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Toc, Lean, And Six Sigma Tools: Improving Quality And Productivity At Indian Automotive Component Manufacturing Sector

Mrigendra Nath Mishra[1], Dr. Ashutosh Mohan[2]

[1,2]*Institute of Management Studies, Banaras Hindu University, Varanasi, India*

Processes that are not managed, lead to significant damage along with the disruption of production schedules by causing the production of a large number of defective products before nonconformity is detected. It is important to develop an effective system of management and control capable of detecting process differences as early as possible so that corrective actions can be taken before the production of a large number of defective products. The purpose of this study was to identify the strengths and weaknesses of the existing Theory of Constraints (TOC), Lean, and Six Sigma manufacturing processesof the Indian Automotive Organization improve quality and productivity. An empirical study was carried out, using a survey questionnaire and the results of the study showed evidence of misalignment and discrepancies for TOC, Lean, and Six Sigma in the organization. Several important findings on the implications of TOC, Lean, and Six Sigma activities affecting manufacturing activities were revealed. The study concluded that a significant relationship exists between the TOC, Lean and Six Sigma to achieve overall business excellence on the shop floor for those who are documented.

Key words: Theory of Constraints, Lean manufacturing, Six Sigma, automotive industry, operational performance, quality, excellence, productivity

1. INTRODUCTION

1.1. Background Of The Study

Meeting customer expectations and demands is inevitable. The way a business reacts to achieve these expectations and impacts their competitor-ness and profitability. In Karatepe and Ekiz (2004), cites Parasuraman et al. (1991) where increasing global competition, understanding customer expectations, and meeting customer needs is important if better service quality is provided. It is under considerable pressure on organizations around the world to reduce their costs, increase their service levels, and supply better quality goods. To meet these goals and remain more competitive, organizations adopt the use of many different tools, techniques, and strategies to make their production processes more efficient. In addition, organizations are always searching for ways to optimize business processes so that they can reduce manufacturing costs. Encouraged by this desire, organizations are turning to TOC, Lean, Six Sigma systems as a way to rapidly reduce production costs, improve quality and provide better customer service.

1.2. Problem Description

The extent of the current global financial crisis has damaged many jobs in India's automotive industry. In 2019, the Indian automotive industry is reducing its workforce as a result of the decline in new vehicle sales, and as part of a campaign to improve their efficiency and overall competitiveness. On the other hand, many motor companies have reduced workdays in their production

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week, which is expected to last until the economic situation changes.

Currently, the organization faces similar challenges as the rest of the global manufacturing community. Organizations have reduced their sales forecasts in 2019-20 due to decreasing order from their customers. Many customers found themselves in a state of overstock due to declining market demand and thus reduced their orders even further. Although sales volume has decreased over the past year, problems such as process defects, excessive scrap, incorrect inventory levels, and defective products supplied to customers continue to surface. Therefore, in an effort to continuously satisfy customer requirements, this organization selectively adopted TOC, Lean, and Six Sigma systems.

1.3. Purpose And Objectives

The purpose of this research is to develop a roadmap to improve the current TOC, Lean and Six Sigma processes in the Indian automotive component organization, while the purpose of the study will be to analyze the TOC, Lean and Six Sigma principles of this organization on process and quality improvement.

1.4. Hypothesis

H0: There is no significant relationship exist between the TOC, Lean and Six Sigma to achieve overall business excellence.

H1: There is a significant relationship exist between the TOC, Lean and Six Sigma to achieve overall business excellence.

2. LITERATURE REVIEW

Andersson et al. (2006) provide strong empirical support of other quality management concepts such as Total Quality Management, Value Engineering, TOC and Six Sigma.

Lean concepts had their origin in Japan and revolve around minimising waste and resources while improving customer satisfaction and financial results. More specifically, Total Quality Management centres on customer satisfaction; Value Engineering concentrates on systematically improving the value of products and services, TOC concentrates on systematically controlling constraints and Six Sigma drive towards processes to reduce defects by minimising variation. These authors further postulate that the TOC, Lean and Six Sigma concept appears to be the more wide-spread and successful attempts when compared to other quality management concepts.

