Implementation of Lean Six Sigma (LSS) Methodology, through DMAIC Approach to Resolve Down Time Process; A Case of a Paper Manufacturing Company

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Abstract

Lean six-sigma as quality improvement tool is widely gaining attention in the optimization of production process in manufacturing industries as it helps to trim down waste. The work aimed at improving down time as manufacturing waste in a Paper Company. The analysis of the production process was done using Pareto analysis, Overall Equipment Effectiveness indicator and cause and effect analysis which revealed the down time problem, traceable to high rate of setup time and changeover of order due to incessant ink wetting, plate misalignment of the printing machines and other factors related to work organization. Lean six sigma tools of Single Minutes Exchange of Die and 5S techniques were implemented and these reduced the down time from 32. 6 to 11% and therefore increase customer satisfaction.

Keywords
Cause and Effect analysis, Non-Conformity, Optimization, Pareto analysis, Single Minutes Exchange of Die

1. Introduction

Maintaining quality and reliable performance have become priorities to production industries in order to gain customer satisfaction, as demand for the products increases (Gupta *et al.,* 2018). Companies have to define, measure, analyze, make improvement and effect control on their existing manufacturing systems to comply with market competition (Gupta *et al.,* 2018). Different methods, approaches and tools are being used for continuous productivity and quality improvements (Gupta *et al.,* 2018). Aside these, each company or production sector requires to use a proper selection or combination of different approaches or tools in its implementation process (Sokovic *et al.,* 2010). Down time and variations are inevitable in the course of production of any product, but the main goal of process management or process capability analysis in any organization is to investigate the courses of the down time during the production process of the product (Pearn and Chen, 1999). This aids manufacturing organizations to monitor and measure the potential of process (Wu *et al.,* 2004).
Continuous improvement of process is a key concept of total quality management (Chem *et al.,* 2015), but other methodologies like re-engineering or automation, lean manufacturing will also give similar results of improved performance (Gupta *et al.,* 2018). Lean Manufacturing, a multidimensional production optimization approach that captures various management practices, aimed at waste reduction and improving operational effectiveness (Roriz, 2017). The evidence of implementation of the approach in the manufacturing sector is not limited to quality and productivity improvement, but also considers non-tangible change factors such as initiation of supportive learning environment and developing leadership in the organization (Gupta *et al.,* 2018). To this effect, companies now trend strategy for continuous improvement on quality of their products/services to retain customers in order to gain market share (Chen *et al.,* 2015). Immediately after the inception of TQM, lean six-sigma appear in the model as element of TQM, viewed as present state of evolution in quality management (Gupta *et al.,* 2012). The claim that lean and Six Sigma have a complementary relationship is widely accepted today and more companies are establishing lean Six Sigma (LSS) programs, especially after the proven capability of lean and Six Sigma in leading companies like GE and Toyota (Salah *et al.,* 2018). LSS can be described as a methodology that focuses on the elimination of waste and variation, following the DMAIC structure, to achieve customer satisfaction with regards to quality, delivery and cost (Crawford, 2004). It focuses on improving processes, satisfying customers and achieving

