Available online: www.ijsrmes.com

International Journal for Scientific Research in Modern Engineering and Science

International Journal for Scientific Research in Modern Engineering and Science, 3(6): 18- 38 (2022)

# AN INTEGRATED APPROACH FOR RANKING OF EMPLOYEES APPRAISAL RATING: A CASE STUDY

**Praveen Rathore [1]*, Dr. Abhijeet Ganguly [2], Revendra Kumar Deshmukh [3]**

[1]*M. Tech Scholar, Department of Mechanical Engineering, CSIT, Durg, C.G. India.*
[23]*Assistant Professor, Department of Mechanical Engineering, CSIT, Durg, C.G. India.*

## Abstract

The search for new avenues of sustainable developments is driven by globalization and the competitive economic environment. Any organization that wants to be profitable, gain market share, enhance brand value, and remain competitive must create and implement Continuous Improvement techniques that adhere to certain criteria over an extended period of time. In this research, an effort is aimed at demonstrating how Lean, Six Sigma and Theory of Constraints may work together to achieve maximum throughput, which is every industry's top priority. Further research is done to demonstrate the efficiency gain in performance successes of the team goals. Finally, a comparison of the two integrated approaches' levels of efficiency improvement is done.

An integrated methodology employing lean and six sigma is recommended at the initial stage of the task. For this reason, the process improvement throughout product development of the heavy engine team objective achievements is taken into consideration as a case study example. In order to demonstrate the advancement of process improvement, performance data for the individual goals of a team are gathered and a statistical approach is put into use. The second stage of the project involves the proposal of an integrated methodology that combines lean, six sigma, and theory of constraints. To forecast the teams and the individual team members' performance metrics, an empirical model is developed. Through an iterative process, the weights for each team member's individual goals are allocated and updated. Each employee's and team's grade ranks are calculated and reported using an iterative process. The team and the employees gain insight over how to improve their performance. Furthermore, this method to constant improvement inspires confidence in the top management.

With the use of the Lean & Six Sigma methodology, it is inferred from the research data that the objective rate has improved. Moreover, it has been determined that the effectiveness of the objective achievements using the theory of constraints, lean manufacturing, and six sigma. Lean, Six Sigma, and the Theory of Constraints, the second strategy, perform better than the first way. The second integrated strategy improves both employee and employer knowledge of the performance metric. The second strategy boosts shareholder and employer confidence more effectively. Implementing this strategy thereby boosts the financial gains for the shareholder and the employee.

***Keywords:*** *Lean Management, Six Sigma, TOC, Ranking, Weightage, Standard Deviation.*

* Corresponding author

## 1. INTRODUCTION

The recent swift in globalization of business creates a stiff competition among the competitors. Subsequently, organizations are constrained to hunt for new sources of sustainable developments. With these circumstances, increased competition, reduced cycle time between products in terms of performance and quality are the major concern for the success. The researcher and industry experts are obligated to volte-face about functioning of managing plant operations effectively and efficiently. Since, the possibility for further improvement within the organization is progressively decreasing; henceforth researcher and the leaders of industry are striving hard to improve the performance of the organization in terms of operating expenses, delivery, quality etc. This leads to find new alternative way of integrating business actions further on.

**Continuous improvements methods**

The most primitive method Continuous Improvement (CI) started in 19th century. In any organization CI is created and implemented with some paradigm to a continued period to gain productivity, increase market share, customer confidence and improve brand value and to survive in the market. CI methods create new procedure and alternate method to gain more efficiency in the existing model and change business operation to make profit. Old primitive methods like lean, kanban, total quality management (TQM), just in time(JIT), six sigma and total productive management (TPM) are used for predetermined improvement to make process implementation easier. Also, standard logical algorithms and techniques like fuzzy logic, neural networks, artificial intelligence etc. are aligned with old primitive methods.

Integration of these techniques is the best approach to meet operational requirements rather than inventing a new procedure and techniques (Ehie and Sawhney, 2005). It is identified that implementation of Lean, Six Sigma and Theory of Constraints (TOC) independently or combination of these techniques will yield a better result. Lean principles emphasize the elimination of hidden waste from a production system in order to make it well-structured. Identifying the hidden waste can be categorised as waste from over production, transportation waste, waste of motion and processing waste, waiting time, defective products, unutilized resource and excess inventory. Working on this waste on a systematic process or technique with identified tools can lead to minimizing the variance.

**1. Lean**

The foundation of lean manufacturing initiated by Henry Ford, Fredrick Taylor and Dr. Deming in the US. In Japan Lean culture started by Taiichi Ohno, Shingeo Shingo, and Eliji Toyoda. Taiichi Ohno created a goal and mission to achieve Toyota Production System, simply in order to minimize the time consumed from the stage of raw material ordering to selling of final product, by removing hidden (non-value added) wastes (muda) (Taiichi Ohno, 1988).

**Eight Wastes of Lean**

**i. Over Production**: Producing the components more than the customers demand. Without predicting the future demand, the components are manufactured in batch can lead to over production waste.

**ii. Waiting**: The time spent on waiting to get a product or service to start. This non-value added time can be from inventory, people, parts or information.

**iii. Transportation**: The unwanted movement of products and material, moving multiple times, additional movement without adding value. The improper layout of inventory yards, system and priority shifting are non-value added transportation.

**iv. Inventory**: Needless raw material and finished goods. The investment done for the customer without predicting the future needs. Long cycle times, long work flow process and inconsistency in flow can lead to inventory issues. Unaccounted warehouse and pileup of raw materials are considered as inventory.

**v. Motion**: Additional movement of resource or operator that consume more time less value. Deprived workplace or batch order plant and unsophisticated flow can lead to excess motion and time.

**vi. Over Processing**: Additional steps or process with no value to the customer. Anticipating that more work processing on product can give high quality product or service. This leads to waste when the customer expects finite cycle life on the product.

**vii. Defects**: Any effort that leads to rework or even of inferior quality, effort that ends up in scrap. Bad procedure, low quality tools and without operation sequence in place can lead to defect product. Apparently the poor quality of work in the system leads to the higher defects.

**viii. Unutilized Resource**: The employee, machine, software when not utilized to maximum extend can lead to this waste.

## 2. Six sigma

Six Sigma(6σ) is a sequence of procedure implemented with certain tools to improve the process. It was suggested by Bill Smith & Mikel J Harry in association with Motorola in the year 1986. Jack Welch implemented to his operation strategy at General Electric in the year 1995. (Ehie and Sawhney, 2005)

Six Sigma improves the quality and reduces variance of the system. The output of a process can be improved by identifying, removing defects and suggesting alternate plans in manufacturing and business operation. Implement sequence of procedure on quality control procedures, empirical formula, statistical approaches and five stages of instructions for the resource within the system. Every six sigma project executed within a company should follow a sequence of procedural steps and has specific value. The aim of executing the procedure is to reduce operation cycle time, variance, cost, improve customer feedback and profit.

### Six Sigma Methodologies

All the Six Sigma projects executed should follow two set of procedural methodologies inspired by Deming's "Plan-Do-Check-Act" Cycle. These methodologies consist of five stages of instructions for each modules as follows.

A. Define, Measure Analyze, Improve and Control(DMAIC)

B. Define, Measure, Analyze, Design and Verify(DMADV)

Table 1.1: Summary of the sigma failure scale.

| Sigma Level | Defects Per Million parts | % Defective | % Yield | Sigma Shift |
|---|---|---|---|---|
| 1 | 691462 | 69 | 31 | -0.5 |
| 2 | 308538 | 31 | 69 | 0.5 |
| 3 | 66807 | 6.7 | 93.3 | 1.5 |
| 4 | 6210 | 0.62 | 99.38 | 2.5 |
| 5 | 233 | 0.023 | 99.977 | 3.5 |
| 6 | 3.4 | 0.00034 | 99.99966 | 4 |

**Six Sigma Tools**

The most commonly used tools across industries for implementing Six Sigma are tabulated in Table 1.2

Table 1.2: Summary of the standard methods used to execute six sigma

| Project phase | Define | Measure | Analyze | Improve | Control |
|---|---|---|---|---|---|
| Tools | • VOC tools<br>• Project charter<br>• Process map<br>• Benchmarking<br>• QFD, SIPOC | • Data mining<br>• Run charts<br>• Pareto analysis<br>• Exploratory data analysis<br>• Descriptive statistics | • Cause-and-effect diagram<br>• Tree diagram<br>• DOE<br>• Enumerative statistics<br>• FMEA<br>• Simulation, ANOVA | • Force field diagram<br>• 7m tools<br>• Prototype pilot studies | • SPC<br>• FMEA<br>• Reporting system |

**3. Theory of Constraints(TOC)**

Theory of Constraints main focus is to improve the system performance. Any independent system is framed as a series of interdependent process. The core analogy of the system consists of multiple chains. This group of interdependent process (link in a chain) working together to achieve overall goal. The constraint is a weak process in the chain. The performance achievement of the overall process (chain) is restricted by the capacity of the weakest process (link). Theory of constraints targets on the bottle necks that decelerate the production output in the overall system.

**Combined Approach of CI Methods (TOCLSS Integrated Model)**

The effective way to get maximum yield is to integrate the methodologies like TOC, Lean and Six Sigma and establish a new strategy. The strategic roadmap will lead to improve the plant operations and effectiveness. The strategic roadmap arrived in line to benefit the organization and improve the efficiency of the entire system. After the new plan from the Theory of Constraints, Lean and Six Sigma (TOCLSS) model, the specific tasks to the subsystem are implemented and this result in the improvement of the bottom line and to the end result. The efficiency improvements must be sustained in a long run to see the maximum benefits, return on investment and gain the investor confidence.

**Comparative Study of the Methods**

A comparative study on the methods with Primary theory and fundamental philosophy on each of the methodology is mentioned in the Table 1.3. Detailed objectives and assumption of each methodology's primary and secondary outcome are also compared (Dave Nave 2002).