Russ Pirasteh (2006) developed a model that integrates and harmonizes concepts, techniques, tools, and methodologies of TOC, Lean Manufacturing and Six Sigma called iTLS(TM). The objective of the paper is to study the model from a literature review that analyses the approaches as well as the related points and develop a real case study. In this sense, this study examined the use of iTLS(TM) through a method that identified the constraints, then eliminated wastes of the constraint, and as a final point, reduced the process variability. It made for a problem of Value Chain management of Home Appliances Multinational Subsidiary located in Brazil by application of Russ Pirasteh's model in seven steps. Consistent with preliminary results, it observed the model strength and its applicability to the problem studied. Finally, the study discusses the implications of the finding and presents some directions for future research.

Creasy (2014) has focused on improving operational results while reducing inputs or keeping them the same is what led one organization to embark on a multiyear quest resulting in a method called 6TOC and results worthy of examination. 6TOC is the unique combination of Six Sigma, Lean, and Theory of Constraints (TOC), which focuses on quality improvement with reduction in variation, eliminating waste, and lean focus on bottleneck makes a potent combination for immediately finding root causes and producing solutions with a direct bottom-line impact.

Based on the review of literature, some success dimensions can be established that TOC, Lean and Six Sigma principles in the manufacturing are: top management commitment, plant management and product development management. These are defined in the following sub-sections.

1. **Top management commitment:** The decision of Process Excellence implementation is taken by top management considering the need of the organization. The role of leadership is crucial here. The leadership of the organization gives the direction, motivation to the employees. They also provide the necessary organizational infrastructure for PEM implementation. Management involvement and commitment influences the success of PEM implementation.

2. **Plant Management:** To flow of smooth production, the plant hasto maintain five M's (Men, Machines, Methods, Materials, Money), inventory control, production planning control, and continues improvement in working processes and plansfor PEM selection and implementation. Plant management is an essential part of PEM implementation.

3. **Product Development Management:** To survive in competition, the product development team has required active product management, the ability to identify and focus on the best product ideas, and support for customization towards the successful implementation of PEM. The right product architectureis critical for the successful implementation of PEM.

3. DESIGN OF RESEARCH AND METHODOLOGY

The research approach is based on an empirical study. As suggested by Alam (2011), an interpretive research design has been used to fulfill the purpose of this project. Bubbie and Mouton (2001) describe explanatory research as an investigation to provide an explanation of the cause of the phenomenon. Cooper and Schindler (2006) stated that quantitative research is often used to test a theory and focuses on describing, interpreting and predicting data with the use of statistical and mathematical methods. Hence quantitative research approach is included in this study. According to Alam et al (2010), employees in the organization are easily accessible, so the survey method was considered appropriate. The results of this study apply to this organization and may not generalize to all organizations, although the findings may be useful for organizations that are building or implementing TOC, Lean and Six Sigma techniques.

3.1. Survey Instrument Design

Survey-type questionnaire developed by researcher in TOC, Lean, and Six Sigma techniques was used in this study to inform the design tools of the questionnaire. The content of the questionnaire was based on TOC, Lean, and Six Sigma principles. The purpose of

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the survey, including assurance of confidentiality, was presented by Alam and Hoque (2010) in a covering letter of the questionnaire.

In addition, close-end questions were adopted and the questionnaire was kept as short as possible because the research involved the majority of employees in the production environment who have limited time to participate in the survey. The questionnaire was a list of three TOC, Lean, and Six Sigma principles, where participants were required to rank their adoption probability in their organization's production system.The questions were evaluated on a 5 point Likert scale; ranging from “Strongly Disagree” with a value of (1) to “Strongly Agree” with a value of (5).

3.2. Pilot Testing And Questionnaire Revision

The questionnaire was tested with thirty employees at the plant of various organizations to determine the feasibility of the study. Following the results of the feedback and reliability analysis given by the participants, the questionnaire was edited and improved with the help of the quality manager and the production manager of the organization, so as to increase the accuracy of the main study results.

