

REVIEW OF INTEGRATED APPROACH OF LEAN, SIX SIGMA AND THEORY OF CONSTRAINTS

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Abstract

In any organization Continuous Improvement methods are developed and deployed with some standards to a sustained period to gain profitability, increase market share, and improve brand value and to survive in the market. In this research, an attempt is made for demonstrating the integrated concept of Lean & Six Sigma and Lean & Six Sigma and Theory of Constraints to get the maximum throughput which is the primary goal of any Industry. This paper review the practical implication of Lean management, Six sigma and Theory of Constraints in industry. The globalization and competitive business environment creates a hunt for new sources of sustainable developments. It is investigated to show the research carried out for efficiency improvement on the performance achievements of the team goals. There can be various method to calculate the ranking based on various performance levels.

Keywords: FMEA, TPM, Quality, Reliability, Productivity, TOC, Lean Management, Six Sigma.

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1. INTRODUCTION

The current cut-throat business scenario forces the industries to innovate and improve process to accelerate the product development. The process improvement methods implemented in product development helps in quality, velocity and sustainability in long run. The coordination between the industries and research are the need for the current industries to improve in their process efficiency. Detailed literature survey is carried out on the process improvement methods implemented in industries across different domains. Continuous improvements methods are concerned with the management organizational activities for improving the sequence of process. There is a steep increase in the implementation of the combined approach of methods for the process improvement by the industries. Researchers conduct lot of literature in the field of integrated approach for the continuous improvements methods to carry out their research and conclude the benefits (Dave Nave, 2002). Many researchers carried out their work in the field of process improvement and industries to spend millions of dollars in the process improvements.

Continuous improvement methods implemented in the industries could save million of dollars. Industries look for alternative approach of solving the problem beyond the conventional methods. The future need for the industries is to get an integrated approach in the process improvement to improve their efficiency. Still there is lot of scope for industries to improve the process and products. The objective of this thesis literature survey is to evolve the research gap between the process improvement methods. The literature review is categorised into three sub sections to get more clarity as general techniques implemented alone to benefit the system as Continuous improvements methods, Lean Manufacturing & Six Sigma, second one with either of two techniques of Lean or six sigma or TOC implemented and third one with integration of lean, six sigma and TOC implementation to benefit the system.

Continuous improvements methods

Just in Time(JIT) is a CI method for optimized manufacturing improvement system started in one of the leading car manufacturing company Toyota motors. Lean naming definition was introduced by Taylor as reducing waste. Six Sigma is the well-known CI method for getting better quality in the business operations and it was introduced and implemented in leading telecom company Motorola (Ehie and Sawhney,2006).

Most of the researcher stated that continues improvement with implementation of either of the techniques like particle swarm optimization (PSO), simulated annealing (SA), artificial neural network (ANN), design of experiments (DOE), multi-layer perception(MLP), genetic algorithm (GA) and regression analysis(RA) resulted in the efficiency improvement of their system. For the purpose of improving the efficiency and production output of the industries, few researchers have developed model to improve the major factors in the company performance evaluation. These performance achievements of the company are carried out with data envelopment analysis to provide a suggestions system. Suitable proposal are executed with inputoriented model and better output which in turn depends upon the performance of manufacturing units(Jafarpour et al. 2014).

These manufacturing units are checked to safety and environmental factor, while manufacturing products in the manufacturing industries. The procedures, processes and operations should not affect the environmental aspects like design for environment, green supply chain management, environmental management system and the life cycle analysis. These new proposed models are focused to improve the efficiency of the system and improving the environmental factors in the manufacturing industries (Tanwer et al. 2014, and Maasouman, 2015)

In regard to improving the efficiency and clarity of the system, few of the researchers have implemented algorithms and techniques. Also, carried out a detailed study on heuristic approaches and compared merits and demerits of similar methods and finally concluded that it is inefficient of using heuristic approaches for the case of large size problems with multiple constraints. The PSO algorithm can be used for getting solution for the product mix optimization problem. The key outputs results from the suggested PSO are compared with similar approaches to the best outcome of the system. New developed PSO algorithm predicts the maximum results as compared to other similar methods and concluded that traditional TOC approach and TS-SA approach methods are not feasible (Rezaie et al. 2010). Few conventional GA, a heuristic approach uses techniques and methods like differential mutation probability, elitism and standard local search method. The derived optimal solutions for mass