Table 1.3: Comparative illustration of the process.

| | Six Sigma | Lean | TOC |
|---|---|---|---|
| **Motive** | Reduce variation | Remove waste | Manage constraint |
| **Methodology** | Define | Identify value | Identify constraint |
| | Measure | Identify value stream | Exploit constraint |
| | Analyze | Flow | Subordinate processes |
| | Improve | Pull | Elevate constraint |
| | Control | Perfection | Repeat cycle |
| **Objective** | Quality | Velocity | System constraint |
| **Originated** | Motorola | Toyota | E. Goldratt |
| **Outcome** | Improved effectiveness | Improve speed and efficiency | Improves throughput |
| **Assumptions** | Reducing variance will improve effectiveness of the system | Waste removal will improve performance | Resolving the constraint will improve the system |
| **Censure** | System Processes improved independently | Statistical approach not considered | Works on constraints based model |

## 2. LITERATURE REVIEW

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. Many researchers carried out their work in the field of process improvement and industries to spend millions of dollars in the process improvements (Dave Nave, 2002).

Continuous Improvements Methods

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). he 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). 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). 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). The 5S implementation practices across different employee levels of industry and the benefits &the contributions to the organizations 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 analyzed 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.

**Lean Manufacturing**

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). Aragon and Ros-Mcdonnell (2015) described a project to increase the efficiency of the food manufacturer by applying several lean production control methodology techniques.

**Six Sigma**

Arafeh (2016) implemented the Six Sigma (SS) methodology to improve the effectiveness of the English language for the non-native English speaking students. 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. 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.

**Theory of Constraints**

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. 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. 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. 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.

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.

**Integrated Methodology (Lean, Six Sigma and Theory of Constraints)**

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 is work in integrating the three different approach on the different organizations to improve their efficiency of the system. They also explained that the literature pertaining to the benefits of TQM, SS and lean is limited.

## 3. PROBLEM IDENTIFICATION

**Identification of the Problem**

Implementation of lean and six sigma strategies on an integrated basis for enhancing the efficiency level of the goals of the engine product development team needs to be addressed.

Implementation of lean, six sigma and theory of constraints on an integrated basis for enhancing the efficiency level of the goals of the engine product development team, needs to be addressed.

Comparative analysis of lean & six sigma and Lean, Six Sigma and Theory of Constraints (LSSTOC) needs to be presented in terms of the efficiency level of the goals of the engine product development team.

**Objectives of Research Work**

i. To demonstrate the frame work of developing integrated approach of lean, Six Sigma and theory of constraints.

ii. To study the efficiency improvement level of the goals of the engine product development team in the manufacturing industry as part of productivity improvement.

iii. To perform Kolmogorov-Smirnov Test using MINITAB software for checking Team performance

To compare our results with different tools

iv. To enhance performance of workers analyzing them through various parameters.

v. To Rank the Workers as per the performance throughout the year

## 4. METHODOLOGY

The proposed integrated approach of works better than implementing lean, six-sigma and theory of constraints independently. This integrated approach can improve both quality and velocity of the product and process with a strategic plan to achieve great deal of production enhancement.

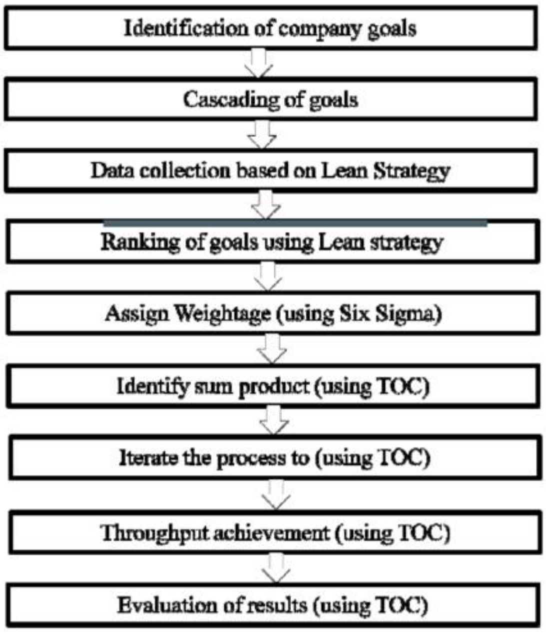



Fig. 4.1: Flow chart representing lean, six sigma and theory of constraints

The flow chart representation of the integrated approach of Lean, Six Sigma and Theory of Constraints is shown in Figure 4.1 to understand the integrated approach in an easier way. It starts from the stage of goal identification, cascading and alignment of the goals to the Lean principle. The data collection and data processing is carried out through six sigma strategy. Data analysis is carried out through theory of constraints.

Every company has a vision to be fulfilled and the employees have to create a mission to accomplish that vision. The director frames the goal to be achieved in line to the company vision, the next level joint director takes an accountability of the goal and distribute the responsibility amongst the sub teams based on their domain expertise. The next hierarchy level of managers takes the sub task of goal from their respective joint directors. An integrated methodology of Lean, Six Sigma and Theory of Constraints for process improvement is considered for heavy engine during product development phase. This approach is implemented with a team of 11 members on their performance metrics of 16 Goals of XYZ Manufacturing Firm. Employees across the company are working with their leaders to craft their Goals. Goal setting process is the mandatory work of any company to ensure their leaders and employees identify the right goal based on their capability and resource availability. Also, they make sure that they deliver the targeted results.

In the current integrated methodology of lean, six sigma and TOC, the procedural activities like goal setting process, data collection procedure, number of goals under consideration, team under consideration and their target level are done based on methodology adopted. But data collection approach is different but for similar teams, same set of goals and levels are considered. The post processing of the data is carried out on an iterative mode.
The first goal is the effective production hours, i.e. the total time the employee spends on the work for a month. It is the top priority goal so that weightage is set to 16. The second goal is the quality metrics, i.e. measuring number of errors in the output. It is measured to 100 percentile and the goal is set to weightage of 13. The third goal is the efficiency improvements on quality enhancements, which is carried out with some standard procedures. It is measured in terms of percentage and weightage is assigned as 10. The fourth goal is the customer feedback score on different aspects, which is collected and measured in terms of percentage and the goal weightage is assigned as 8. The fifth goal is the paper publication in a forum by each of the employees. Each employee has to produce four papers yearly. Sixth goal is about the punch in and punch out timing of the employee and the work-hour entry time accuracy is measured in terms of percentage. The paper publishing and punch in and punch out timing goal are set with priority weightage of 8 and 7 respectively. Goals from seventh to eleventh, are about documenting the working nature of the employee. Goals from seven and eleven, are assigned with the weightage of 6, 7, 6, 5 and 4 respectively. The twelfth goal is about the delegation of the work to the peer groups and getting it on time. Goals thirteenth and fourteenth tell about the knowledge acquired by employee through training. Mentoring and training of the new engineer is the fifteenth goal and is measured in terms of percentage.

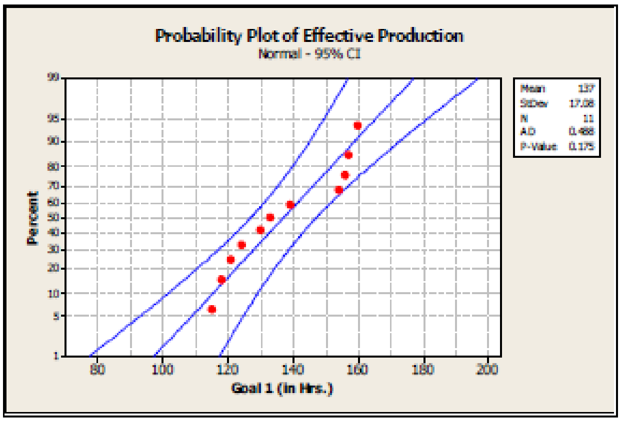
The last goal measures the number of conference paper presentations and paper submissions in journals, which is also measured in terms of percentage. The goals from twelve to sixteen are the least priority goals and their weightages assigned are 3, 3, 2, 1.5 and 1.5 respectively.

Table 4.1: Goal performance metrics of the team for the month of January

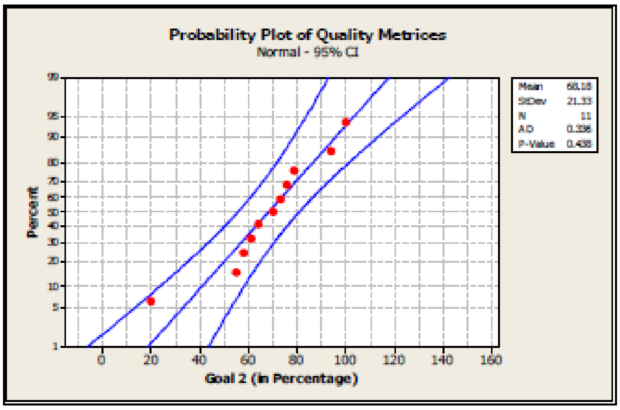
| Weightage | Goals | Employee level of achievement | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 16 | Effective production hours | 160 | 157 | 154 | 124 | 121 | 118 | 115 | 139 | 156 | 133 | 130 |
| 13 | Quality metrics | 100 | 20 | 94 | 64 | 61 | 58 | 55 | 79 | 76 | 73 | 70 |
| 10 | Efficiency improvement | 72 | 66 | 62 | 34 | 31 | 28 | 25 | 50 | 45 | 60 | 43 |
| 8 | Customer feed back | 90 | 86 | 82 | 42 | 38 | 34 | 30 | 62 | 58 | 54 | 82 |
| 8 | Work highlights published | 4 | 3.8 | 3.6 | 1.6 | 1.4 | 1.2 | 1 | 2.6 | 3.6 | 2.2 | 2 |
| 7 | Clock time accuracy | 90 | 78 | 96 | 76 | 74 | 86 | 84 | 82 | 84 | 82 | 80 |
| 6 | Project management documents | 95 | 98 | 58 | 78 | 96 | 65 | 60 | 55 | 84 | 82 | 80 |
| 7 | Project management survey | 90 | 59 | 77 | 95 | 90 | 19 | 45 | 78 | 84 | 78 | 96 |
| 6 | Team and HR compliances | 78 | 56 | 66 | 24 | 90 | 20 | 45 | 86 | 87 | 95 | 90 |
| 5 | Internal documents | 100 | 78 | 96 | 76 | 28 | 72 | 70 | 86 | 84 | 24 | 90 |
| 4 | Internal project archival | 92 | 95 | 86 | 84 | 82 | 78 | 96 | 68 | 60 | 55 | 50 |
| 3 | Delegation of work | 80 | 86 | 65 | 60 | 55 | 95 | 90 | 86 | 84 | 82 | 50 |
| 2 | Additional training | 95 | 65 | 19 | 45 | 78 | 24 | 78 | 65 | 60 | 55 | 50 |
| 2 | Mandatory training | 98 | 19 | 45 | 78 | 35 | 30 | 95 | 19 | 45 | 78 | 50 |
| 1.5 | Mentoring new engineers | 88 | 88 | 90 | 40 | 35 | 30 | 24 | 90 | 20 | 55 | 50 |
| 1.5 | Conference presentation | 100 | 59 | 90 | 40 | 35 | 30 | 25 | 65 | 60 | 55 | 88 |
| | Grading ranks | 9406 | 7449 | 8362 | 6576 | 6582 | 5603 | 6010 | 7594 | 7870 | 7326 | 7551 |