better financial results for the business (Salah *et al.,* 2018). Some organizations have been applying lean six sigma to tackle problems of product variation (Hines *et al.,* 2004). However, their frame work uses six sigma only as a tool within lean and this undermines the power of the DMAIC approach. Mader (2008) gives an example of a model where a traditional Six Sigma approach can be used in parallel with a lean Six Sigma light approach, which mainly uses a lean Kaizen event approach to decrease the project duration. After a project is selected as a result of value stream mapping (VSM), a decision is made on which method is more suitable and what phase of DMAIC is shortened. However, this does not achieve the integration intended as it still proposes two separate approaches. An LSS model as proposed by Crawford (2004) has presented how Six Sigma can first be applied to improve the processes effectiveness followed by lean to improve the system efficiency. However, it is better to draw on both simultaneously to achieve the idea of integration. To succeed in integrating lean with Six Sigma, organizations need to adopt a holistic improvement method, where lean and Six Sigma mutually reinforce each other. Although DMAIC originated in Six Sigma, it can be generalized as an overall framework for process improvement. Data show that improvements remain slow without the Six Sigma infrastructure (George, 2002). Snee (2004) has indicated that Six Sigma has a unique characteristic of sequencing and linking improvement tools into an overall approach. An integrated approach is expected to include the use of a current state VSM as a platform for applying Six Sigma and lean tools, applying Six Sigma to adjust process parameters, integrating lean techniques into DMAIC and using future state VSM as a way to change the structure of the process. The integration of lean and Six Sigma is the solution to overcome the shortcomings of both, as they complete each other. The fusion of the two is the way for organizations to increase their potential improvement (Bhuiyan and Baghel, 2005). The integration of Six Sigma and lean helps companies achieve zero defects and fast delivery at low cost. A more detailed description of this integration is needed in order for organizations to succeed in exceeding future customer demands. LSS addresses issues that are overlooked by lean and Six Sigma when applied individually, such as the process steps that should be tackled first and the order of what to apply first and to what extent; it identifies the ways to achieve significant simultaneous cost, quality, variability and lead time improvements (Bhuiyan and Baghel, 2005; Lachica, 2007; Lean Sigma Institute, 2008). Drawing on the principles, tools and philosophies of both methodologies has enabled them to produce breakthrough innovations that resulted in profound business improvements (Byrne et al., 2007). The integration of the industrial engineering tools of lean with the statistical tools of Six Sigma (which complement each other) provides an operational excellence methodology (Basu, 2004, Chapman and Hyland, 1997). The goal of LSS initiatives is to transform the organizations from separate reactive operations, which are functionally oriented, into cross-functional process focused organizations. The result will be a customer focused, employee empowered and flexible organization (Martin, 2007; George, 2002, Bogart, 2007). There are several works reported on the use of lean six sigma by different authors which are not limited to manufacturing sector. Chiarini (2012) reported the use of lean six sigma as a tool for risk management and cost reduction of cancer drugs in health services. Furterer (2011) also implemented lean six sigma in similar health sector to reduce linen loss in an acute care hospital. The use of lean six sigma in in-service sector for the improvement of productivity and performance were reported by Edgeman (2010); Laureand and Antony (2010); Meza and Jeong (2013) and Rakusa 2016. Lean six sigma, DMAIC approach was used to address non-compliances in quality of customer's specification in a computer design service system. The DMAIC approach was used to define the problem, measure the extent of the problem, analyzed the problem to identify the root cause, find solutions to reduce the effects of the problems and finally sustain the improvement made (Ramani and Banuelos, 2018). For successful implementation of six sigma, the understanding of barriers and motivations is pertinent (Hekmatpanah *et al.,* 2015). Six-sigma is targeted to achieve perfection in every single process of a production (Narula and Grover, 2015). It means having less than 3.4 defects per million opportunities or a success rate of 99.99 %. In view of this, lean six-sigma is a method that permits organizations to review their existing status and guide in improvement decision via analysis of status (Erbiyik and Saru, 2015). The DMAIC approach of lean six sigma is a strict approach that aids manufacturing organizations to focus on developing perfect product, process and services as well as cost reduction (Gupta *et al.,* 2018; Roriz, 2017; Smetkowska and Mngalska, 2018).

This study aimed at improving on the down time in the production line of a paper production company. This was carried out with the investigation of the immediate and remote causes, thus, leading to the formulation of suitable Lean methodology for productivity improvement.

