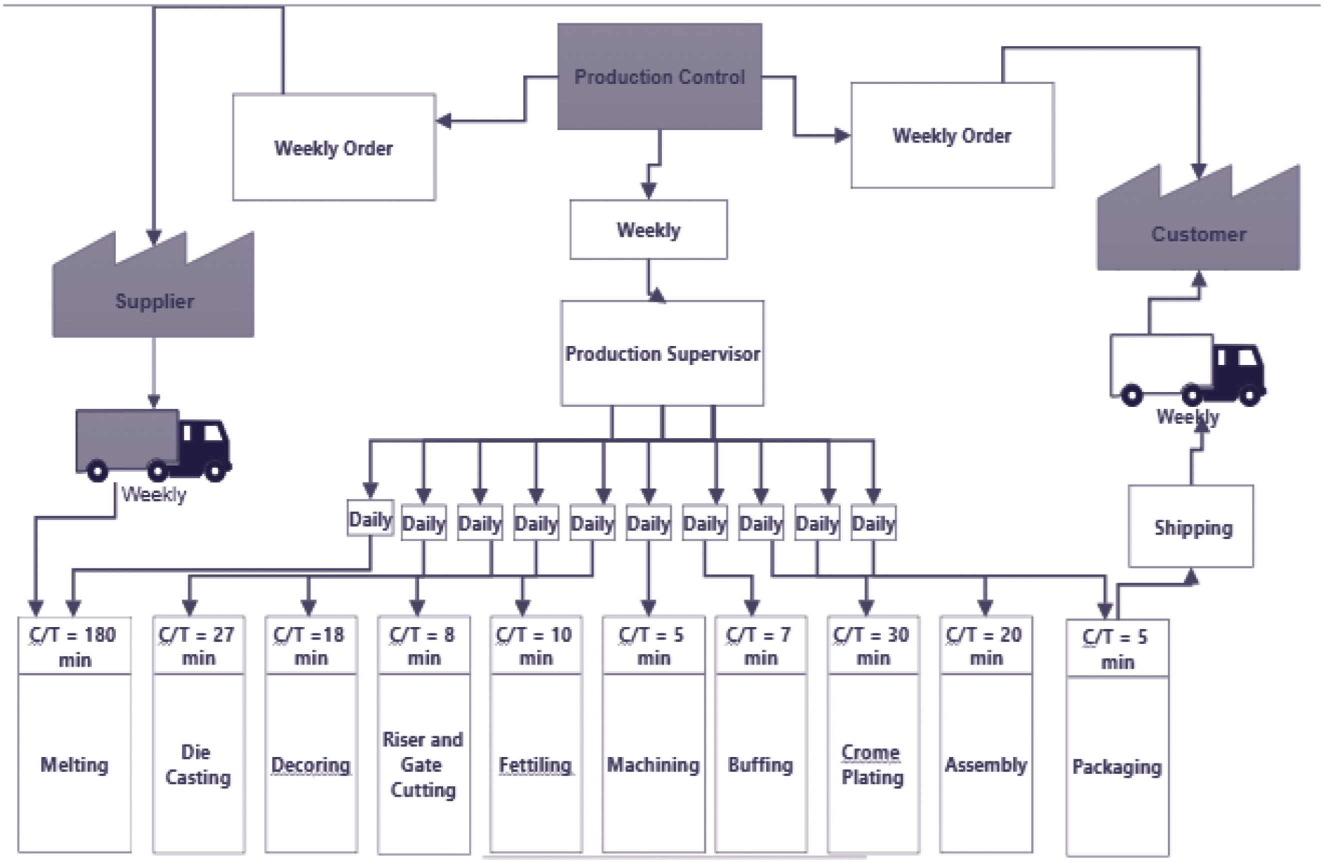

Figure no 4: Value Stream Mapping

Step 2

In the second stage of the implementation data of last four years has been gathered which revealed that rejection rate was 16.4% and rework rate was 33.08 % both on higher side. Rework is also non value adding activity and indicative of poor quality (Table no 1). It has been discussed that Lean Six Sigma is a methodology that relies on a collaborative team effort to improve performance by systematically removing waste and reducing variation. It combines lean manufacturing/lean enterprise and Six Sigma to eliminate the eight kinds of waste:

- Defects
- Over-Production
- Waiting
- Non-Utilized Talent
- Transportation
- Inventory
- Motion
- Extra-Processing

Further the data of past four months i.e Jan –Apr 2018 representing the number of rejected parts and the number of parts reworked is collected as represented in table no 4.