**Normality plotting**

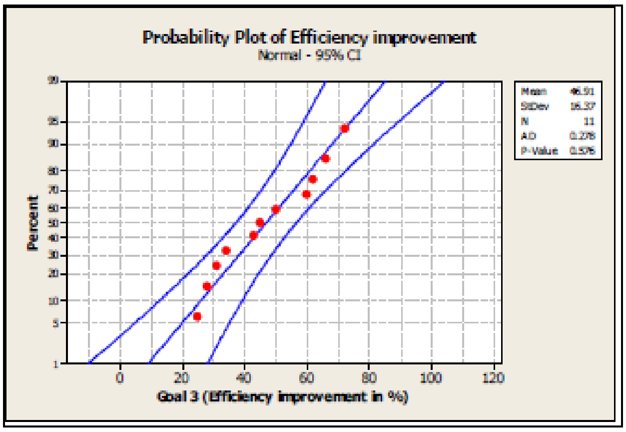
Graphs are plotted to verify the normality of the collected data for the month of January for all the goals using Minitab. 12 months' data for 11 employees on their achievement levels of 16 goals is considered in this work. Using statistical tool in MINITAB, i.e. Kolmogorov–Smirnov test (K–S test or KS test), the data is validated for normality. Data is shown only for January here.



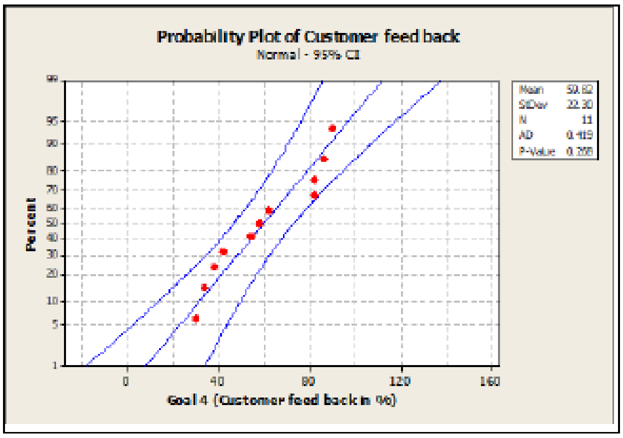

(a) Goal 1 (Effective Production in Hrs.)



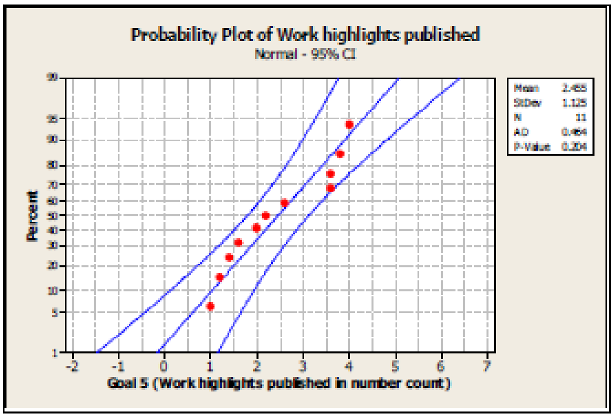

(b) Goal 2 (Quality Matrices in %)



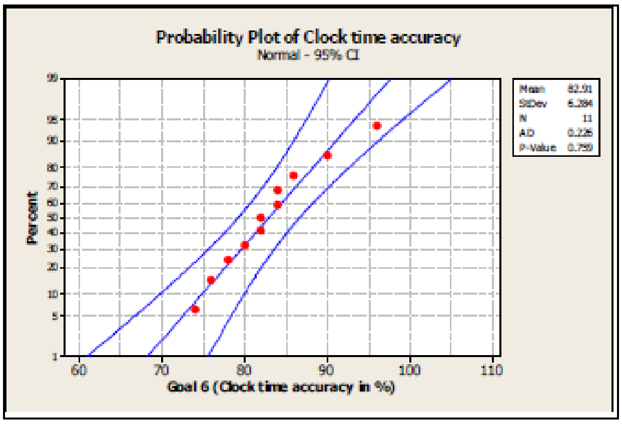

(c) Goal 3 (Efficiency Improvement in %)



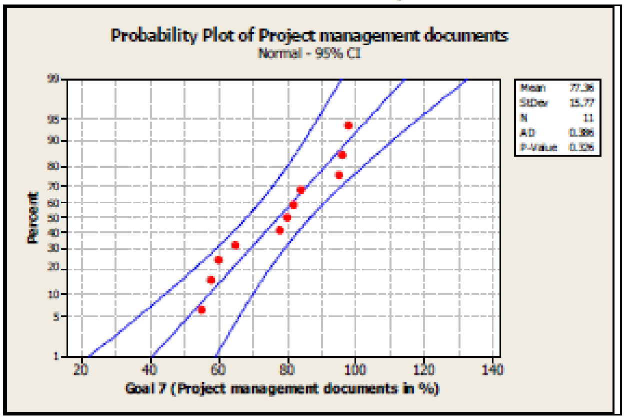

(d) Goal 4 (Customer feedback in %)



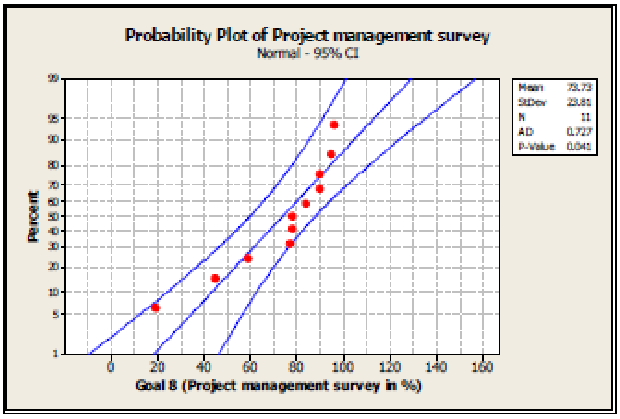

(e) Goal 5 (Work Highlights Published in Number counts)



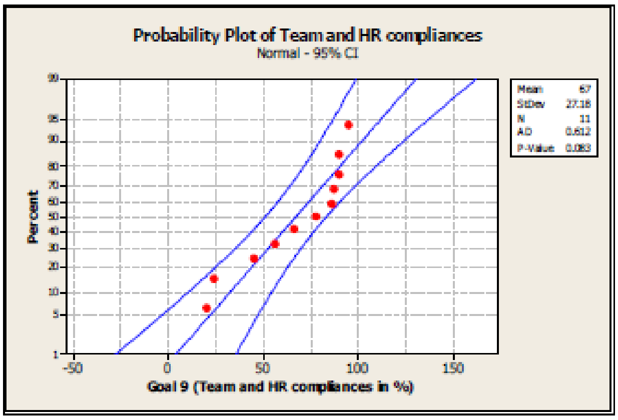

(f) Goal 6 (Clock Time Accuracy in %)



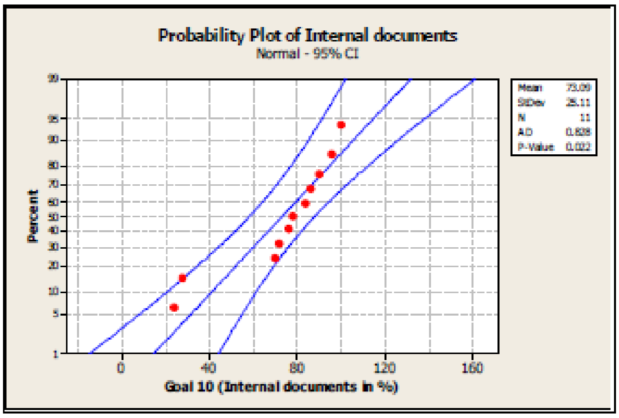

(g) Goal 7 (Project Management Document in %)