3.3. Sampling

Upon examining the IBEF report, March 2018, in India, the appropriate automotive component manufacturing units in the organized and unorganized sector are 10700. Based on estimates by experts, 30 % of manufacturing organizations using PEM, so taken population is 3210.It was decided to distribute 321 questionnaires (10% of 3210) to employees within the different manufacturing units in the organized and unorganized sector over a two month period. Out of 141 total returned questionnaires, 127 responses were found suitable for analysis, which indicated a response rate of 43.93%.

3.4. Method Of Data Analysis

The Statistical Package for Social Sciences (version SPSS-20.0) was used to analyze and process data for each question in terms of individual validity, content, and frequency of responses. Validity and internal validity tests of the construct to verify the usefulness of the measuring instrument, and were verified by testing the Cronbach’s alpha (0.801) to confirm reliability.Methods employed such as frequencies, means, and gap values for the analysis of the data collected include descriptive statistics, and inferential statistics such as factor analysis, communalities, and hypothesis testing.

The gap value represents the difference between the actual mean score and the assumed absolute score of 5. The emphasis on the mean score of 3 is that "agree" as well as "disagree" were numerous. This oddity will increase the results.

Assessing communality can assess the ability of the questionnaire model to function well. Getting values close to one is ideal, which would indicate that the model explains most of the variation for those variables. In the case of this study, the model is acceptable as it explains approximately 73% of the variation for the 40 variables.

In hypothesis testing, the null hypothesis indicates no relation between variables, and the alternative hypothesis is a relation. Pearson's chi-square test was used to determine whether there is a statistically significant relationship between the variables (rows vs. columns). As suggested by Kinnear and Gray (2009) and Pallant (2005), a p-value is generated from the test-value, with a significant result indicated by "p < 0.05". The results of this study suggest that there are differences between each statement and the corresponding category. All important chi square values are highlighted and discussed in the results section.

4. RESULTS AND DISCUSSION

The focus of the questionnaire was to determine the existing manufacturing practices of the organizations in this study. It comprises three investigation areas that link questions related to the principles recommended for the Theory of Constraints, Lean, and Six Sigma technique. These investigation areas include top management commitment, plant management, and product development management.

4.1. Top Management Commitment

The purpose of this section evaluates how the management team embraces their objectives, both by challenging and motivating the employees. The questions structured around this section aim to assess the responses of managements' direct involvement with the employees and the processes. The overall results from the survey data about this section have demonstrated in Table-1. These include mean scores, gaps, communalities, p-values, and reliability. The reasons for selecting the aforementioned statistical data to evaluate the results were explained in above section.

Top Management Commitment	**Mean**	**Gap**	**Communality**	**The p-value for the type of practice**	**Cronbach's Alpha**
TM1- The management team knows how to build motivation in the organization.	3.37	-1.63	0.742	0.000	
TM2- Management has arrangements to support skills, experience and competence retention.	3.68	-1.32	0.769	0.005	
TM3- Managers go to where the action takes place (Gemba).	3.39	-1.61	0.784	0.007	
TM4- Organization defines the appropriate roles and responsibilities of the employee.	3.16	-1.84	0.739	0.001	
TM5- The organization tackles the problems immediately as they arise.	3.56	-1.44	0.708	0.000	
TM6- Top management assume the responsibility of interdepartmental coordination.	3.39	-1.61	0.708	0.000	
TM7- Top management provides personal leadership for quality products and quality improvements.	3.57	-1.43	0.781	0.000	
TM8- Management is working on improvement in working capital.	3.53	-1.47	0.744	0.000	
TM9- Management is working on improvement in employee productivity.	3.46	-1.54	0.702	0.167	
TM10- Management provides continuous feedback to employees on their performance.	3.44	-1.56	0.719	0.000	
TM11- Established visual management techniques are useful in the manufacturing process.	3.35	-1.65	0.709	0.000	
Overall	**3.45**	**-1.55**	**0.737**		0.931