Table no 4: Monthly Record of Rejected / Reworked parts (Before LSS implementation)

S.No	Month	Total No. of parts produced	No. of parts rejected	Rejection Percentage (%)	No. of Parts Reworked	Rework Percentage (%)
1	Jan-18	468	88	19	143	30
2	Feb-18	531	105	20	181	34
3	Mar-18	549	99	18	162	29
4	Apr-18	568	77	13	202	35
Total		2016	369	18	688	34

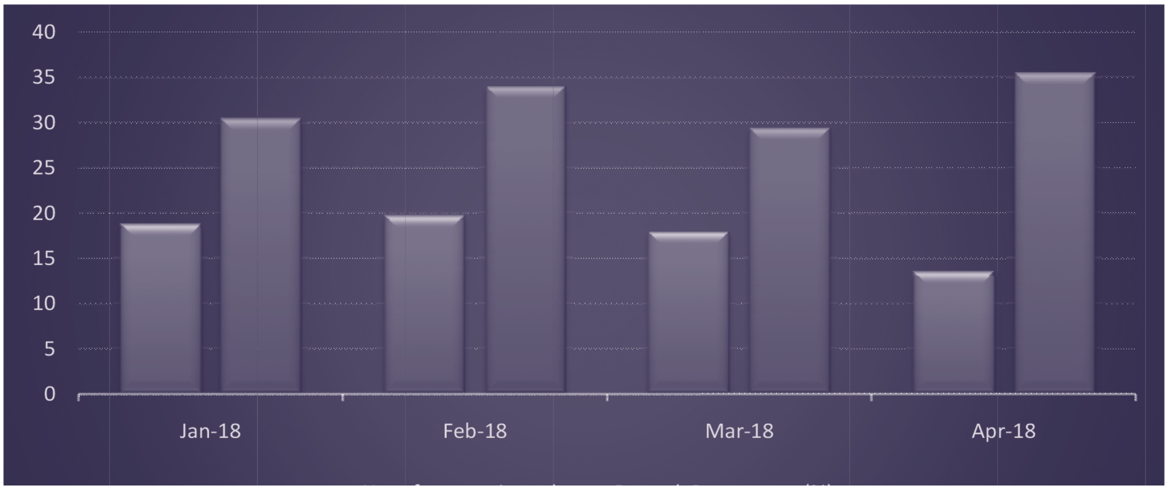

Figure no 5: Scrap Analysis by Histogram

After studying the monthly record of scrap over the past four months i.e. Jan to April 2018, it has been observed that around 19% of the total production is scraped out whereas 30% to 35% of the products are needed to be reworked, such high level of the scrap rate and reworking enhances the overall cost and expenditures of the organization. Figure no 5 reflects the bar graphs of the no of parts rejected and reworked across Jan to April 2018.

Step 3

The next question arises for this is "What are the major factors of the scrap?" there are a number of reasons for the defects has been identified, there are blow holes, shrinkage, gas porosity, sand wash, pinholes, scars and hot tears. Therefore a pereto analysis has been performed. Pareto Analysis is a statistical technique in decision-making used for the selection of a limited number of tasks that produce significant overall effect. It uses the Pareto Principle (also known as the 80/20 rule) the idea that by doing 20% of the work you can generate 80% of the benefit of doing the entire job. Table no 4 represents the pereto analysis of major casting defects.

Table 5: Pareto analysis of Major casting defects

S.No.	Casting Defects	Frequency	Cumulative Frequency	Percentage (%)
1	Blow Holes	61	61	32
2	Shrinkage	43	104	55
3	Gas Porosity	34	138	73
4	Sand Wash	26	164	86
5	Pinholes	17	181	95
6	Scares	6	187	98
7	Hot Tears	2	189	100