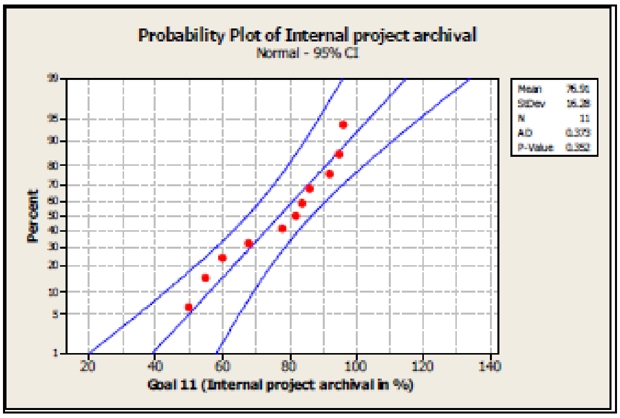

(h) Goal 8 (Project management survey in %)



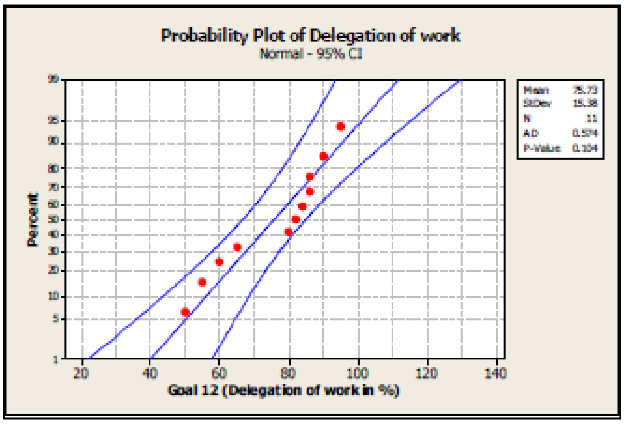

(i) Goal 9 (Team and HR compliances in %)



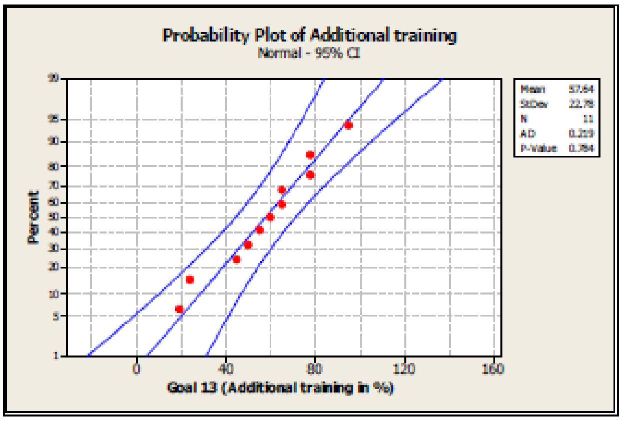

(j) Goal 10 (Internal documents in %)



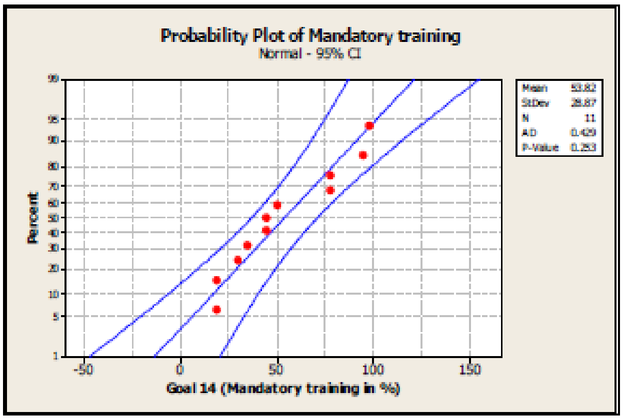

(k) Goal 11 (Internal project archival in %)



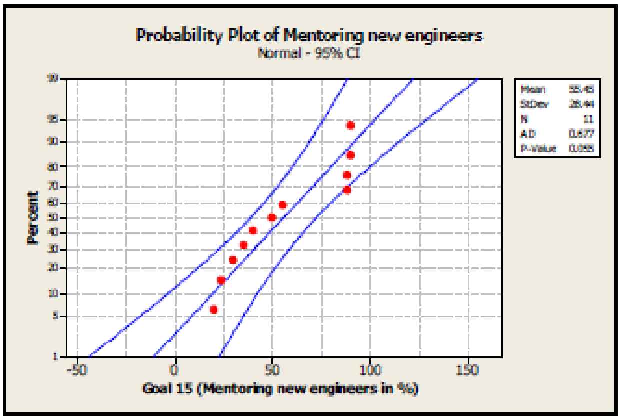

(l) Goal 12 (Delegation of work in %)



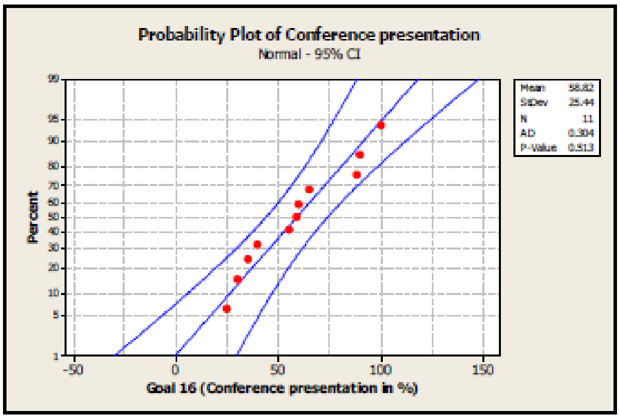

(m) Goal 13 (Additional training in %)




(n) Goal 14 (Mandatory training in %)




(o) Goal 15 (Mentoring new engineers in %)




(p) Goal 16 (Conference presentation in %)

Fig. 4.3 Normality probability plots of the achievement levels of team members on various goals for the month of January

Table 4.7 Mean of the goal performance metrics of the team for the entire year

| S No. | Goals | Mean Summary | | | | | | | | | | | | YEAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | |
| 1 | Effective production hours | 137.0 | 131.3 | 123.5 | 140.9 | 134.8 | 133.5 | 128.7 | 127.6 | 125.8 | 128.8 | 130.4 | 128.7 | 130.9 |
| 2 | Quality metrics | 68.6 | 65.7 | 71.3 | 70.3 | 69.5 | 73.5 | 61.1 | 67.3 | 66.6 | 62.8 | 67.0 | 66.6 | 67.5 |
| 3 | Efficiency improvement | 46.9 | 34.6 | 45.5 | 38.5 | 38.5 | 44.5 | 30.4 | 52.2 | 60.5 | 30.3 | 36.9 | 39.5 | 41.5 |
| 4 | Customer feed back | 59.8 | 40.5 | 56.9 | 47.4 | 47.4 | 54.7 | 35.8 | 61.2 | 71.8 | 35.4 | 45.1 | 45.3 | 50.1 |
| 5 | Work highlights published | 2.5 | 2.0 | 2.0 | 1.2 | 1.0 | 2.1 | 0.9 | 2.0 | 2.4 | 1.6 | 1.6 | 1.8 | 1.8 |
| 6 | Clock time accuracy | 82.9 | 70.9 | 79.4 | 75.8 | 69.7 | 78.7 | 39.3 | 78.5 | 77.2 | 78.0 | 73.3 | 73.8 | 73.1 |
| 7 | Project management documents | 77.4 | 70.8 | 55.6 | 73.5 | 46.4 | 67.0 | 19.1 | 64.3 | 67.0 | 73.9 | 68.0 | 81.5 | 63.7 |
| 8 | Project management survey | 73.7 | 73.1 | 73.3 | 69.9 | 45.1 | 58.2 | 39.5 | 66.7 | 63.8 | 65.5 | 70.5 | 80.4 | 65.0 |
| 9 | Team and HR compliances | 67.0 | 53.8 | 72.8 | 46.6 | 45.9 | 63.7 | 27.8 | 71.3 | 72.9 | 55.9 | 70.0 | 77.3 | 60.4 |
| 10 | Internal documents | 73.1 | 51.5 | 73.7 | 45.5 | 56.8 | 60.5 | 54.5 | 71.9 | 73.9 | 68.2 | 72.1 | 82.2 | 65.3 |
| 11 | Internal project archival | 76.9 | 64.0 | 56.5 | 66.8 | 43.6 | 51.5 | 49.3 | 61.0 | 62.5 | 51.1 | 55.4 | 47.7 | 57.2 |
| 12 | Delegation of work | 75.7 | 55.5 | 47.3 | 38.5 | 32.1 | 40.8 | 29.0 | 44.9 | 55.5 | 42.9 | 64.1 | 73.5 | 51.6 |
| 13 | Additional training | 57.6 | 58.4 | 57.5 | 59.5 | 47.1 | 69.5 | 39.9 | 65.4 | 80.8 | 68.0 | 66.8 | 56.0 | 60.5 |
| 14 | Mandatory training | 53.8 | 74.8 | 42.0 | 42.8 | 37.4 | 47.3 | 20.9 | 44.0 | 65.2 | 51.5 | 57.4 | 51.5 | 49.2 |
| 15 | Mentoring new engineers | 55.5 | 57.3 | 56.1 | 44.7 | 38.9 | 65.8 | 37.1 | 49.7 | 56.5 | 48.5 | 49.3 | 50.7 | 50.7 |
| 16 | Conference presentation | 58.8 | 53.3 | 67.7 | 40.1 | 32.8 | 54.4 | 25.5 | 41.9 | 52.4 | 44.5 | 40.9 | 47.6 | 46.7 |