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Table -1Results about top management commitment

It can be noted from Table-1 that the average score for this section is 3.45. Since the responses for statements TM2, TM5, TM7, TM8, and TM9 have higher mean values (greater than 3.45), it can be interpreted that these statements have positively inclined towards "agreement". Statements TM1, TM3, TM4, TM6, TM10 and TM11 showed smaller mean values (less than 3.45). That indicates a degree of "negativity" since the 5-point Likert scale represents '3' as "neutral". These questions have larger gaps and will, therefore, require closer inspection of the scoring patterns. The scoring patterns will be evaluated between the different practices grouped as percentages. To this end, the data will be grouped into organizations as follows: those that practice any one technique only, practice any two techniques together, organizations that incorporate Theory of Constraints Lean and Six Sigma together, and organizations that incorporate neither technique. The overall community value of 0.737 in Table-1 indicates that the questionnaire model is explaining variations 73% of the time. The Cronbach's Alpha Coefficient 0.931 of this section maintains the high reliability for the established scales. The Chi-square test per question confirms the mean scores were not random, but are indicative of the response type. There are the same levels of agreement from respondents for all statements ($p<0.05$). That indicates that all statements are significantly related to the type of technique practiced. Hence, the respondents' type of technique adopted did play a role in terms of how the statements were scored.

4.2. Plant Management

The essence of this section is to investigate the control mechanisms organizations employ in their plant environment. It links questions related to the PEM tools and employee participation in response to evaluating the effectiveness within the organization. The purpose of the PEM tools is to create value for customers with fewer resources. The overall mean scores, gaps, p-values, and Cronbach's Alpha for each of the 13 statements representing this section have illustrated in Table-2.

Plant Management	**Mean**	**Gap**	**Communality**	**The p-value for the type of practice**	**Cronbach's Alpha**
PM1- Five M's (Man, Machine, Methods, Materials, Money) are more responsible for uninterrupted process flow.	3.62	-1.38	0.644	0.027	
PM2- Single piece flow of material has maintained between processes.	3.52	-1.48	0.758	0.000	
PM3- Organization uses Kanban systems to signal for material requirements in each process.	3.68	-1.32	0.649	0.000	
PM4- The factory layout has divided into manufacturing cells that encompass product families with similar processing requirements.	3.69	-1.31	0.825	0.000	
PM5- The production schedule has directly linked with the rate of customer demand.	3.69	-1.31	0.692	0.000	
PM6- Organization practices the 5S tool to ensure that the organization's shop floors are well organized, clean, and	3.72	-1.28	0.780	0.000	0.928

safe.					
PM7- Production use to stop immediately for every abnormality.	3.64	-1.36	0.730	0.023	
PM8- "Poke-Yoke" devices are used in an organization to minimize the chances of errors.	3.80	-1.20	0.699	0.000	
PM9- All equipment and processes on the floor are under statistical process control for reducing process variability.	3.16	-1.84	0.730	0.000	
PM10- All processes are continuously questioned for adding more value in Continuous improvement to working processes.	3.54	-1.46	0.746	0.384	
PM11- The algorithm Rope Drum-Buffer-Rope is used to free stuff.	3.64	-1.36	0.621	0.003	
PM12- Organization works for planning the restriction and less detailed non- bottlenecks DBR.	3.70	-1.30	0.701	0.000	
PM13- Organization uses a pull production system in manufacturing process.	3.55	-1.45	0.668	0.000	
Overall	3.61	-1.39	0.711		

Table -2Results about plant management

It can be noted from Table-2 that the average score for this section is 3.61. Since the responses for statements PM1, PM3, PM4, PM5, PM6, PM7, PM8, PM11 and PM12 have higher mean values (greater than 3.45), it can be interpreted that these statements have positively inclined towards “agreement”. Statements PM2, PM9, PM10, and PM13 showed smaller mean values (less than 3.61).