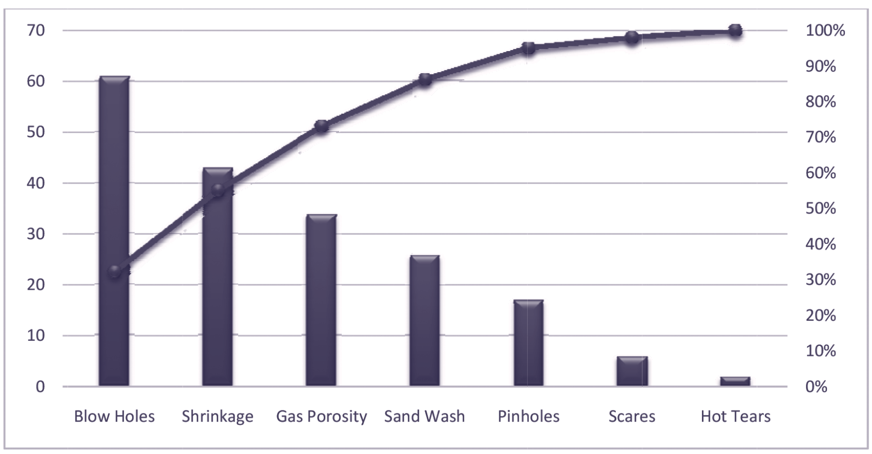

Figure no 6: Pareto Analysis for defect analysis

A proper analysis has been done to estimate the main reasons of the problem. From the graphical representation of pareto analysis in figure no 6, it has been recognized that 86% reasons for the rejection and reworking is the blow holes, shrinkage, gas porosity and sand wash. It means that work has to done to eliminate these main four casting defects in order to overcome 86% of the problems.

Step 4

Afterwards analysis of individual processes has been done in order to find the short comings in the process. Next step of the implementation of Lean Six Sigma model is improvement, process prioritization is done (Fig no 7). In this phase the proper sequencing of the processes performed during the casting were suggested and implemented in the same order as suggested in fig no 7 below. Further Graphite deposits in the core box were removed by deep acid cleaning. This helped in recreation of cavities which were not visible earlier. Cavities further minimized the solidification time of the defective cross section. Also depth of the port increased from LHS leading to further reduction in solidification time. Diameter of the core in threaded portion was increased by few microns by polishing of the core box at the said location.in order to control the whole process in the routine activities, regular quality checks and the periodic verifications of the process are done.

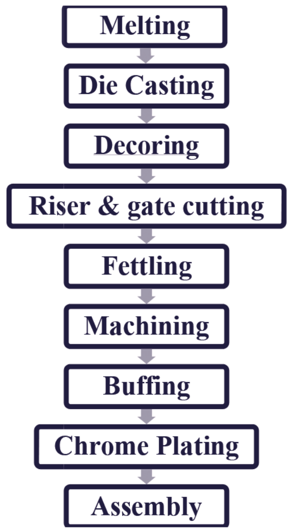

Figure no 7: Process flow chart

After the implementation as recommended above, significant improvements in the results were noticed.

Table no 6: Monthly Record of Rejected / Reworked parts (After LSS implementation).

S.No	Month	Total No. of parts produced	No. of parts rejected	Rejection Percentage (%)	No. of Parts Reworked	Rework Percentage (%)
1	May-18	532	33	6	41	8
2	Jun-18	572	27	5	39	7
3	Jul-18	589	19	3	31	5
Total		1693	79	5	111	7

After the implementation of the Lean Six Sigma recommendations to the organization, number of parts rejected and number of parts reworked were observed over the three months i.e May to July 2018 (as shown in table no 6). From the observations it has been noticed that there is significant improvement in the no of parts rejected and reworked in these three months, as the rejection percentage is improved to 5% from 18% and the number of parts reworked are reduced to 7% which was 34% before the implementation of Lean Six Sigma.

Figure no 8: represents the comparison of percentage of material rejected / reworked before and after the implementation of Lean Six Sigma in their organization.