Table 4.8 Standard deviation of the goal performance metrics of the team for the entire year

| S No. | Goals | Standard Deviation | | | | | | | | | | | | YEAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | |
| 1 | Effective production hours | 17.1 | 15.2 | 19.6 | 17.7 | 21.3 | 20.6 | 16.9 | 16.9 | 5.0 | 18.4 | 16 | 8.2 | 4.62 |
| 2 | Quality metrics | 21.3 | 19.2 | 21.3 | 18 | 19.7 | 20.6 | 20.4 | 18.7 | 16.4 | 19.9 | 17.5 | 10.1 | 2.95 |
| 3 | Efficiency improvement | 16.4 | 18.2 | 15.8 | 19.2 | 19.2 | 19.6 | 19.5 | 18.9 | 14.4 | 17.8 | 17.2 | 13.5 | 1.98 |
| 4 | Customer feed back | 22.3 | 23.9 | 21.2 | 25.8 | 25.8 | 27.4 | 25.7 | 23.9 | 19.2 | 23.1 | 23 | 13.7 | 3.53 |
| 5 | Work highlights published | 1.1 | 1.2 | 0.9 | 1.2 | 0.7 | 1.2 | 0.7 | 1.1 | 1.4 | 1.3 | 1.2 | 0.7 | 0.23 |
| 6 | Clock time accuracy | 6.3 | 21.3 | 14.3 | 12 | 17.1 | 11.3 | 29.1 | 14.4 | 14.9 | 12.2 | 11.5 | 15.3 | 5.49 |
| 7 | Project management documents | 15.8 | 20.7 | 32.5 | 17.3 | 26.5 | 22.3 | 22.5 | 28.6 | 32.4 | 16 | 22.2 | 6.6 | 7.18 |
| 8 | Project management survey | 23.8 | 11.9 | 18.8 | 14 | 28.5 | 26.9 | 29.1 | 22.4 | 23.8 | 12 | 12.3 | 9.6 | 6.87 |
| 9 | Team and HR compliances | 27.2 | 17.1 | 15.7 | 21.1 | 30.5 | 7.5 | 26.5 | 16 | 18.0 | 17.3 | 13.2 | 16.1 | 6.20 |
| 10 | Internal documents | 25.1 | 25.6 | 17.9 | 19.8 | 23.5 | 23.7 | 26.3 | 19.7 | 20.1 | 21.1 | 19.3 | 7.2 | 4.87 |
| 11 | Internal project archival | 16.3 | 20.8 | 23.5 | 24.3 | 28.7 | 32.7 | 23.1 | 27 | 34.4 | 20.6 | 24.3 | 22.1 | 4.04 |
| 12 | Delegation of work | 15.4 | 26.6 | 26.0 | 25.2 | 26.7 | 30.8 | 26.7 | 25.1 | 30.6 | 25.9 | 23.4 | 11.5 | 5.38 |
| 13 | Additional training | 22.8 | 23.0 | 24.7 | 23.9 | 34.5 | 23.6 | 30.2 | 25 | 28.8 | 25.7 | 18.9 | 24.1 | 3.88 |
| 14 | Mandatory training | 28.9 | 16.6 | 27.6 | 23.8 | 24 | 27.3 | 23.3 | 26.8 | 23.0 | 30.7 | 21.3 | 13.3 | 4.82 |
| 15 | Mentoring new engineers | 28.4 | 25.9 | 22.8 | 26.1 | 26.6 | 19.0 | 29.4 | 26 | 39.7 | 30.1 | 24.2 | 24.8 | 4.80 |
| 16 | Conference presentation | 25.4 | 23.7 | 13.9 | 25.9 | 23.6 | 29.2 | 25.6 | 15 | 30.6 | 24.1 | 25.6 | 20.9 | 4.77 |

## 5. RESULT AND DISCUSSION

### Result

The cumulative monthly mean performance achievement level of each goal, i.e., from the month of January to December, is summarized in the Table 5.1. This table gives a better understanding on the performance metrics of the team members. From this table, it is evident that the target levels are achieved for most goals except for the two goals, i.e., clock time accuracy and internal project archrivals. These two goals surpass the required target levels by 2% and 5% respectively. The least performance is identified as 49 and 59 percent against the target level of 60 and 70 percent for the goals, i.e., customer feedback & Team and HR compliances, respectively. The most consistent goal is the effective production hours, maintaining the achievement level of 129.9 hours, against the required target level of 130 hours.

Table 5.1 Cumulative mean of the performance metrics (for entire year based on the iterative weightage)

| S. No. | Goals | Mean summary | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1 | Effective production hours | 131.5 | 129.4 | 126.6 | 130.2 | 131.1 | 130.9 | 130.6 | 130.2 | 129.9 | 129.8 | 129.9 | 129.9 |
| 2 | Quality metrics | 67.2 | 66.5 | 67.9 | 68.5 | 68.7 | 68.5 | 67.5 | 67.5 | 62.9 | 67.4 | 67.3 | 67.0 |
| 3 | Efficiency improvement | 38.3 | 36.9 | 37.4 | 37.7 | 37.9 | 37.9 | 36.9 | 39.0 | 40.2 | 40.1 | 39.8 | 40.0 |
| 4 | Customer feed back | 48.2 | 43.0 | 44.4 | 45.2 | 45.6 | 45.7 | 44.3 | 45.4 | 46.6 | 48.2 | 47.9 | 47.6 |
| 5 | Work highlights published | 1.9 | 1.8 | 1.8 | 1.7 | 1.5 | 1.5 | 1.4 | 1.5 | 1.6 | 1.6 | 1.6 | 1.6 |
| 6 | Clock time accuracy | 79.7 | 73.5 | 74.5 | 74.8 | 73.8 | 74.2 | 69.2 | 70.3 | 71.3 | 71.8 | 72.1 | 72.2 |
| 7 | Project management documents | 75.5 | 72.7 | 68.4 | 69.7 | 65.0 | 63.5 | 57.1 | 59.0 | 59.3 | 60.8 | 61.4 | 62.9 |
| 8 | Project management survey | 64.2 | 66.5 | 64.4 | 65.8 | 61.6 | 60.5 | 57.5 | 59.2 | 59.2 | 59.8 | 60.8 | 61.9 |
| 9 | Team and HR compliances | 58.8 | 59.7 | 63.3 | 58.3 | 56.5 | 56.1 | 53.0 | 54.4 | 56.7 | 56.6 | 57.9 | 59.2 |
| 10 | Internal documents | 67.0 | 60.0 | 62.7 | 58.4 | 58.1 | 58.0 | 57.5 | 59.3 | 60.6 | 61.4 | 62.4 | 63.7 |
| 11 | Internal project archival | 71.6 | 63.3 | 59.0 | 61.0 | 57.5 | 56.1 | 53.1 | 55.0 | 57.3 | 56.6 | 56.5 | 53.7 |
| 12 | Delegation of work | 67.8 | 59.4 | 53.6 | 54.8 | 50.3 | 48.3 | 45.5 | 45.4 | 46.6 | 46.2 | 47.8 | 49.7 |
| 13 | Additional training | 58.7 | 61.0 | 60.4 | 60.2 | 57.6 | 58.3 | 55.6 | 55.9 | 59.2 | 60.1 | 60.7 | 61.1 |
| 14 | Mandatory training | 52.4 | 63.4 | 54.4 | 51.5 | 48.7 | 48.0 | 44.1 | 44.1 | 46.1 | 46.9 | 47.8 | 48.2 |
| 15 | Mentoring new engineers | 47.6 | 51.7 | 53.5 | 51.3 | 48.8 | 50.7 | 48.7 | 48.8 | 47.7 | 49.4 | 49.3 | 49.6 |
| 16 | Conference presentation | 41.2 | 43.5 | 49.3 | 47.0 | 44.2 | 44.3 | 41.6 | 41.6 | 42.6 | 42.8 | 42.6 | 42.8 |