2. Methodology

The methodology adopted in the study is case study. This method illustrates how lean six sigma (LSS) is used to evaluate the existing production process in a paper company in Nigeria based on productivity and manufacturing waste. The study also presented lessons learned and managerial implications of LSS implementation. The case study method was chosen because its offers flexibility in design and implication by allowing both quantitative and qualitative analysis, which are more sensitive to organization complexities phenomena (Sanchez-Marquez *et al.,* 2020; Merriam and Grenier, 2019; Sunder and Mahalingam, 2018; Krueger *et al.,* 2014). A case study method offers a means of investigating complex and critical functions of the value chain (Vinodh *et al.,* 2014; Ingason and Jonsdoitir, 2017). Another advantage of the method is it helps to make direct observations, collect data in a natural setting and compared so as to rely on the derived data (Sunder *et al.,* 2019; Ingason and Jonsdoitir, 2017). In this study, a real-time problem of customers' dissatisfaction was considered. The Lean six sigma DMAIC (define, measure, analysis, improvement and control) approach was used to address the down time in the production line based on machine functionality. The Lean six sigma DMAIC approach is focus on the machine running process stages of the production line. The assessment and optimization of the production processes of the company were based on Lean six sigma tool such as overall equipment efficiency indicator, Ishikawa diagram, Pareto chart and analysis. DMAIC is an acronym from the words Define, Measure, Analysis, Improvement and Control, according to Demming cycle (Sokovic *et al.,* 2010; Sin *et al.,* 2015)

3. Case-Study Background

This case study was undertaken in a paper production company manage as Private Limited Liability Company. The organization was established in 2010 as a printing and publishing company, located in the South-West province in Nigeria. The company is made up of five (5) functional Departments namely; Central Account, Production, Marketing, Logistics and Procurement with a total of seventy (70) staffs. The production Department takes about 50 % of the entire labour force of the organization. The company receives, processes and makes deliveries of orders on a daily basis, up to an average of fourteen thousand (14, 000) pieces/order. Figure 1 shows the value chain of the production line. Value chain gives idea that a production system composes of other subsystems, each with input, transformation process and their respective output (Sayidmia, 2016; Michael, 1985). It is a systematic approach to examine the development of competitive advantage (Sayidmia, 2016). The stages that represent the value chain of AB production line are described below:

i. Concept Visualization: this is the conceptual design of the text and graphic, which involves strategic and creative work, as well as finalization of the idea and approval of the conceptual design.
ii. Design/ Plate cutting: this involves the creation of the image and text in the real form on the plate using software
iii. Printing: this is the impression of the text and image from the plate to a paper in hard form
iv. Cutting /Trimming: this is the removal or dressing of the offset of the printed paper in preparation for folding
v. Folding: this is the arrangement of the printed sheet pieces in pages
vi. Stitching/Gluing: this involves the bringing together of the printed sheet piece in pages. It can also be bond adhesive
vii. Finishing: this is the final stage of book development where the book is examined for any process error from the previous stages and preparation for delivery

The case organization shows little or no compliance to lean manufacturing, thus providing opportunity for academia-Industry collaboration (Sunder and Mahalingam, 2018)

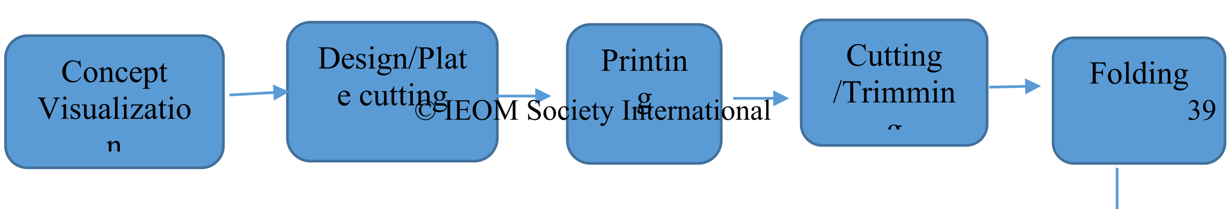

Figure 1 Value Chain of AB Production line

3.1 Business Case

In the bid to maintain a good customer-client relationship by the management of the organization, there is a need to improve on the production process efficiency, lead time and takt time. Also reduce the manufacturing wastes in terms of percentage down time. The management decided to engage lean six sigma practitioners to evaluate the current production process of the company. The lean six sigma team composed of a postgraduate student that specialized on quality management and a lecturer in the University who is also a Black Belt certified. The team engaged in company's document review and one-on-one interview with some selected customers and staff from the production Department. These were further supported by self-observation on the production floor for a period of three months to understudy the production processes.