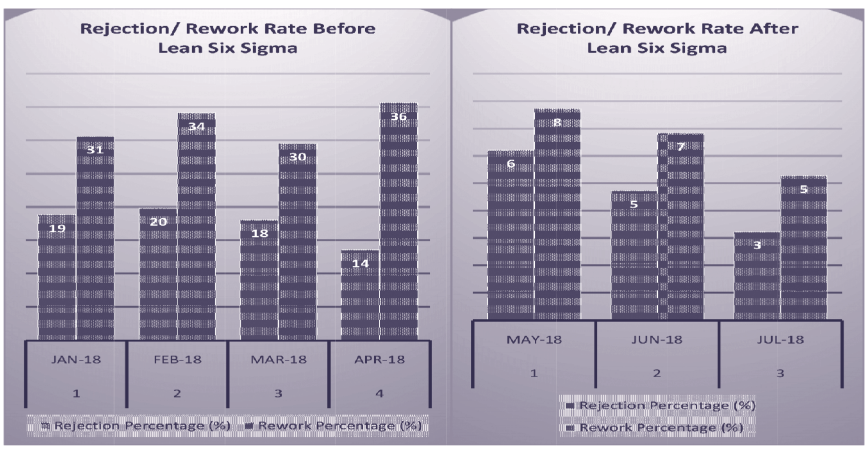

Figure no 8: Comparison of Rejection / Rework before and after implementation of Lean Six Sigma

A Significant improvement in the quality of the product has been achieved after the implementation of Lean Six Sigma in that organization. Fig no 9 represents the image of the final product produced after systematically implementation of the proposed waste management technique, i.e Lean Six Sigma. Further the overall sigma value of the process is assessed by using the simple software of sigma level calculator available on internet. Sigma level measurements are shown in table no 7.

Table no 7: Sigma calculator (detail of process)

Production Result in May to July 2018		
Total no of Parts Produced 1693		
S.NO	**Casting Defects**	**Frequency**
1	Blow Holes	61
2	Shrinkage	43
3	Gas Porosity	34
4	Sand Wash	26
5	Pinholes	17
6	Scares	6
7	Hot Tears	2
Total Scrap		**189**
No of Opportunities		7
DPMO		15948
Sigma Level of Process		**3.65**
Yield		98.41%

In order to monitor overall manufacturing, the production data of May to July 2018 is considered and defects per million opportunities (DPMO) has been calculated, which comes out to be 15948 after calculation., further the sigma value of the overall process is calculated as 3.65.

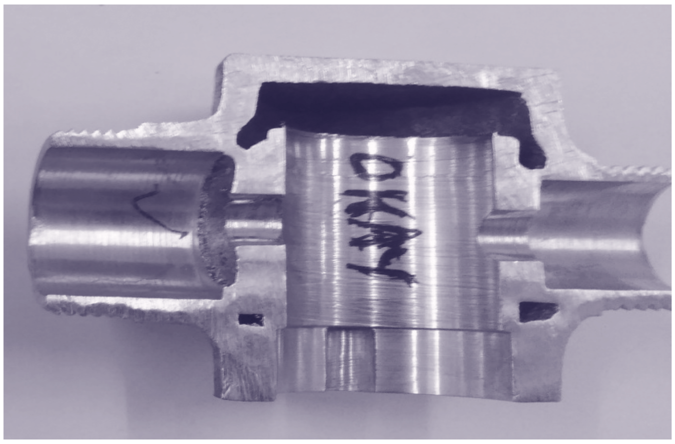

Figure no 9. Cut section of Part Wallmixer after Improvements in corebox and die

Step 5:

In the next phase of achieving perfection it has been advised to the organization to implement the quality standards. All manufacturing industries are largely dependent on their machines, and sometimes very creation situated occurs due to the sudden breakdown of the machinery during the working. Therefore it becomes important to have periodic maintenance of the machines at different stages. Hence it becomes completely necessary for such organizations to implement Total Productive Maintenance (TPM) in their organizations in order to improving the integrity of production and quality systems through the machines, equipment, employees and the supporting processes. TPM can be of great value and its target is to improve core business processes.

Therefore, a schedule of regular maintenance of machines and equipment restoration is implemented with the discussed with the management of the organization. Afterwards adequate sequencing of the processes is done and some changes has been proposed in the layout of the organization in order to reduce the flow times of the product on shop floor.