production and batch machine loading approaches results in minimum computational cost. The newly developed approach is efficient in managing large and difficult machine loading problems in the manufacturing units (Ginoria et al. 2014). The framework, based on ANN, DOE, MLP and RA for calculating the housing electricity consumption by considering environmental affecting factors, is discussed. These frame work of environmental affecting factors are analysed by conventional approach of asking standard questions. The new approach of the research is the integration of ANN, RA and DOE for the efficient modelling reduces the housing electricity usage(Azadeh et al. 2014). In addition, improvements methods like total productivity maintenance (TPM), total quality management (TQM) and 5S are also investigated by many authors and few of them are summarised. The 5S implementation practices across different employee levels of industry and the benefits &the contributions to the organisations are summarized. Also, presented the systematic 5S procedure and implementation guidelines recommended by experts and researchers. The most influencing factors that improve 5S implementation in the business are selected and analysed in detail(Randhawa and Ahuja 2017). Chen et al. (2017) stated that Taiwan government created inclusive environment for the industries to execute business operations effectively. Also examined principles that can help security of the industry by providing better solution, customer satisfaction and loyalty. Further, he discussed a case study approach by considering 516 security industries across different region in Taiwan, as the participants in his survey. Finally, concluded that the customer satisfaction and the TQM philosophy, positively influences customer loyalty.

Lean manufacturing

Lean processes have been generally used to progress velocity in the manufacturing industries. Most researchers summarised the critical success factors (CSFs) of lean implementation in the system to improve the velocity. The results demonstrate the evidence for improvement in system by implementing the lean and lean success which concludes the proposed methodology of implementing lean (Noori, 2014; Zhang and Chen, 2016). Anderson et al. (2015) and Soliman and Saurin (2017) carried out their research in implementing the lean in their work environment to investigate the outcome of the system. The research focuses on challenges and experiences in implementing the Lean. The research is carried out with a case study using data collection from the sector. The results are evident that there are some useful benefits of using lean are better communication, workflow and organisation policy. The lean implementation served as an eye-opener and created environment that employees realised a huge amount of waste of time and money in the daily operations. The findings also indicate that there are some advantages and disadvantages of lean in the sector. Also states that there is no hard follow-ups, lack of interest from senior management and less inclination to holistic view were the main issues in the company. Aragon and Ros-McDonnell (2015) described a project to increase the efficiency of the food manufacturer by applying several lean production control methodology techniques. The food manufacturer has decided to increase the production in several specific sub-products within their organization, where less knowledge and lack of productivity procedures were observed in some of their batch shifts. Also explained the lean implementation steps as diagnosis, improvement ideas proposed and implementation of work procedures in the organization. Final

recommendations made to the company were suggested that implementation of lean culture and production control methods gradually increase the performance of the whole company.

Six Sigma

From the detailed literature review, it is evident that six sigma is implemented by many researchers and industries to evaluate their system efficiency and concluded that there is quantifiable improvement in the outcome of the system. Six Sigma, the wellknown approach, with five stages of implementation like define, measure, analyse, improve, and control(DMAIC), helps the management to improve the performance of manufacturing industries. In the phases of analyse and improve, design of experiments is implemented by using Taguchi's L series experimental approach.

DMAIC approach coupled with statistical technique is found to be effective in improving the performance of manufacturing products (Al-Refaie and Al-Hmaideen 2014). DMAIC is the most common approach among the researcher and academician to improve the education system and frame guidelines for implementation of six sigma technique. Arafeh(2016) implemented the Six Sigma (SS) methodology to improve the effectiveness of the English language for the non-native English speaking students. The cause and effect diagrams and quality function deployment have been successfully implemented within the Six Sigma DMAIC work flow instructions in the school to improve the effectiveness of students in English communication and teaching process. The principle motive is to guide and educate quality improvement tools to improve student performance, better understanding between the school management, teachers and parents. De Mast and Lokkerbol (2012) stated that DMAIC method in Six Sigma is often described as an approach for problem solving. They compared critically the DMAIC procedure with some scientific problems for solving similar kind of works. They also state the characterization of the system and explained various problems present in executing the DMAIC and also identified problems in which DMAIC is not effective. The most effective statistical analysis and empirical validation is DMAIC, which is used in solving the most critical problem in the industries. Potra and Pugna(2015) implemented the Design for Six Sigma (DFSS) for a case study problem in industry so as to introduce a new product. The approach built a positive note on the quality for the launch of new products, new workflow procedure and services of the products. The error free design with all validations is the most influencing success factor for manufacturing industries. Also made an attempt to improve the efficiency of the sales and market share in a cross disciplinary approach with the introduction of DFSS. The quality attributes are customer engagement and adequate design. He explained sustained value and innovation for sales operation sustainability in the globalization. They also discussed the outcome of the case study when DFSS is used in marketing campaign with structured layout of DFSS plan.