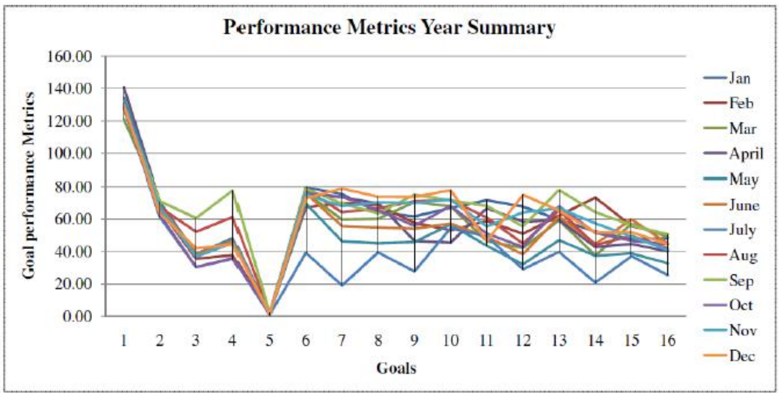



**Fig. 5.1**. Mean of the team's performance metrics on the goals for the entire year

Table 5.2 Weightage values of the goals for the entire year

| S. No. | Goals | Mean summary | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 1 | Effective production hours | 16.00 | 16.443 | 15.853 | 15.319 | 13.244 | 9.989 | 7.408 | 4.913 | 3.442 | 2.641 | 2.070 | 1.653 |
| 2 | Quality metrics | 13.00 | 14.706 | 15.420 | 14.452 | 13.120 | 10.700 | 8.726 | 6.720 | 5.566 | 4.917 | 4.629 | 4.502 |
| 3 | Efficiency improvement | 10.00 | 15.001 | 20.088 | 22.507 | 24.100 | 22.885 | 21.595 | 18.643 | 16.699 | 15.579 | 15.097 | 15.145 |
| 4 | Customer feed back | 8.00 | 13.579 | 19.789 | 23.392 | 25.821 | 24.992 | 23.951 | 21.012 | 19.111 | 17.960 | 17.566 | 17.730 |
| 5 | Work highlights published | 8.00 | 8.500 | 8.344 | 7.451 | 6.661 | 5.417 | 4.361 | 3.180 | 2.451 | 2.043 | 1.735 | 1.534 |
| 6 | Clock time accuracy | 7.00 | 2.958 | 1.375 | -0.485 | -2.210 | -2.995 | -3.682 | -2.285 | -1.735 | -1.743 | -1.907 | -2.183 |
| 7 | Project management documents | 6.00 | 3.806 | 2.508 | 2.827 | 2.576 | 3.679 | 4.988 | 7.196 | 8.785 | 10.176 | 10.776 | 11.257 |
| 8 | Project management survey | 7.00 | 9.855 | 10.791 | 11.672 | 11.718 | 11.965 | 12.347 | 12.128 | 12.107 | 12.745 | 13.043 | 13.235 |
| 9 | Team and HR compliances | 6.00 | 9.918 | 13.987 | 14.556 | 16.690 | 17.578 | 18.134 | 17.704 | 17.374 | 17.568 | 17.768 | 17.901 |
| 10 | Internal documents | 5.00 | 6.563 | 10.269 | 11.518 | 14.603 | 15.410 | 15.850 | 14.551 | 13.654 | 13.460 | 13.082 | 12.744 |
| 11 | Internal project archival | 4.00 | -5.478 | -11.389 | -13.486 | -15.782 | -14.844 | -13.444 | -10.717 | -9.425 | -9.535 | -9.432 | -9.519 |
| 12 | Delegation of work | 3.00 | -4.347 | -8.291 | -8.707 | -9.351 | -7.416 | -5.153 | -2.229 | -0.208 | 0.958 | 1.966 | 2.253 |
| 13 | Additional training | 2.00 | 2.209 | 1.700 | 1.537 | 1.086 | 1.638 | 1.849 | 2.547 | 2.773 | 2.370 | 1.779 | 1.155 |
| 14 | Mandatory training | 2.00 | 1.027 | -4.207 | -5.386 | -5.239 | -3.663 | -2.172 | 0.222 | 1.943 | 2.660 | 3.043 | 3.089 |
| 15 | Mentoring new engineers | 1.50 | 2.638 | 1.820 | 0.259 | -0.229 | 0.214 | -0.048 | 0.340 | 0.591 | 0.540 | 0.638 | 0.714 |
| 16 | Conference presentation | 1.50 | 2.342 | 2.443 | 2.413 | 3.198 | 4.441 | 5.291 | 6.076 | 6.868 | 7.623 | 8.148 | 8.792 |

The weightage values, for all twelve months, i.e., January to December, of all respective goals are summarized and presented in Table 5.2. The pictorial representation of the weightages of all the sixteen goals for all twelve months is shown in Fig. 5.1. From this graph, it is observed that five goals, i.e., clock time accuracy, internal project archival, delegation of work, mandatory training and mentoring new engineers, surpass the goal target levels in few months. Finally, two goals, i.e., clock time accuracy and internal project archival, resulted with negative weightage values. Fig. 5.3 is showing the analysis of weightages of all the sixteen goals for the starting month (January) and ending month (December) of the fiscal year. Weightage values of the goals for the month of January is based on the priority of the goals whereas for December month weightages are the results of twelfth iteration obtained from empirical formula.

Table 5.3 Grading rank of the employees for the entire year

| S.No | Months | Grading rank of the employees | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1 | January | 9406 | 7449.9 | 8362.8 | 6575.8 | 6582.2 | 5603.6 | 6009.5 | 7594.3 | 7870.8 | 7325.6 | 7551 |
| 2 | February | 7836 | 7665.9 | 5803.2 | 5997.1 | 6983.9 | 6129.8 | 5307.4 | 6228.8 | 6985.7 | 6234.6 | 6427 |
| 3 | March | 8359.3 | 7604.9 | 8421.8 | 6785.2 | 5844.1 | 6029.5 | 5092.4 | 6771.7 | 7214.7 | 6331.1 | 6213.5 |
| 4 | April | 7741.2 | 8398.1 | 7989 | 6294.6 | 5989.5 | 6242.4 | 5811.7 | 7127.8 | 6746.5 | 7001.1 | 6716 |
| 5 | May | 7368.8 | 7090 | 7391.8 | 5394 | 5631.2 | 5247.6 | 5663.8 | 6350 | 7235.8 | 6446 | 6493 |
| 6 | June | 9378 | 8426.9 | 8221.8 | 6139.8 | 5959.7 | 6605.5 | 6190.9 | 4837.3 | 4752.5 | 7560.8 | 6513 |
| 7 | July | 3798.8 | 3988 | 6840.8 | 6256 | 3977.4 | 4143.3 | 5200 | 4626.3 | 5335.4 | 5338.3 | 5602 |
| 8 | August | 6448.8 | 7463.9 | 8207.8 | 6604.8 | 6258.7 | 7824.8 | 7194.4 | 7992.8 | 8197.8 | 7719.4 | 7636.3 |
| 9 | September | 6304.8 | 6969.9 | 7887.8 | 6546.8 | 7659.9 | 8057.8 | 6967.8 | 5935.2 | 7059.3 | 7388.4 | 7814.8 |
| 10 | October | 7624.4 | 6017.7 | 6311.6 | 6676.4 | 5847.8 | 5390.4 | 6591.8 | 7030.2 | 6827.6 | 7018 | 6508.4 |
| 11 | November | 6771.7 | 8426.9 | 6617.7 | 6577.8 | 6501.2 | 6167.6 | 5637 | 7850.8 | 7724.7 | 7413.1 | 7079.5 |
| 12 | December | 6424.6 | 5889 | 7756.8 | 7738.7 | 6215.6 | 5637 | 7668.8 | 7538.7 | 7413.1 | 7508.7 | 6263.6 |
| | Total rank | 87463.4 | 85393.1 | 89815.9 | 77591 | 73456.2 | 73085.3 | 73342.5 | 79891.9 | 83372.9 | 83295.1 | 80829.1 |

Table 5.4 show the rank grading of 11 members of the team for the entire year. From this table or figure, it is evident that highest rank is obtained by 3rd employee whereas the lowest rank is obtained by 6th employee.

Table 5.4 Grading rank of the employee

| Employee no. | Grading rank | Rank obtained |
|---|---|---|
| 1 | 87828 | 2 |
| 2 | 85393 | 3 |
| 3 | 89816 | 1 |
| 4 | 77591 | 8 |
| 5 | 73456 | 9 |
| 6 | 73085 | 11 |
| 7 | 73343 | 10 |
| 8 | 79892 | 7 |
| 9 | 83661 | 4 |
| 10 | 83295 | 5 |
| 11 | 80829 | 6 |

In this study an attempt is made to improve our result by implementing lean, six sigma and TOC. From Table 5.5 comparison is done among our research study and previous study (Rajini, et al., 2018).

The efficiency comparison of the conventional approach, integrated methodologies of lean & six sigma and the lean, six sigma & theory of constraints, is also carried out and the results are tabulated in Table 5.5. The performance achievement level, of team members in an integrated approach of lean, six sigma and TOC, is better compared to the other two approaches. The performance improvement in lean, six sigma and TOC shows 2-10% with respect to the conventional approach and 0-5% with respect to the lean & Six Sigma.

Table 5.5 Efficiency comparison of the integrated methodologies

| S.No. | Goals | Efficiency Achievement (in %) | | | | |
|---|---|---|---|---|---|---|
| | | Conventional method | Lean and six sigma | Lean, six sigma and TOC | Benefit over conventional method | Benefit over the lean and six sigma |
| 1 | Effective production hours | 75 | 83 | 86 | 7 | 3 |
| 2 | Quality metrics | 84 | 90 | 94 | 6 | 4 |
| 3 | Efficiency improvement | 70 | 74 | 80 | 4 | 5 |
| 4 | Customer feed back | 74 | 80 | 88 | 6 | 8 |
| 5 | Work highlights published | 78 | 82 | 85 | 2 | 3 |
| 6 | Clock time accuracy | 90 | 92 | 90 | 0 | 5 |
| 7 | Project management documents | 80 | 82 | 87 | 0 | 5 |
| 8 | Project management survey | 88 | 94 | 95 | 7 | 1 |
| 9 | Team and HR compliances | 80 | 80 | 80 | 0 | 0 |
| 10 | Internal documents | 88 | 98 | 98 | 10 | 0 |
| 11 | Internal project archival | 80 | 80 | 80 | 0 | 0 |
| 12 | Delegation of work | 88 | 92 | 90 | 2 | -2 |
| 13 | Additional training | 60 | 60 | 60 | 0 | 0 |
| 14 | Mandatory training | 60 | 60 | 60 | 0 | 0 |
| 15 | Mentoring new engineers | 74 | 82 | 80 | 6 | -2 |
| 16 | Conference presentation | 60 | 70 | 70 | 10 | 0 |

From all these derived data, an employee gets a clear understanding of the team performance achievement level of the goals. Thus, on every month, an employee gets motivated to perform well to reach the target level. With the help of dash board data, the management takes necessary steps to reduce the variance (in terms of performance achievement level).

## Discussion

In this study, an attempt is made to implement the integrated methodology of lean six sigma and theory of constraints for efficiency improvement on team goal performance metrics. Initially identification and cascading of goals is executed to the sub team levels based on their capability and capacity. A case study with a team of eleven members and sixteen goals is considered in the proposed methodology implementation. Data collection, data verification and data analysis is carried out through statistical approach. Mean, standard deviation and normal distribution is computed to plot the bell curves with respect to each of the goals for better understanding of the performance achievement levels of team members. The overall rank grading is computed from the empirical equation derived in this work.

From the research findings of this chapter, it is concluded that the arithmetic mean of the goals performance achievement levels on each of the twelve months achieved by the team members shows a positive trend towards the specified target level. Most of the top priority goals have been achieved to the expected target levels. It is also concluded that the weightage calculated from the empirical model are fluctuating based on the achievement by team members. The weightage from the first iteration predicts that two goals outperformed and reported negative values. Few of the goals, i.e., project management, mentoring new engineers and conference presentation, too out performed over the month. In the year end, project management and delegation of work ended with negative values. Still there is scope for improvement on internal document, work highlights published and customer feedback. These three goals reported the highest values of weightage. The most achieved goal is the effective production hours.