9. CONCLUSION

Present study has been undertaken in order to design a theoretical Lean Six Sigma model which can be implemented in any manufacturing organization in order to improvise the waste management. Initially the various factors/causes responsible for the waste has been identified and complete analysis has been done in order to find out the root cause for the same. Further the study of various tools and techniques has been carried out and a synergy of two waste management techniques has been done, i.e. Lean manufacturing and Six Sigma. Various tools and techniques associated with Lean manufacturing and six Sigma has been identified and studied in detail and the tools of Lean manufacturing has been reinforced in the Six Sigma approach (DMAIC approach), and an advanced model of Lean Six Sigma is proposed which can be applicable in any kind of manufacturing organization. Further implementation of Lean Six Sigma model in the foundry industry results rigorous pursuit of the reduction of variations recorded in various process to achieve perfection that can affect the primary concern or best line of the association and increment consumer satisfaction on each working ground. Step by step implementation of various phases of Lean Six Sigma model has been done At the end, we can say "operation measurement is just like a necessary evil" and must be involved before improve phase on the grounds that however it don't bring any change yet it reveal to us the bearing and key factors that would give mind blowing results. We can't stay away from measure stage however the main thing that we can do is, to lessen the time and exertion by appropriate implementation of task estimation apparatuses/ methods by fruitful execution of suggested framework.

REFERENCES:

[1] L. Alessandro, and A. Jiju, (2011) "Standards for Lean Six Sigma certification" International Journal of Productivity and Performance Management, Vol. 61, No. 1, 2012 pp. 110-120

[2] D. A. Aaker, and B. Macarenhas, (1984), "The need for strategic flexibility", Journal of Business Strategy, Vol. 5 No. 2, pp. 74-82.

[3] R. Amit and P. J. Schoemaker, (1993), "Strategic assets and organizational rent", Strategic Management Journal, Vol. 14 No. 1, pp. 33-46.

[4] A. Singla, and Ahuja, IPS. (2018) "Technology push and demand pull practices for achieving sustainable development in manufacturing industries", Journal of

Manufacturing Technology Management, Vol. 29 Issue: 2, pp.240-272.

[5] J. N. Ambe, (2017) "The SWOT model's utility in evaluating energy technology: Illustrative application of a modified version to assess the sawdust cookstove's sustainability in Sub-Saharan Africa" Elesvire journal of Renewable and Sustainable Energy Reviews Volume 69: 313-323.

[6] H. Ansoff, (1965), Corporate Strategy: An Analytic Approach to Business Policy For Growth and Expansion, McGraw-Hill, New York, NY.

[7] H. Ansoff, and R. G. Brandenburg, (1971), "A language for organizational design: parts I and II", Management Science, Vol. 17 No. 12, pp. 705-731.

[8] Andersson, Roy, E. Henrik, and T. Håkan. (2006). "Similarities and Differences between TQM, Six Sigma and Lean." The TQM Magazine 18 (3): 282–296.

[9] J. Antony, (2011) "Six Sigma vs Lean: Some Perspectives from Leading Academics and Practitioners", International Journal of Productivity and Performance Management, Vol.60, Issue 2 pp 185–190.

[10] A. J. Thomas, (2007). "Creating sustainable small to medium enterprises through technological innovation". Journal of Engineering Manufacture, Vol. 2, No. 2, pp 513–528.

[11] J. Andrew (2014),"An empirical analysis of Lean Six Sigma implementation in SMEs – a migratory perspective", International Journal of Quality & Reliability Management, Vol. 31, No. 8 pp. 888 – 905.

[12] Ben Clegg, M.P.J. Pepper, T.A. Spedding, (2010),"The evolution of lean Six Sigma", International Journal of Quality & Reliability Management, Vol. 27, No. 2, pp. 138-155.

[13] J. Barney, (2001), "Resource-based theories of competitive advantage: a ten-year retrospective on the resource-based view", Journal of Management, Vol. 27 No. 6, pp. 643-650.

[14] R. Beach, P. M. Alan, and Price, D.H.R. (2000), "Manufacturing operations and strategic flexibility: survey and cases", International Journal of Operation and Production Management, Vol. 30 No. 1, pp. 7-30.

[15] V. L. Bertalanffy, (1973), General System Theory, Penguin University Books, London. R. A. Bettis, and M.A. Hitt, (1995), "The new competitive landscape", Strategic Management Journal, Vol. 16, pp. 7-19.

[16] E. H. Bowman, and D. Hurry, (1993), "Strategy through the option lens: an integrated view of resource investments and the incremental-choice process", Academy of Management Review, Vol. 18 No. 4, pp. 760-782.

[17] S. Callaway, K. Celuch, and G. Murphy, (2009). Strategic flexibility and SMEs: The role of information technology for managing internal and external relations. New England Journal of Entrepreneurship, 12(1), pp.9-17.