Kumar et al. (2008) stated that Six Sigma is at the top priority of implementing in the manufacturing industries to reduce cost and improve productivity. They also stated that most of the manufacturing industries execute thousands of Six Sigma improvement projects year on year. This project execution expects a considerable investment in improving the overall productivity. Also, Six Sigma implementation requires a continuous monitoring to get the level of profits and benefits, more than the capital cost. They proposed two optimization models that are used to help top management for selecting the best process improvement techniques. They framed

the models for multi-stage, asynchronous manufacturing process that gives rise to high quality at the early stages of each sub process. The proposed procedure concludes that an investment cost and outcome the system leads to high sales and revenue. Also explains that implementation of the optimization models using Six Sigma may not be cost effective in some scenarios. Parast (2011) and Mishra and Sharma (2017) developed a conceptual and theoretical framework for the Six Sigma projects based on the innovation and performance of the company. Also proposed that Six Sigma project will give better roadmap on the technological innovation of the company in a long run. Also they are beneficial for old primitive companies that focus on the conventional products. Generally, Six Sigma programs are focused on reducing variance and increasing efficiency. These initiatives are ineffective in dynamic environments, where there is a rapid increase in technological up gradation. Six Sigma programs can be effective to catch up the high demanding innovation. Accordingly, executing six sigma projects in quick turnaround conditions with high demanding innovation and continuous process change may be a challenging one and may be ineffective in the expected results. They proposed few theories from process management and quality management to address the effect of Six Sigma projects on demanding innovation and performance outcome of the company.

Few research authors have concluded that six sigma is implemented on large scale in several industries and got benefited with long term results. This process influences the core working process in a better way. With implementation of six sigma, project can be completed on time and increases the organizational performance. The outcome of the case study conveys that usage of Six Sigma completely impacts operational performance of the employees and process outcome. Also concluded there was rapid increase in the employee productivity, under both static and dynamic approach. Also, Six Sigma implementation provides benefits in terms of improvement in the asset management, return on investment and operational effectiveness.

Shafer and Moeller (2012) and Sagnak and Kazancoglu(2016) investigated the impact and the outcome of adopting Six Sigma in the corporate performance measures. They also stated that there are comparatively huge volume of companies and increasing community of unreliable evidence pertaining to the benefits of executing Six Sigma. They conducted systematic survey and precise research investigation on 84 Six Sigma implemented companies that include different types manufacturing industries, for better utilization. They concluded that company ensures the validity of their comparisons, and investigation on the impact of implementing Six Sigma on the performance with the help of an event case study continued for ten years life span. The ten year validation seems to be the best duration for the analysis and the first three years without Six Sigma implementation to measure the actual performance, the next phase with 1 year for the Six Sigma implementation and finally last phase with six years to validate the benefits of the process implemented. They also validate the impact of incorporating SS on business efficiency and measures the most critical factors, i.e., operating income to that of net company assets, operating income to that of the operational cost of the sales, net sales to that of net company assets and net volume of sales to that of the number of employees.

Sin et al. (2015) and Mousa (2013) stated that Six Sigma is a process improvement method that helps business to increase organizational performance as well as end user requirement. It reduces the operational expenses and directly increases revenue. From the study of research practitioners, it is evident that Six Sigma implementation

results in increased industrial output. Also stated that most of the companies carried out less volume of empirical work in six sigma domain. They also concluded that detailed analysis on how Six Sigma helps in improving the business performance is not evident. They explained the strong bonding between Six Sigma and organizational performance in a better way with the help of a case study problem. Also, they discussed Six Sigma implementation by integrating organizational core domain area and experts knowledge. Frame work for a theoretical research approach is created based on the selected literature. Also, they investigated the comparison and relationship between organizational knowledge creation processes (socialization, externalization, combination, and internalization) in line to DMAIC work flow procedure. Also, studied various factors influencing the completion of the project, and analysed the organizational performance using structural equation modelling approach.