Further, it is concluded that the observation of the bell curve plot states that most of the goal turns to be better in the third and last quarter results. The communication of the statistical approach shows the improvement in most of the goals. The ten top priority goals, i.e., quality metrics, customer feedback, work published, project management document, project management survey, internal documents, delegation of work, additional training, mandatory training and conference presentation, outperformed in last quarter as compared to all other quarters. The goals, i.e., effective production hours and efficiency Improvement, outperformed in the third quarter as compared to all other quarters. Team and HR compliances goal outperform in the first quarter as compared to all other quarters. Clock time accuracy goal outperform in the conventional methods as compared to all other quarters. For the goals, i.e., mentoring new engineers and internal project archival, the performance is same in all the quarters.

## 6. CONCLUSION

### Summary of Findings and Conclusions

This research work is an attempt to investigate the efficiency improvement on the performance achievement levels of the team goals. In this work, two integrated methodologies are developed by combining and implementing lean and six sigma in the first phase and lean, six sigma and theory of constraints in second phase. Commonly for both the methodologies, identification and cascading of goals is executed to the sub team levels based on their capability and capacity. A case study with a team of eleven members and sixteen goals is considered. Data collection, data verification and data analysis is carried out through statistical approach. Mean, standard deviation and normal distribution is computed to plot the bell curves with respect to each of the goals for better understanding of the performance achievement levels of team members. In addition, with respect to the integrated methodology of lean, six sigma and theory of constraints, the overall rank grading is computed by using the empirical equation. Detailed comparison, interpretation and plotting of the result were carried out. From the research findings of the integrated methodology of lean and six sigma, it is concluded that for effective production hours the lowest mean happens to be in the December and highest mean on the April. The performance achievement on production hours is closer to the mean in May. The second important goal quality metrics records very low in February and July and closer to the mean in September and in overall the goal is lower than the required target. In rest of the months it falls between the range of the target level and lower limit. Similar pattern is observed on the efficiency improvement goal as that of the quality metrics. The feedback from the customer occurs at wide range with February recording the lowest and September records the highest. Rest of the goals observed in the similar range of values. Internal project archival goal surpasses the mean target in most of the months. But still there is lot of scope for improvement and most of the mean achieved by the team is not par to expected target levels.

Finally, it is concluded that the combination of lean, six sigma and theory of constraints outperforms the combination of lean and six sigma and gives better yield for thirteen goals. Furthermore, implementation of lean, six sigma and Theory of constraints together gives better understanding on the grading rank of the employees.

**Future scope of the work**

This research work is investigated and implemented with certain assumptions. In the present innovative and competitive business environment, this research can be further extended with diverse criteria as outlined here.

a) The methodology can be extended by considering the cost parameters.

b) The methodology can be applied to any process, service industry, discrete manufacturing Industry and also in the upcoming field like IoT/Industry 4.0 etc

c) The methodology can be further extended to all the teams across the enterprise with multi factor parameters to get the overall benefit

## REFERENCES

[1] Aguilar Escobar, V.G. and Garrido Vega, P. (2016), 'Applying the theory of constraints to the logistics service of medical records of a hospital', European Research on Management and Business Economic 22(3), 139-146.

[2] Alhuraish, I., Robledo, C. and Kobi, A. (2016), 'Assessment of lean manufacturing and Six Sigma operation with decision making based on the analytic hierarchy process'. IFAC-Papers OnLine 49(12), 59-64.

[3] Alhuraish, I., Robledo, C. and Kobi, A. (2017), 'A comparative exploration of lean manufacturing and six sigma in terms of their critical success factors', Journal of Cleaner Production 164, 325-337.

[4] Al–Refaie, A. and Al–Hmaideen, K. (2014), 'Six Sigma management and grey relational analysis to improve performance of tableting process'. International Journa of Productivity and Quality Management 15(1), 57-71.

[5] Andersson, R., Hilletofth, P. and Hilmola, O.P. (2015), 'Lean implementation in the geriatric care sector in Sweden', International Journal of Six Sigma and Competitive Advantage 9(1), 56-71.

[6] Antony, J. (2011),'Six Sigma vs. lean: some perspectives from leading academics and practitioners', International Journal of Productivity and Performance Management 60(2), 185–190.

[7] Antunes, D.S.L., Sousa, S. and Nunes, E.P. (2013),'Using project six sigma and lean concepts in internal logistics', In World Congress on Engineering, News wood Limited Publisher. pp. 414-419

[8] Aqlan, F. and Al-Fandi, L. (2018), 'Prioritizing process improvement initiatives in manufacturing environments', International Journal of Production Economics 196, 261-268.

[9] Arafeh, M. (2016), 'Leveraging Six Sigma Tools and Methodology to Improve Student English Language Performance at Elementary School', American Journal of Operations Research 6(04), 261.

[10] Aragon, M.V.D.L.F. and Ros-McDonnell, L. (2015), 'Implementing a lean production system on a food company: a case study', International Journal of Engineering Management and Economics 5(1-2), 129-142.

[11] Azadeh, A., Narimani, A. and Nazari, T. (2014), 'Estimating household electricity consumption by environmental consciousness', International Journal of Productivity and Quality Management 15(1), 1-19.

[12] Badri, S.A., Ghazanfari, M. and Shahanaghi, K. (2014),'A multi-criteria decisionmaking approach to solve the product mix problem with interval parameters based on the theory of constraints', The International Journal of Advanced Manufacturing Technology 70(5-8), 1073-1080.

[13] Bos Van den, A., Kemper, B.P.H., Dongen, J.V. and Krute, M.S. (2014),'Generic Lean Six Sigma project definitions for the construction industry', International Journal of Six Sigma and Competitive Advantage 8(3-4), 257-273.

[14] Caldera, H.T.S., Desha, C. and Dawes, L. (2017), 'Exploring the role of lean thinking in sustainable business practice: A systematic literature review', Journal of Cleaner Production 167, 1546-1565.

[15] Chakravorty, S.S. and Atwater, J.B. (1998),'Implementing quality improvement programs using the focusing steps of the theory of constraints', International Journal of Technology Management 16(4-6), 544-555.

[16] Chen, S., Fan, S., Xiong, J. and Zhang, W.(2017),'The Design of JMP/SAP Based Six Sigma Management System and its Application in SMED'. Procedia Engineering 174, 416-424.

[17] Chen, S.H., Hsu, C.C. and Wu, I.P., (2017). 'The effects of total quality management implications on customer satisfaction and customer loyalty: an empirical study in the Taiwanese security industry'. European Journal of Industrial Engineering 11(1), 1-21.

[18] Cherrafi, A., Elfezazi, S., Chiarini, A., Mokhlis, A. and Benhida, K., (2016). 'The integration of lean manufacturing, Six Sigma and sustainability: A literature review and future research directions for developing a specific model'. Journal of Cleaner Production 139, 828-846.

[19] Ciccullo, F., Pero, M., Caridi, M., Gosling, J. and Purvis, L., (2017). 'Integrating the environmental and social sustainability pillars into the lean and agile supply chain management paradigms: A literature review and future research directions'. Journal of Cleaner Production 172, 2336-2350.

[20] Costas, J., Ponte, B., de la Fuente, D., Pino, R. and Puche, J., (2015). 'Applying Goldratt's Theory of Constraints to reduce the Bullwhip Effect through agent-based modeling'. Expert Systems with Applications 42(4), 2049-2060.

[21] De Mast, J. and Lokkerbol, J., (2012). 'An analysis of the Six Sigma DMAIC method from the perspective of problem solving'. International Journal of Production Economics 139(2), 604-614.

[22] De Freitas, J.G., Costa, H.G. and Ferraz, F.T.,(2017). ‘Impacts of Lean Six Sigma over organizational sustainability: A survey study’, Journal of Cleaner Production 156, 262- 275.

[23] Ehie, I. and Sheu, C., (2005). ‘Integrating six sigma and theory of constraints for continuous improvement: a case study’.Journal of Manufacturing Technology Management, 16(5), 542-553.

[24] Ehie, I. and Sawhney, R., (2006). ‘Integrating Six Sigma and Lean Manufacturing for process improvement: a case study’. AB Badiru, Handbook of Industrial and Systems Engineering, pp 36. Boca Raton: CRC.

[25] Fekri, K., Shafiabady, A., Nooranipour, R. and Ahghar, G., (2012). ‘Determine and compare effectiveness of entrepreneurship education based on multi-axial model and theory of constraints and compromises on learning entrepreneurship skills’. Procedia- Social and Behavioral Sciences 69, 566-570.

[26] Garre, P., Bharadwaj, V.N., Shashank, P.S., Harish, M. and Dheeraj, M.S., (2017). ‘Applying lean in aerospace manufacturing’. Materials Today: Proceedings 4(8), 8439-8446.

[27] Ginoria, S., Samuel, G.L. and Srinivasan, G., (2014). ‘Optimisation of a machine loading problem using a genetic algorithm–based heuristic’. International Journal of Productivity and Quality Management 15(1), 36-56.

[28] Goldratt, E.M. and Cox, J., (1984). ‘The goal: excellence in manufacturing’. North River Press.

[29] Golmohammadi, D., (2015). ‘A study of scheduling under the theory of constraints’. International Journal of Production Economics 165, 38-50.

[30] Gupta, M.C. and Boyd, L.H., (2008). ‘Theory of constraints: a theory for operations management’. International Journal of Operations & Production Management 28(10), 991-1012.

[31] Hilmola, O.P., (2001). ‘Theory of constraints and outsourcing decisions’. International Journal of Manufacturing Technology and Management 3(6), 517-527.

[32] Indrawati, S. and Ridwansyah, M., (2015). ‘Manufacturing continuous improvement using lean six sigma: An iron ores industry case application’. Procedia Manufacturing 4, 528-534.

[33] Izmailov, A., (2014). ‘If your company is considering the Theory Of Constraints’. Procedia-Social and Behavioral Sciences 150, 925-929.