[18] S. Chang, N. Lin, and C. Sheu, (2002), "Aligning manufacturing flexibility with environmental uncertainty: evidence from high technology component manufacturers in Taiwan", International Journal of Production Research, Vol. 40, No. 18, pp. 4765-4780.

[19] G. A. Churchill, (1995), Marketing Research: Methodological Foundations, Dryden, London. Collis, D.J. and Montgomery, C.A. (1995), "Competing on resources: strategy in the 1990s", Harvard Business Review, Vol. 73 No. 4, pp. 118-128.

[20] Chang-YuanGao. (2011) "Consolidating SWOT analysis with nonhomogeneous uncertain preference information" Elesvire journal of knowledge based systems, Vol. 24, No. 6, pp 796-808.

[21] Chih,H, and Wei-Luo (2017) "Identifying key performance factors for sustainability development of SMEs – integrating QFD and fuzzy MADM methods" Journal of Cleaner Production. Vol. 161, No. 10, pp 629-645.

[22] D. Everton. E. Sergio. Gouvea da Costa, Edson Pinheiro de Lima and Paula Andrea da Rosa Garbuio "Lean, Six Sigma and Lean Six Sigma: an analysis based on operations strategy" International Journal of Production Research, Vol. 52, Issue 3, pp 804–824.

[23] Hee-Kweon Yoon & Jai-Hyun Byun (2012) A Design for Six Sigma: A Robust Tool in Systems Engineering Process. Industrial Engineering and Management Systems. Vol 11, No 4, pp.346-352.

[24] M. John, A. Edward (2012),"The continuing evolution of Lean Six Sigma", The TQM Journal, Vol. 24, Issue 6, pp. 542-555.

[25] B. Jaiprakash. and K. Singh. (2014),"Lean manufacturing: literature review and research issues", International Journal of Operations & Production Management, Vol. 34, Iss 7, pp. 876-940.

[26] R. L. Manisha Lande, Shrivastava, Dinesh Seth, (2016) "Critical success factors for Lean Six Sigma in SMEs (small and medium enterprises)", The TQM Journal, Vol. 28 Issue: 4, pp.613-635.

[27] J. Sarkis & J. Dijkshoorn (2007) Relationships between solid waste management performance and environmental practice adoption in Welsh small and medium-sized enterprises (SMEs), International Journal of Production Research, 45:21, 4989-5015.

[28] M. Lozi "Small scale Industries in Jordan in the Globalization", Journal of social science publication, Vol.4, No.2, pp.98-102, 2008.

[29] M.P.J. Pepper, T.A. Spedding, (2010),"The evolution of lean Six Sigma", International Journal of Quality & Reliability Management, Vol. 27 Iss 2 pp. 138-155.

[30] Nashmi Chugani, Vikas Kumar, Jose Arturo Garza-Reyes, Luis Rocha-Lona, Arvind Upadhyay, (2017) "Investigating the green impact of Lean, Six Sigma and

Lean Six Sigma: A systematic literature review", International Journal of Lean Six Sigma, Vol. 8 Issue: 1, pp.7-32.

[31] C. Okoli, and K. Schabram, (2010), "A guide to conducting a systematic literature review of information systems research", Sprouts: Working Papers on Information Systems, 26: 1-51.

[32] J. Poonsook, P. Kusuma and H. Pong (2005). An application of Total Quality Management for Thai Communities Knowledge Management Systems, Proceeding of the Fourth International Conference on Business, Bangkok, Thailand. SIDO Half Century by DCSSI, Govt. of India, 2004 and Economic Survey, Govt. of India, 2006-07, Feb.

[33] G. Spina, E. Bartezzaghi, A. Bert, R. Cagliano, D. Draaijer, and H. Boer, (1996), "Strategically flexible production: the multi-focused manufacturing paradigm", International Journal of Operation and Production Management, Vol. 16 No. 11, pp. 20-41.

[34] Investigating the readiness of people in manufacturing SMEs to embark on Lean Six Sigma projects: An empirical study in the German manufacturing sector (2016), International Journal of Operations & Production Management, Vol. 36 Iss 8 pp. 850-878.