The analysis of communality scores in Table-2 indicates that the questionnaire model explains approximately 71% of the variations for all questions, while the reliability score of 0.928 for this section confirms that the instrument measured what it purports to measure. Further statistical analysis of Chi-Square testing indicates significant relationships for all questions ($p<0.05$) except for statement PM10. The responses for statement PM10 could be interpreted as standard operating practice for all processes are continuously questioned for adding more value in Continuous improvement to working processes.

4.3. Product Development Management

The purpose of the Product Development Management is to optimize existing processes to meet higher performance levels of productivity and quality. It can be classified as an ongoing practice within organizations. Closely related to product development management is the concept of PEM, which is to remove variation from processes and strive to manufacture defect-free products. Therefore, this section incorporates tools associated with PEM to measure the level of improvements sustained within the organizations. The statistical scores for each of the sixteen statements representing product development management are illustrated in Table-3.

Product Development Management	Mean	Gap	Communality	The p-value for the type of practice	Cronbach's Alpha
PDM1- Product development team can identify and focus on the best product ideas.	3.52	-1.48	0.745	0.001	
PDM2- Organization uses the Single-Minute Exchange of Dies (SMED) technique to provide rapid change-over of tooling and fixtures.	3.28	-1.72	0.624	0.000	
PDM3- The elimination of seven forms of production waste (overproduction, waiting, transportation, processing, inventory, motion, defects, increases the constraints) are identified and highlighted in the organization processes.	3.50	-1.50	0.933	0.069	
PDM4- Organization has standard operating procedures for all processes for capability and stability.	3.59	-1.41	0.763	0.000	
PDM5- Involvement of manufacturing and quality people in the product development process improves the process implementation.	3.82	-1.18	0.677	0.000	
PDM6- Organization pays close attention to design for manufacturability or the right product architecture to understanding the various design features affecting the manufacturing cost.	3.51	-1.49	0.920	0.000	
PDM7- Always investigating for robust and effective processes is being needed for improving process flow.	3.50	-1.50	0.773	0.000	
PDM8- There is an appropriate infrastructure for improvement specialists in the organization.	3.74	-1.26	0.752	0.000	
PDM9- The value stream is continuously evaluated and monitored for improvement opportunities.	2.83	-2.17	0.690	0.000	
PDM10- All process improvement decisions are based on the gathered process from statistical data by examining variations.	3.70	-1.30	0.768	0.000	
PDM11- Quality data (error rates, defect rates, scrap, defects, cost of quality) are available throughout the plant to manage quality.	3.37	-1.63	0.767	0.003	
PDM12- The constraints are continuously identified and evaluated for improvement opportunities.	3.54	-1.46	0.780	0.479	
PDM13- Measures are in place to assess process performance for possible improvements.	3.17	-1.83	0.734	0.000	
PDM14- Support for customization is being required for continuous process flow.	3.55	-1.45	0.723	0.082	
PDM15- All improvement projects are structured and undertaken systematically.	3.08	-1.92	0.766	0.000	
PDM16- Linking Advanced Statistical Process Control and analytical tools is a diagnose process improvement.	3.59	-1.41	0.593	0.024	
Overall	3.46	-1.54	0.750		0.922

Table -3Results pertaining to product development management

It can be noted from Table-3 that the average score for this section is 3.61. Since the responses for statements PDM1, PDM3, PDM4, PDM5, PDM6, PDM7, PDM8, PM10, PDM12 and PDM14 have higher mean

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values (greater than 3.46), it can be interpreted that these statements have positively inclined towards “agreement”. Statements PDM2, PDM9, PDM11, PDM13, and PDM15 showed smaller mean values (less than 3.46).

Aside from the positive responses to the questions discussed above, it is noted in Table-3that statements PDM2, PDM9, PDM11, PDM13, and PDM15 have the most substantial gaps in this section and will, therefore, be evaluated further by the type of technique practiced. The Chi-square values for statements PDM3, PDM12, and PDM14 indicate that there were no significant relationships as the questions related directly to the type of technique practiced. On the other hand, the significant relationships ($p<0.05$) established for the remainder of the statements indicate that product development management priorities differ between organizations. It can be inferred from Table-3that the questionnaire model explains 75% of the variation for all questions. This section also indicates relatively high reliability with a score of 0.922.