Theory of constraints

Theory of Constraints (TOC) is also a continuous improvement method combined with management philosophy that concentrates on efficiency improvement of the industries. TOC explains that a chain(continuous link) is not stronger than its weakest link(Goldratt and Cox, 1984). With the help of a case study, Rand (2000) explained that TOC is a management philosophy for CPM/PERT problem and executed a complete analysis. Also explained that critical chain concepts can be implemented in the industries to improve the performance. Jin et al. (2009) carried out a detailed study on the implementation of TOC with various business organizations to improve their performance. They explained the importance of strategic questions like “what to change”, “what to change to”, “how to cause the change and overcome resistance to change”. Plenert (1993) demonstrated a procedure for theory of constraints. He demonstrated that TOC based course of action is not efficient, when multiple constrained resources exist in the system. He also explained that the fox model helps on a point in predicting the time consumed by the system to complete the task. Linearinteger programming is a most appropriate planning tool and enables to achieve the TOC targets of maximizing throughput. Linhares (2009) analyzed the conventional product mix problems with the help of a case study containing four different examples. There are some scenarios in which the optimum product mix problems include products where profit as well as the net outcome ratio throughput per constraint time is less. He also mentioned that the best outcome of results is calculated for more occurrences with high quality given by advanced heuristics very similar to GA that have been under research. He conveys that TOC philosophy should be properly used to industries with the combined effect of other cases involved in the integer production approach procedures. Finally he concluded that the new process implemented in the product-mix decision should not create bottle neck.

Watson et al. (2007) explains that theory of constraints crossed twenty five years from the stage of initial implementation by Goldratt. Initially originated as a scheduling tool that changed into a management philosophy with lot of strategic approach and set instructions to achieve throughout. TOC has been implemented by all the community people like practitioners and academicians to gain benefit. They also explained the development and the importance of what has been successfully accomplished and what is the scope for improvement. Singh et al. (2006) stated that standard heuristic techniques or Artificial Intelligence techniques with latest optimization tools to derive the required optimal solutions. They developed the main objectives of new algorithm called psycho-

clonal. They carried research to study the principles of artificial immune system and the well-known behavioural theory called Maslow's hierarchy theory. They also explained the computational approach for experiments carried out and the advantages of proposed heuristic based on a given parameters. They concluded that outcome achieved are far more better than the result obtained from TOC heuristic, revised theory of constraint heuristic(RTOC), integer linear programming (ILP) and tabu search method.

Wei et al. (2002) explained the major bottlenecks present in the project management. He expressed that the project scheduling, i.e. estimation of project completion time and resource allocation, is a vital problem, especially, when the amount of resources are limited. Conventionally, resource constraint in any project is scheduled and decision is taken using heuristic algorithms. These decisions include completion of the project on or before the scheduled time, and the extension of delivery due date. Also, they explained the concept of theory of constraints (TOC) developed by Dr.Goldratt, in the year 1986, that provides the concept of activity based resource allocation.

Golmohammadi(2015) and Sukalova and Ceniga (2015) discussed the implementation procedure of TOC approaches for the manufacturing industries in their job-shop in order to improve the research and development on constraint scheduling. They also explained that literature studies have confirmed the TOC strategic procedure to make the process flow simple, but the working model of machining shop add more complexity in scheduling the jobs. Case study from the automotive industry is taken and the wide ranges of scheduling of jobs are considered for the implementation of TOC. Costas et al. (2015) implemented TOC in supply chain management (SCM) for the improvement of business. The bullwhip consequence is the verified cause for the inefficiencies in supply chain management.

They also stated that supply chain efficiency can be increased with the usage of Theory of Constraints developed by Goldratt. They developed the new methodology with conceptual model for a multiple scenarios. Also, the same methodology can be used to experiment with standard simulation model 'Beer distribution Game' to take gain of the supply chain exercise. They presented that TOC the best management strategy through the Drum-Buffer-Rope (DBR) procedures and the major improvements in the system. TOC systematic methodology creates huge amount of throughout, less operating expenses, financial investment cost and less inventory for the supply chain system without disturbing the core working principles.