[35] A. Saja and J. Antony, (2014),"Critical failure factors of Lean Six Sigma: a systematic literature review", International Journal of Quality & Reliability Management, Vol. 31, Issue 9, pp. 1012-1030.

[36] Sima Ghayebloo, Kamran Shahanaghi, (2010) "Determining maintenance system requirements by viewpoint of reliability and lean thinking: a MODM approach", Journal of Quality in Maintenance Engineering, Vol. 16 Issue: 1, pp.89-106.

[37] D. Tranfield, D. Denyer, and P. Smart, (2003), "Towards a methodology for developing evidence informed management knowledge by means of systematic review", British Journal of Management, Vol.14, Issue 3, pp. 207-222.

[38] C. Meredith Zott, (2003), "Dynamic capabilities and the emergence of intra-industry differential firm performance: insights from a simulation study", Strategic Management Journal, Vol. 24, No. 2, pp. 97-125.

[39] G. McNamara, P. M. Vaaler and C. Devers, (2003), "Same as it ever was: the search for evidence of increasing hypercompetition", Strategic Management Journal, Vol. 24 No. 3, pp. 261-278.

[40] M. Kumar, J. Antony, R. K. Singh, M. K. Tiwari & D. Perry (2006) Implementing the Lean Sigma framework in an Indian SME: a case study, Production Planning & Control: The Management of Operations, Vol. 17 Issue 4, pp 407-423.

[41] T. Yang, and C. Li, (2011), "Competence exploration and exploitation in new product development: the moderating effects of environmental dynamism and competitiveness", Management Decision, Vol. 49 No. 9, pp. 1444-1470.

[42] C.C. Tsai, and C. C. Chen. (2006). "Making Decision To Evaluate Process Capability Index C p with Fuzzy Numbers." The International Journal of Advanced Manufacturing Technology, Vol. 30, Issue 3, pp 334–339

[43] RM Chandima Ratnayake Osman Chaudry, (2017)," Maintaining sustainable performance in operating petroleum assets via a Lean-Six-Sigma approach: a case study from engineering support services", International Journal of Lean Six Sigma, Vol.8, Issue 3, pp 102-117

[44] S. Michael Gnanaraj, S.R. Devadasan, R. Murugesh & C.G. Sreenivasa (2012) Sensitisation of SMEs towards the implementation of Lean Six Sigma – an initialisation in a cylinder frames manufacturing Indian SME, Production Planning & Control: The Management of Operations, Vol. 23, Issue 8, pp 599-608.

[45] S.J. Thanki Jitesh Thakkar, (2014),"Status of lean manufacturing practices in Indian industries and government initiatives", Journal of Manufacturing Technology Management. 25 (5): 655 – 675.

[46] Six Sigma: a systematic literature review", International Journal of Quality & Reliability Management, Vol. 31 Iss 9 pp. 1012 – 1030.

[47] D. Singh, J. Singh. and Ahuja. IPS, (2013),"An empirical investigation of dynamic capabilities in managing strategic flexibility in manufacturing organizations", Management Decision, Vol. 51, pp. 1442 – 1461.

[48] S.G. Gautham & Anesh Ramiya R. (2011) Implementing lean sigma framework in an Indian automotive valves manufacturing organisation: a case study, Production Planning &Control: The Management of Operations, Vol. 22, Issue 7, pp 708-722.

[49] Pius,A. and Geoff, N. (2012) A fuzzy-logic advisory system for lean manufacturing within SMEs, International Journal of Computer Integrated Manufacturing, Vol. 9, Issue 6, pp 839-852.

[50] W Derks, R Weston, A West, R Harrison & D Shorter (2003) Role of workflow management systems in product engineering, International Journal of Production Research, Vol 41, Issue 15, pp 3393-3418.

[51] S. Yang, J. Zheng, T. Li, and A. Zhang, (2008), "Empirical research on dynamic capability and relationship quality and cooperation performance", 15th International Conference on Management Science and Engineering, September 10-12, 2008, Long Beach, CA, pp. 431-436.

AUTHORS

Harsimran Singh Sodhi, IKG Punjab Technical University, Jandhar, Punjab
Email id: harsimransinghsodhi@yahoo.com

Doordarshi Singh, BBSBEC, Fatehgarh Sahib, Punjab

Bikram Jit Singh, Maharishi Markendeshwar University, Ambala, Haryana