3.2 Definition of the Problem Stage

The major problem of down time on the production line was defined based on data gathered from self-observation and one-on-one interview with the production supervisor and some of the machine operators. The estimation of percentage down time in the production line is presented in Table 1, with consideration given to machine running process stages. Figure 2 shows the Pareto chat of the down time of processes of the production line

Table 1 Estimation of Percentage Down-Time in the Production Line

Unit	Causes of the Down time	Down Time (sec)	Average Down Time	Cycle Time (sec)	% Down Time	Machine
Design/Plate Cutting	Plate Damage	630	765	2880	26.6	Computer-To-Plate
	Poor Impression on plate	900				
Printing	Plate Misalignment	1116	1158	2880	40	Curd 64/G70
	Ink Wetting	1200				
Cutting/ Trimming	Machine break down due power source	1334	1567	4680	33.5	Minabmda
	Job Misalignment	1800				
Gluing /Stitching	Skipped Stitches	816	858	2880	30	Polar-Motta 90
	Variable Stitch Density	900				
	Overall Down Time		4348	13,320	32.64	

The percentage down time in the production line is 32.64 %. This means about one-third of the production cycle goes into idle time which contributed to low productivity.

3.2.1 Pareto Analysis of Down-Time in the Production line

Magar and Shinde (2014) described Pareto diagram as a tool for arrangement of items in the order of the degree of input, thus identifying the minor item with maximum influence. Based on this case, application of Pareto diagram was able to achieve the following:

1. Prioritized sections for quality improvement
2. Identified the type of machine on which most complaints were received from
3. Identified the type and frequency of the complaints most often occurring
4. Identified the most recurrent causes of the complaints.

Figure 2 presents the Pareto diagram of the down time of AB production line. From Figure 2, it can be deduced that about 90 % of the down time of the production line was as a result of ink wetting. Plate misalignment and job misalignment contributed between 80-90 % of the down time, poor printing impression and variable stitch density also contributed about 70 %, machine breakdown due to power source and skipped stitches contributed 60 % of the down time, while about 50 % of the down time was caused by plate damage. Further analysis of the Pareto diagram prioritized printing section for most down time improvement, followed by cutting/trimming; gluing/stitching and design/plate cutting sections.