[34] Jacob, D., Bergland, S. and Cox, J., (2009). ‘Velocity: Combining Lean, Six Sigma and the Theory of Constraints to achieve breakthrough performance-A business novel’. Simon and Schuster.

[35] Jafarpour, E., Shafei, R., Sadeghani, M. and Moradi, M., (2014). ‘Evaluation of the suggestions system performance using DEA, the case of Esfahan's Steel Company’. International Journal of Productivity and Quality Management 15(1), 20-35.

[36] Jin, K., Hyder, A.R., EIKASSABGI, Y., Zhou, H. and Herrera, A., (2009). ‘Integrating the theory of constraints and Six Sigma in manufacturing process improvement’. In Proceedings of world academy of science, engineering and technology 37, 120-135 .

[37] Kovach, J.V., Carden, L.L. and Ramos, M.A., (2014). ‘‘Flipping’ the Lean Six Sigma classroom’. International Journal of Six Sigma and Competitive Advantage 8(3-4), 227-246.

[38] Kubilius, A., Winfrey, K., Mayer, C., Johnson, G. and Wilson, T., (2015). ‘Applying Lean Six Sigma tools to reduce the rate of slips, trips and falls for Joint Commission field staff’. International Journal of Six Sigma and Competitive Advantage 9(1), 37-55.

[39] Kumar, U.D., Nowicki, D., Ramirez-Marquez, J.E. and Verma, D., (2008). ‘On the optimal selection of process alternatives in a Six Sigma implementation’.International Journal of Production Economics 111(2), 456-467.

[40] Lakshmi, K.S., Jasim, K.M., Prabhakar, K. and Parveen, S.J., (2017). ‘Brand positioning of ayurvedic medicine in Indian millennium’. International Journal of Business Excellence 11(1), 16-37.

[41] Lee, M.C. and Chang, T., (2012). ‘Combination of theory of constraints, root cause analysis and Six Sigma for quality improvement framework’. International Journal of Productivity and Quality Management 10(4), 447-463

[42] Linhares, A., (2009). ‘Theory of constraints and the combinatorial complexity of the product-mix decision’.International Journal of Production Economics 121(1), 121-129.

[43] Maasouman, M.A. and Demirli, K., (2015). ‘Assessment of lean maturity level in manufacturing cells’.IFAC-PapersOnLine 48(3), 1876-1881.

[44] Mishra, P. and Sharma, R.K., (2017). ‘Measuring business performance in a SCN using Six Sigma methodology-a case study’.International Journal of Industrial and Systems Engineering 25(1), 76-109.

[45] Morais, V.R., Sousa, S. and Lopes, I.D.S., (2015). ‘e’.In World Congress on Engineering 2015 (Vol. 2, pp. 847-852).

[46] Mousa, A., (2013). ‘Lean, six sigma and lean six sigma Overview’. Internationa Journal of Scientific & Engineering Research 4(5), 1137-1153.

[47] Mukhopadhyay, S.K. and Panda, J.P., (2006). ‘Applying theory of constraints on ongoing improvement in manufacturing system dealing with animal feed’. International journal of manufacturing technology and management, 10(2-3), 261-275.

[48] Nave, D., (2002). How to compare six sigma, lean and the theory of constraints. Quality Progress 35(3), 73.

[49] Niemeijer, G.C., Trip, A., de Jong, L.J., Wendt, K.W. and Does, R.J., (2012). ‘Impact of 5 years of lean six sigma in a University Medical Center’. Quality Management in Healthcare 21(4), 262-268.

[50] Niu, G., Lau, D. and Pecht, M., (2010). ‘Computer manufacturing management integrating lean six sigma and prognostic health management’. International Journal of Performability Engineering 6(5), 453-466.

[51] Noori, B., (2014). ‘The critical success factors for successful lean implementation in hospitals’. International Journal of Productivity and Quality Management 15(1), 108- 126.

[52] Ohno, T., (1988). ‘Toyota production system: beyond large-scale production’. CRC Press

[53] Okutmuş, E., Kahveci, A. and Kartašova, J., (2015). ‘Using theory of constraints for reaching optimal product mix: an application in the furniture sector’. Intellectual Economics 9(2), 138-149.

[54] Pamfilie, R., Petcu, A.J. and Draghici, M., (2012). ‘The importance of leadership in driving a strategic Lean Six Sigma management’.Procedia-Social and Behavioral Sciences 58, 187-196.

[55] Panagopoulos, I., Atkin, C. and Sikora, I., (2017). 'Developing a performance indicators lean-sigma framework for measuring aviation system's safety performance'. Transportation research procedia, 22, pp. 35-44.

[56] Parast, M.M., (2011). 'The effect of Six Sigma projects on innovation and firm performance'. International Journal of Project Management 29(1), 45-55.

[57] Pepper M.P.J. and T.A. Spedding, (2010) 'The evolution of lean Six Sigma', International Journal of Quality & Reliability Management 27(2), 138-155.

[58] Plenert, G., (1993). 'Optimizing theory of constraints when multiple constrained resources exist'. European Journal of Operational Research 70(1), 126-133.

[59] Potra, S. and Pugna, A., (2015). 'DFSS in marketing: designing an innovative value cocreation campaign'. International Journal of Six Sigma and Competitive Advantage 9(1), 21-36.

[60] Ramos, A.R., Ferreira, J.C.E., Kumar, V., Garza-Reyes, J.A. and Cherrafi, A., (2017). 'A lean and cleaner production benchmarking method for sustainability assessment: A study of manufacturing companies in Brazil'. Journal of Cleaner Production 177(10), 218-231

[61] Rand, G.K., (2000). 'Critical chain: the theory of constraints applied to project management'. International Journal of Project Management 18(3), 173-177.

[62] Randhawa, J.S. and Ahuja, I.S., (2017). '5S implementation methodologies: literature review and directions'. International Journal of Productivity and Quality Management 20(1), 48-74.

[63] Rezaie, K., Nazari-Shirkouhi, S. and Ghodsi, R., (2010). 'Theory of constraints and particle swarm optimization approaches for product mix problem decision'. Australian Journal of Basic and Applied Sciences 4(12), 6483-6491.

[64] Sagnak, M. and Kazancoglu, Y., (2016). 'Integration of green lean approach with six sigma: an application for flue gas emissions'. Journal of Cleaner Production 127, 112- 118

[65] Shafer, S.M. and Moeller, S.B., (2012). 'The effects of Six Sigma on corporate performance: An empirical investigation'. Journal of Operations Management 30(7-8), 521-532.

[66] Simşit, Z.T., Gunay, N.S. and Vayvay,O., (2014). 'Theory of constraints: A literature review'. Procedia-Social and Behavioral Sciences 150, 930-936.

[67] Sin, A.B., Zailani, S., Iranmanesh, M. and Ramayah, T., (2015). 'Structural equation modelling on knowledge creation in Six Sigma DMAIC project and its impact on organizational performance. International Journal of Production Economics 168, 105- 117.

[68] Singh, R.K., Kumar, S. and Tiwari, M.K., (2006). 'Psycho-clonal based approach to solve a TOC product mix decision problem'. The International Journal of Advanced Manufacturing Technology 29(11-12), 1194-1202.

[69] Soliman, M. and Saurin, T.A., (2017). 'Lean production in complex socio-technical systems: A systematic literature review'. Journal of Manufacturing Systems, 45, pp. 135-148.

[70] Sukalová, V. and Ceniga, P., (2015). 'Application of The Theory of Constraints Instrument in The Enterprise Distribution System'. Procedia Economics and Finance, 23, pp. 134-139.

[71] Taghizadegan, S., (2006). 'Introduction to essentials of lean six sigma (6 [sigma]) strategies: Lean six sigma: Six sigma quality with lean speed'. Essentials of Lean Six Sigma, pp. 1-6.

[72] Tanwer, A.K., Prajapati, D.R. and Singh, P.J., (2014). 'Effect of various factors for achieving environmental performance in manufacturing industry: a review'. International Journal of Productivity and Quality Management 15(1), 72-107.

[73] Tenera, A.M.B.R. and Luís Carneiro, P., (2014), 'A Lean Six Sigma (LSS) project management improvement model'. Selected Papers From The 27thIPMA (International Project Management Association) 912-920.

[74] Watson, K.J., Blackstone, J.H. and Gardiner, S.C., (2007). 'The evolution of a management philosophy: The theory of constraints'. Journal of operations Management 25(2), 387-402.

[75] Wei, C.C., Liu, P.H. and Tsai, Y.C., (2002). 'Resource-constrained project management using enhanced theory of constraint'. International Journal of Project Management 20(7), 561-567.

[76] Wetzel, E.M. and Thabet, W.Y., (2016). 'Utilizing Six Sigma to develop standard attributes for a Safety for Facilities Management (SFFM) framework'. Safety science 89, 355-368.

[77] Wiegel, V. and Brouwer-Hadzialic, L., (2015). 'Lessons from higher education: adapting lean six sigma to account for structural differences in application domains'. International Journal of Six Sigma and Competitive Advantage 9(1), 72-85.

[78] Wu, H.H., Chen, C.P., Tsai, C.H. and Tsai, T.P., (2010). 'A study of an enhanced simulation model for TOC supply chain replenishment system under capacity constraint'. Expert Systems with Applications 37(9), 6435-6440.

[79] Wu, S. and Wee, H.M., (2009). 'Why the Big Three Decline Despite Their Lean Management-A Study Based on the Theory of Constraints'. In Global Perspective for Competitive Enterprise, Economy and Ecology, Springer, London pp. 691-699.

[80] Youssouf, A., Rachid, C. and Ion, V., (2014). 'Contribution to the optimization of strategy of maintenance by lean six sigma'. Physics Procedia 55, 512-518.

[81] Zhang, L. and Chen, X., (2016). 'Role of lean tools in supporting knowledge creation and performance in lean construction'.Procedia Engineering 145, 1267-1274.