5. CONCLUSION

The practice of quality management of production processes a multifaceted with existing problems and unsolved problems. To ensure efficient operation of production units it is necessary to solve these challenges quickly and find practical solutions on how to work in specific conditions of production processes.

It is important to know, what should be done and how exactly to improve the quality of management processes, since their order of execution is largely dependent on the nature of products, forms of production organization and so on. They should be progressive and reflect the current level, use advanced methods of technical control and processing, to ensure increased productivity and product quality, reduce costs, reduce harmful effects on humans and the environment.

One of the fundamental principles of quality assurance is continuous improvement. The process of continuous improvement is essential as a means of improving the effectiveness and efficiency of the organization, improve customers and other stakeholders satisfaction.

Indisputably, as shown by numerous examples of top world level companies, integrated implementation of three methodologies in the development of modern manufacturing is extremely important. Any change makes sense only if it brings the desired result. Integrating Lean, Six-Sigma and Theory of constraints is one of the most promising combinations of methodologies that provide an opportunity for focused and long-term improvements in both production processes and in the organization as a whole.

The organization in which this research was undertaken has a well-documented production system and is a good practitioner of TOC, Lean and Six Sigma, yet significant improvement opportunities were highlighted from the study for certain techniques.

TOC, Lean and Six Sigma Principle	**Improvement area**
Top Management Commitment	The management team knows how to build motivation in the organization.
	Managers go to where the action takes place (Gemba).
	Organization defines the appropriate roles and responsibilities of the employee.

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Plant Management	Top management assume the responsibility of interdepartmental coordination.
	Management provides continuous feedback to employees on their performance.
	Established visual management techniques are useful in the manufacturing process. Single piece flow of material has maintained between processes.
	All equipment and processes on the floor are under statistical process control for reducing process variability.
	All processes are continuously questioned for adding more value in Continuous improvement to working processes.
	Organization uses a pull production system in manufacturing process.
Product Development Management	Organization uses the Single-Minute Exchange of Dies (SMED) technique to provide rapid change-over of tooling and fixtures.
	The value stream is continuously evaluated and monitored for improvement opportunities.
	Quality data (error rates, defect rates, scrap, defects, cost of quality) are available throughout the plant to manage quality.
	Measures are in place to assess process performance for possible improvements.
	All improvement projects are structured and undertaken systematically.

Table -4 Improvement areas for lean principles (devised by researcher).

It should be noted that even if an organization claims to manufacture TOC, Lean and Six Sigma it may be possible to improve performance significantly. Hence, it can be deduced that organizations only practice certain tools and techniques but do not understand what makes them work together as a system. It can also be inferred that despite the wide knowledge and resources available, organizations fail to complete the transition from theory to practice. Both the above conclusions are consistent with Liker (2004) from the review of the literature. It can, therefore, be surmised that organizations which claim to successfully manufacture TOC, Lean and Six Sigma are very few. This study demonstrated that the research hypothesis is correct that there are certain TOC, Lean and Six Sigma principles that are not adequately applied. The hypothesis is supported by the results of insufficient TOC, Lean and Six Sigma adoption, which reveal the extent and nature of the differences between the idealized prescription in the organization and the reality on the shop floor. The most significant conclusion is what the organization is currently doing and not what it should be doing.

This research is intended to improve productivity and quality through TOC, Lean and Six Sigma. It is hoped that the research carried out demonstrates to the organization in which this study was undertaken and other organizations that documented procedures should have structured follow up mechanisms to ensure sustainability. The research has also presented a checklist for monitoring and measuring the current TOC, Lean and Six Sigma process on the shop floor. In conclusion, it should be emphasized that the study contributes to the literature by increasing the understanding of TOC, Lean and Six Sigma processes and performance from an Indian Automotive manufacturing perspective.

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