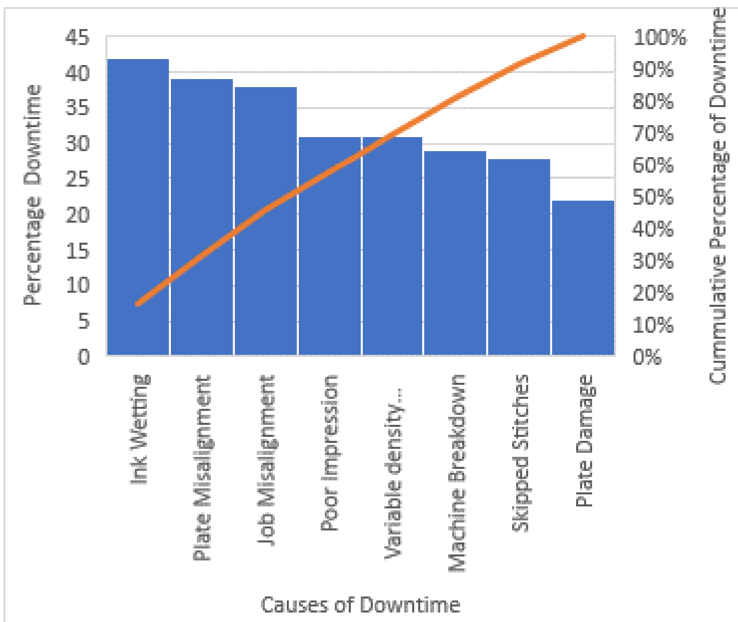

Figure 2 Pareto Chart of the Down Time of the Production Line

3.3 Measurement of the Problem

The major equipment of this section consists of two printing machines (Curd 64 and G70) with the main function of creating impression of texts and images on the paper as hard copy. Other materials involved are: cardboard, ink and lithographic plates. Equipment performance analysis of the machines were conducted using Overall Equipment Effectiveness Indicator (OEE). Production data in terms of number of piece produced per machine was gathered over a period of 4 months from June-September. Figure 3 shows the performance plot of the curd 64 and G70 machines based on the cumulative number of piece produced over the investigation periods. It was observed that the effectiveness of curd 64 was better than that of G70 all through the investigation periods. The highest cumulative pieces produced by Curd 64 was between August and September with 90,000 and 100,000 pieces difference compared to G70 machine. This was due to the fact that order from the customers increases but decrease in the number of printed volumes per order, thus led to the rise in number of change over on the G70 machine. Invariably, majority of the down time arises from G70 machine.

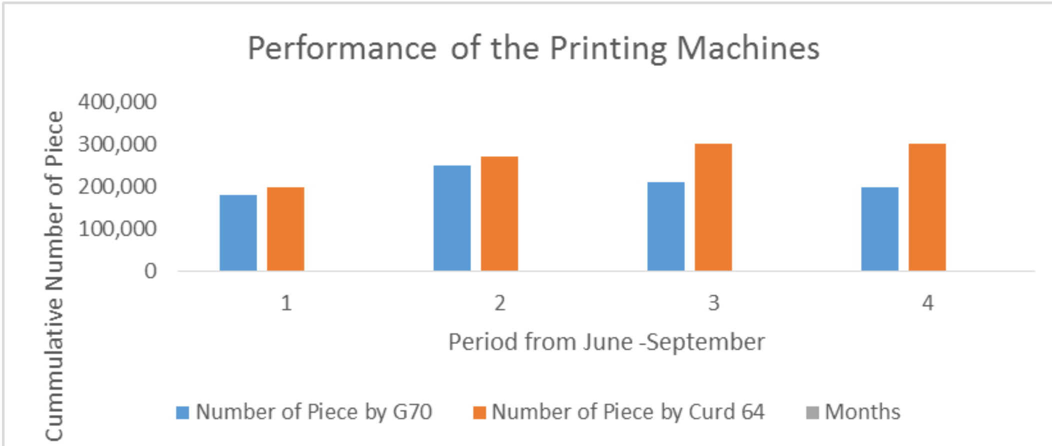

Figure 3 Performance Chat of the Printing Machines

3.4 Analysis of the Problems

The analysis of the identified down time problem of the production line was carried out to find out the root cause using ISHIKAWA Diagram (Root and Effect Analysis), so as to design improvement and subsequent control (Gupta *et al.,* 2018; Sokovic *et al.,* 2010; Roriz, 2017). The cause and effect analysis was done through brain storming session, and the causes were grouped into four main categories, namely: work organization, machine, method and man. Insufficient implementation of control system was found in the work organization. Poor control system by the organization results in attitudinal behavior of workers. These also affect setup time and changeover of machines in the course of production of customer's order. The order performed on the machines was based on earliest delivery date of materials, which invariably affect the production cycle time and number of piece produce per order per machine. Technical state or depreciation of the machines was also diagnosed. This causes incessant break down of the machines, adding more to the frequency of down time, most especially for G70 machine. Also, depreciation results in prolonged production, high cost of maintenance and rate of non-conformity pieces. Lack of standard procedure and specification were observed under the method of work group. No clear instruction or manual guide on the usage of the machines for the operators majorly affects G70 machine. Deficiency in technical know-how of the operators of Curd 64 contributed to the rate and frequency of non-conformity as it requires slight specialized skill. Operators need to be guided on how to choose formats of orders to make the process much more effective. Too much familiarities with old methods also affect the effectiveness of the process. Low performance in the production process is also traceable to predisposition of the workers, linked to motivation for work. These really tell on the frequency of produced pieces per order, non-conformity and cycle time. No special training for operators except some verbal obligatory safety advice. Figure 4 shows the cause and effect Diagram of the problems.