Fekri et al. (2012) compared the effectiveness of Shafiabady's multi-axial model and Gotfredson's theory of constraints and compromises on learning entrepreneurship skills to students of Islamic Azad University. Forty-five groups are in different scenarios were identified and allowed to take training sessions and experimental were conducted in eight questioner sessions. They analysed the data with analysis of covariance. The results are evident that there is a huge dissimilarity between the achievement of the selected entrepreneurship skills of control group and experimental groups. Indrawati and Ridwansyah(2015) stated that the 20th century of globalization is categorized by the volatile change in all areas of social and economic life. Technological innovation and tough competition creates high demand in the management to cultivate a better environment to current and future competitiveness among for the employees. Izmailov(2014) explains that theory of constraints philosophy, three strategic approach(what to change, what to change to, how to execute)and performance measures(throughout,

inventory, operating cost). Also they mentioned that TOC can set the goal, validate, set target to achieve and earn money.

Wu et al. (2010) proposed a new method called theory of constraints-supply chain replenishment system (TOC-SCRS). Also stated that TOCSCRS is been implemented by many industries as a replacement for the TOC and supply chain solution implemented as alone. The most of the companies reported the advantages of less inventory level, lead-time, transportation costs and increasing forecast accuracy and customer satisfaction. Also explains that TOC-SCRS implemented in inventory yard, the consistent replacement time will turn indifference with the replenishment quantity, on constraint capacity of the plant layout. Chakravorty and Atwater. (1998) stated that industries have made substantial improvement in the quality of the products and services. Japanese has now changed the working culture of rapid design change and offer products in lowest price. They also explained that United States is reluctant to change to Quality Improvements (QI) and mentioned that studies reveal only 20% of the QI are carried out in United States. Also proposed that QI program is not implemented correctly to get the maximum efficiency out of the system. Also demonstrates how the use of the Theory of Constraints (TOC) can help the top management to execute QI process to get better results.

Mukhopadhyay and Panda. (2006) explains that Theory of Constraints (TOC) is a management philosophy implemented by the industries to improve the performance of their sub systems. TOC philosophy helps management to achieve top priority goals that the system is expected to deliver. Bottleneck problems that influence a company's ability to achieve most of its goals are referred as a constraint in the system. Operational experts need to identify and exploit constraints. The most important process are the five stages identify, exploit, subordinate, elevate, and repeat which ensures that system is giving the productive output. They conclude that implementation of TOC yielded in increasing the throughput and substantial repayment to the business.

Badri et al. (2014) stated that the product mix problems are the most important problems in production line systems. They explained all bottlenecks that influence the product quality and quantity and they suggested a multi-criteria decision-making to move towards for product mix problem with interval parameters. The projected idea consists of identification of bottlenecks, determination of the production priority and the weighting factors for the bottleneck problem, reducing and increasing the major factor in the process to increase production. They concluded a concept and with simulation example is presented to validate the proposed approach.

Lakshmi et al. (2017) stated that Indian Ayurvedic medicine should be advertised in a better way to reach the people. They conducted survey with 202 sick people on their different methods of treatments for the illness. Also they carried out a detailed data analysis through statistical approach and concluded that companies should promote the awareness of the treatments in rural and urban regions.

Integrated methodology

1. Lean and six sigma

Lean and Six sigma concept was initially published in the book entitled 'Leaning in to Six Sigma' in the year 2001. This concept is the combination of both lean and Six sigma and takes advantage of both together. Authors from the universities and industries collaborated in implementing Lean and six sigma. Niu et al.(2010) stated that

most of the blue chip manufacturers are implementing Six Sigma for continuous improvement(CI) whereas Lean Manufacturing for improving the working process to minimize waste in order to maximize output and business expectations. They also concluded that innovation with advanced feature, validating the product with all possible failure modes and identifying the life of the product will improve product life cycle performance with best product in the market over other manufactures.

Alhuraish et al. (2017) Lean concepts and six sigma methodologies have been extensively used by most of the business operations. Many industries face difficult in implementing it successfully and sustain it for a longer run. Also built the knowledge and filled there search gap from the data obtained from the literature and more clarity into the most influencing factors that change the output. They also compared the results with the same domain industries executed similar Lean and six sigma approach. The output of this case study guide companies to create work plan decision and alternate plan to execute the most critical success factors (CSF). The preexecution stage, organizations can judge their capacity and expert can be utilized to accomplish the most critical success factors for the implementation of six sigma and lean manufacturing together or alone.