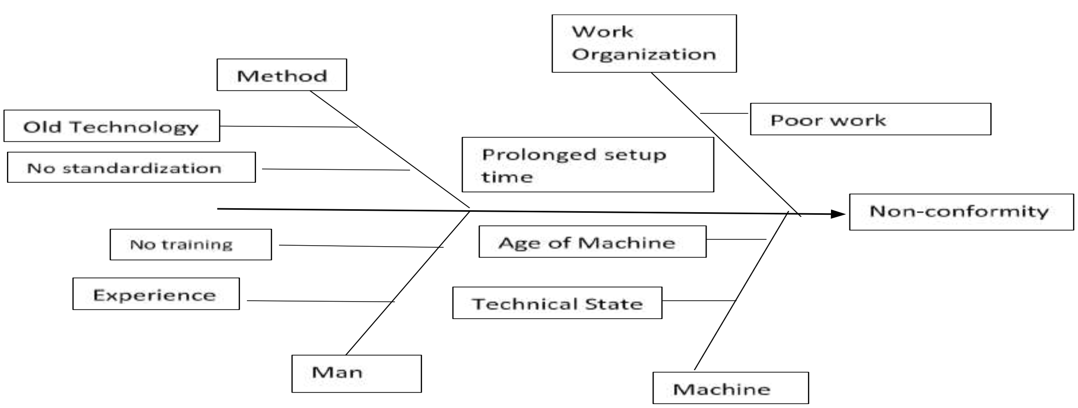

Figure 4 Ishikawa Diagram of the printing Stage

3.5 Improvement stage
In order to find solution to the major problem of down time, linked to high setup time and changeover of manufacturing order, implementation of Single Minutes Exchange of Die (SMED) and 5S techniques were proposed and carried out.

3. 5.1 SMED Implementation
This method was carried out with preliminary evaluation of the production process, setup time and changeover of manufacturing order on the two machines G70 and Curd64 using work measurement and time study methods. The aim of these methods is to investigate and categorize all production, machines setup, and change of manufacturing order activities, into value adding and non-value adding activities. The non-value adding activities waste time and resources, therefore must be eliminated. The value adding activities are further categorize to internal activities (activity performed when the production is stopped) and external activities (activity performed when the machine is running). The target is that all internal activities are converted to external activities. This reduces the frequency of setup times and changeover of manufacturing order. Other improvement approach carried out to reduce down time in the production process to the minimum is the training of the operators, especially those working with G70 machine on how to manage production on the machine. Work standardization was also implemented. Total Productive maintenance was adopted, whereby the over hauling of the machines is not limited to the maintenance department alone. Operators of these machines were taught on how to carry out short corrective and preventive maintenance. These seriously cut down on the down time.

3.5.2 5S Technique
Lastly, 5S technique was also used, which effectively eliminate errors leading to high frequency of down time traceable to break down of machines and injuries of the operators in the production floor (Liker, 2004). Figure 5 shows and explains 5S technique.

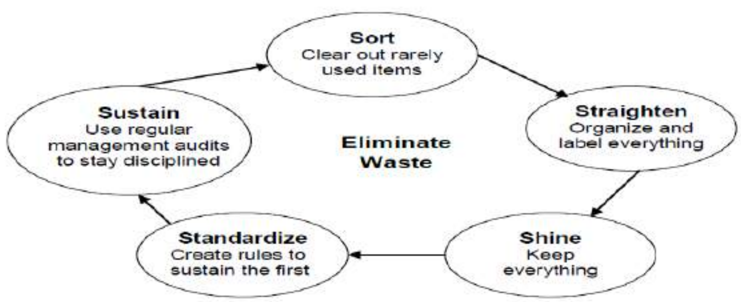

Figure 5 Diagram of 5S Technique

Table 2 Improved Down Time of the Production Line

Unit	Causes of the Down time	Down Time (Sec)	Average Down Time	Cycle Time (sec)	% Down Time	Machine
Design/Plate Cutting	Plate Damage	315	383	2880	13.3	Computer-To-Plate
	Poor Impression on plate	450				
Printing	Plate Misalignment	558	579	2880	20	Curd 64/G70
	Ink Wetting	600				
Cutting/ Trimming	Machine break down due power source	267	314	4680	6.7	Minabmda
	Job Misalignment	360				
Gluing /Stitching	Skipped Stitches	163	172	2880	5.9	Polar-Motta 90
	Variable Stitch Density	180				
	Overall Down Time		1448	13,320	10.9%	

The percentage improvement in the down time in the production line is approximately 11 %.

3.6 Control Measures Stage

The improvement implemented requires to be sustained by putting control measures like standard operating plan (SOP) in place where all necessary details related to getting high production process performance especially in the printing section is documented and review from time to time by the compliance team. Training and re-training of staff should be a continuous exercise.

4. Lesson Learned

The case study has contributed to the body of knowledge on the application of lean six sigma to improve down time in manufacturing industry with process as line of production using DMAIC methodology. The case has demonstrated a form of uniqueness in terms of academia-industry collaboration in solving real-time problem with case investigators involving a student and a senior lecturer from a higher institution with industrial engineering knowledge in quality management as well as Black Belt Certification. This a form of collaboration encouraged in LSS (Sunder and Mahalingua, 2018; Sunder and Antony, 2018) for building academic-industry synergy. There are some lessons learned presented by the case study. The case presents successful application of LSS in the improvement of down time in process focus manufacturing sector as future direction for research as compared to normal discrete manufacturing sector. The case has helped to learn that application of LSS on a project is more of continuous improvement methodology rather than one-off improvement as this is achieved over a period of time (Schroeder *et al.,* 2008; Kwak and Anbari, 2006; McAdam and Lafferty, 2004; Coronado and Antony, 2002). In addition, application of LSS in the case described makes change management easy as resistance to change is less with continuous improvement as compared to one-off improvement (Trader-Leigh, 2002; Huy and Mintzberg, 2003).

5. Conclusion and Implications

DMAIC approach as improvement tool of Lean six-sigma has been implemented in an attempt to solve a real-time problem of low performance due to down time in the printing section of a SME Book Production Company. The analysis of the down time was done using Pareto analysis which revealed that the printing section contributed the majority of the problem. Application of LSS in this case has been able to solve real-time problem of productivity and manufacturing waste which has direct implications on customer's satisfaction. It has also presents some theoretical and empirical implications by establishing a lean frame work for process industries when it comes to improvement of real-time lean problems as listed:

i. Overall Equipment Efficiency Indicator is a suitable metric to measure the performance of a machine or equipment in manufacturing sector
ii. Challenge of manufacturing waste is solved by improving on the level of down time from 32.6 to 11 %, thereby saving cost on labour inventory by implementation of total productive maintenance (TPM), work standardization, inventory management and six sigma methodologies like SMED, 5S, DMAIC and DMADV.
iii. The application of LSS in the presented case-study is an indication that it can be successfully adapted to other process metrics like quality, responsiveness, total turnaround time and so on
iv. Involvement of an expert with black Belt certified alongside with University Faculty resources and quality management students was a leverage during the execution of the project. In view of this, academic-industry collaboration is encouraged.

5.1 Limitations

i. This article has practically and in no doubt contributed to the body of knowledge in the field of LSS with focus to manufacturing sector. Nevertheless, its presents a single case organization which may not be substantial for generalization.
ii. The lesson learned and implications presented can still be further validated using some lean based simulation software

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