Niemeijer et al. (2012) carried out is study in adapting the lean six sigma in the traumatology department, university medical centre, one of the leading hospitals in Netherlands. They mentioned that the transition of the organisation is purely trouble oriented to more structured process, which helps in eliminating the major waste and finding optimum solutions for complicated problems. A major benefit of the program is to provide enough training to the employees so that they become project leaders in future. They concluded that people should be coached to improve the process, stimulated and equipped to become subject matter experts for continuous improvement. Aqlanand Al-Fandi. (2018) and Wetzel and Thabet (2016) stated that competitive and globalization market demands the companies to concentrate in eliminating wastes in their procedures and work flow process and implement continuous improvement approaches. Lean and Six Sigma are two important process improvement philosophies which increases quantity and reduces variance respectively are been successfully executed by many companies to increase their business operations output. They also states that selecting and prioritizing process improvement approaches to maintain the expected workflow can be a demanding, when multiple decision factors influence the outcome of the system. Also they proposed new methodology with workflow procedure with process improvement initiatives in manufacturing industries. Morais et al. (2015) stated that most of bike manufacturing company are facing tough scenarios in the market. They also stated that companies have to innovate constantly and migrate to new products and the increase of market demand. They presented lean six sigma process improvement methodology in a manufacturing bay of the company's machining centre, to reduce waste and increase productivity. They also explained the importance of Pareto analysis, cause and effect diagrams and control charts in the validation of the process. They concluded that errors were reduced by 84 percentages in all the components and productivity increased by 29 percentages.

Many researchers created a vision and guidelines for the execution of lean six sigma. The lean and six sigma integration with step by step procedure of the two approaches is arrived with model, background and reasons for the new approach. This integrated approach of study on the execution of lean and six sigma in wide range of industries are compared. Additional toolbox with many tools and techniques are used in integrating the Lean and

Six Sigma. Even in logistics supply chain of an organization, lean and six sigma are introduced to reduce non value added activity.

Implementation of quality tool six sigma and lean principles leads to identify variables influencing raw material supply process and improvements actions (Pepper and Spedding, 2010; Antunes et al. 2013; Zhang et al. 2015). Andrius et al. (2015) carried out a case study on the employee work place improvement using Lean and Six Sigma DMAIC methodology. The change management tools are created to control the most influencing parameters like to reduce the rate of slips, trips and falls(STFs) for joint commission field staff. The factors include workmen's compensation claims data, multiple risk factors associated with field staff STFs and individual behaviours. They suggested target solutions such as email communication on the weather and safety conditions for the season, general workplace safety awareness, working process safety and personal safety. De Freitas et al. (2017) Stated that integration of Lean, Six Sigma and Sustainability has become the need of current industries in recent year. They identified the most influencing factor that can improve organizational sustainability in long run in the implementation of LSS. The factors are reduced waste, reduced defect rate, increased quality of service, increased product quality and reduce process variability. Tenera and Luis (2014) suggested working flow procedure model for the implementation of lean and six sigma (LSS). The project management tool for the process improvement supporting the DMAIC cycle was tested in a Portuguese telecommunication company. They concluded that the continuous improvement in the project management process within the business operation is the key to the success. Cherrafi et al. (2016) conducted a review of the literature on the integration of lean, Six Sigma and sustainability and the upcoming problems in implementing this integrated approach. They selected 118 journal papers published form the period of 1990 to June 2015. From the literature they identified seven gaps which have lot scope for research. Also, stated that integrated approach need to be developed to improve the metrics and measurement of the system performance by executing the lean/six sigma and sustainability. Panagopoulos et al. (2017) stated that most of the industries target is to improve the existing process using Lean, Six Sigma, or a combination of the two. Also states that both lean and six sigma creates a breakthrough in the existing process change and increases the efficiency of the existing system. They concluded that Lean concepts derived from the Toyota production system and six sigma procedure derived from Motorola creates awareness for the employees on the value of process improvement and provides structured continuous improvement procedures.

In today's competitive business environment there is no room for error in the products. Business operations are forced to execute the core procedure and principles of lean and six sigma. Lean and six sigma is a process improvement methodology in order to increase productivity without compromising on the quality and increase service to the end customers. Six sigma adapt the best statistical process control and engineering process control procedures to improve the efficiency. Lean and six sigma are meant for process capability that continuously improves the quality of the product and increases production (Taghizadegan, 2006).Even in the construction industry where they face very high competition and are forced to look beyond normal production. The construction industries should repeatedly innovate and improve their process in order to deliver a high quality product with a low cost. From the literature of Lean Six Sigma projects, authors suggest that project definitions and procedures are framed to implement the Lean Six Sigma (Van et al., 2014).

Wiegel and Brouwer (2015) carried out a detailed study in the implementation of lean and six sigma in wide range of manufacturing industry, service industry and health care industry to understand the benefit of the system. Also, carried out detailed study on higher education with set of variables using lean six sigma. Also explained the success and failure of implementing the lean and six sigma in different domain applications. Alhuraish et al. (2016) stated that AHP model was executed to determine the optimum solution and the most efficient procedures in the implementation of lean and six sigma in manufacturing industries. The most influencing factors are, innovation, operations and financial benefits. They also concluded that industries executing lean and six sigma are more efficient than industries executing either lean alone or six sigma alone in terms of operational and financial performance. Industries that use conventional methods lean six sigma without AHP gained minimal performance improvements. Automobile, electronics and service industries are more efficient in innovation, operational and financial performance.

2. Lean, six sigma and theory of constraints

Selection of the best suited CI method is the bottle neck in any application. Six sigma focuses on reducing variation and increases uniform process output. Lean focuses on waste removal, increases the flow and reduces time. TOC focuses on constraint and increases throughput (Nave, 2002; Wu and Wee 2009). Jacob et al. (2009) developed a fully integrated approach of TOC, Lean and Six Sigma (TOCLSS) is a new strategy road map to improve the business efficiency and sustain the organization to achieve the results and exceed the goals on time. Six sigma and constraints management has been implemented as an integrated model in production line of an engine monoblock V8 in an automobile industry. They concluded that production rate is increased by 40% for same available resource and dimensional variance is reduced by 0.73% and casting quality is increased by 2.3%.

3. Integrated approach methods

Further from the literature review it is clear that industries and researchers have identified different combinations of approaches with the help of lean, six sigma, TOC, TQM etc. Antony (2011) taken a case study and made a detailed comparative study on the quality management concepts. Total quality management (TQM), Six sigma and the well known lean. He carried out his work in integrating the three different approach on the different organisations to improve their efficiency of the system. They also explained that the literature pertaining to the benefits of TQM, SS and lean is limited. They concluded that industries can combine these three concepts to gain maximum benefits for their products and process improvements.

Another integrated approach of the Six Sigma, Theory of Constraints and Root Cause Analysis(RCA) is discussed by Lee and Chang (2012). This integrated approach in a manufacturing system improves the efficiency. Also six sigma helps in providing the statistical solutions to improve the quality and TOC help to decide the framework of the Continuous improvement. RCA identifies the problems present in the system as well as gives appropriate solution to the system. Hilmola (2001) states that theory of constraints (TOC) a new management philosophy changes the way we think about manufacturing and business operations. Also, states that any business objective is to make money now and in the future and survive in the market. Analyze

the top management parameters like profits, profitability and cash flow to organisation and working towards the goal. Also explains the three different performance measures of the organisation throughput, investment and operating expense. Also compares the TOC with the conventional Management philosophy and states that TOC gives a better approach.

2. CONCLUSION

Most of the research is carried out in implementing lean, SS and TOC independently to improve the efficiency of the system. Implementing lean alone cannot improve the variance of the system in terms of product quality, process capability in any manufacturing industry. Also, lean strategy cannot identify the constraints that are present in the system. Expected throughput cannot be achieved.

Implementing six sigma concepts alone cannot reduce the all kinds of wastes like over processing, waiting time, excessive inventory etc. Implementing TOC alone cannot reap the advantages of the other manufacturing strategies. But, in the current global competitive business environment, there is a stiff competition among manufacturing industries.

The customer expectations are growing day by day, especially in terms of price and quality of the products, reliability and on time delivery. To ensure the long term sustainability and to attract the customers, the manufacturing firms have to produce the products with less cost without compromising with quality. Further, industries have realized that without reaping the benefits of modern manufacturing strategies as a whole, the customer expectations cannot be fulfilled. In order to meet these challenges, efficiency improvement of the goals of the product development team is mandatory. Also, from the literature, it is evident that implementing modern manufacturing strategies on a combined basis, yields better results. Hence, all these factors motivated to carry this research by integrating lean, six sigma and theory of constraints.

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