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An Application of Customized Lean Six Sigma to Enhance Productivity at a Paper Manufacturing Company

Nabeel Mandahawi[a], Rami H. Fouad*[,a], Suleiman Obeidat[a]

[a]*Industrial Engineering Department, Faculty of Engineering, Hashemite University, Zarqa 13115, Jordan*

Abstract

This article presents a process improvement study applied at a local paper manufacturing company based on customized Lean Six Sigma methodologies. More specifically, the DMAIC (Define, Measure, Analyze, Improve, and Control) project management methodology and various lean tools are utilized to streamline processes and enhance productivity. Two performance measures namely production rate and Overall Equipment Effectiveness (OEE) are employed to evaluate the performance of the cutting and the printing machines before and after the DMAIC cycle. Obtained results indicate that the production rate increment for printing machines by 5% and for the cutting machines by 10%. Moreover, the OEE for the printing and cutting machines has increased by 21.6% and 48.45% respectively

Keywords: Six Sigma; DMAIC; Lean manufacturing; Overall Equipment Effectiveness; Paper manufacturing

1. Introduction and Background

Organizations look for ways to improve their production and management processes in order to remain competitive in the market. This calls for ways to reduce production cost, enhance productivity and improve product quality. Therefore, organizations must utilize all the available resources efficiently and effectively in order to cater their customers with high quality products at a low price. For these reasons, researchers all over the world proposed several improvement strategies and tools to satisfy organizations needs. Such initiatives include Total Quality Management, Quality Awards, Total Preventive Maintenance (TPM), Lean and Six Sigma.

The lean concept, which was initially referred to as the Toyota Production system, concentrates on the flow of the entire processes rather than on the optimization of individual operations [13]. Womack (2002) specified the main components of lean management system as follows:

1. Identify process value from the customer perspective.
2. Identify the value stream for each product and eliminate all types of wastes currently imbedded within the production process.
3. Try to develop a continuous production process.
4. Develop the pull management technique within the production lines.
5. Manage toward perfection.

Six Sigma, on the other hand, is a data driven methodology used to identify root causes for variations in a production processes in order to achieve organizational excellence. Six Sigma management strategies require process improvement through identifying problem, root causes, process redesign and reengineering, and process management. Six Sigma follows a model known as DMAIC (Define, Measure, Analyze, Improve, and Control). Therefore, Six Sigma starts by analyzing defects and lean initial focus is on customer, process flow, and waste identifications [23]. However, using one of these tools has limitations. Since lean eliminates the use of Six Sigma's DMAIC cycle as a management structure to define required process capabilities to be truly lean. On the other hand, Six Sigma eliminates defects but does not address how to optimize the process flow. Hence, applying both Six Sigma and Lean tools sets results in far better improvements than could be achieved with either one method alone [16].

DMAIC is a systematic six-sigma project management practice inspired by Deming's PDCA (Plan, Do, Check, and Act) Cycle. The process consists of the five phases called Define, Measure, Analyze, Improve, and control. The Define phase concentrates on forming the team, defining the project's goals, mapping the process, identifying customers, and identifying the high impact characteristics or the CTQs (Critical to Quality). The Measure phase consists of defining and executing a systematic data collection plan for the key measures (CTQs) for the targeted process. Data collected in the Measure phase are analyzed in the Analyze phase to identify the root causes behind the gap between the current performance and the goals identified in the first phase by defining the main type of wastes embedded within the production processes and the root causes for these wastes. The Improve phase focuses on identifying expected solutions, suggest set of alternative solutions to enhance

* Corresponding author. e-mail: rhfouad@hu.edu.jo

performance, and implement some of these solutions according to the available budget and the expected cost for each alternative. The Control phase concentrates on creating and implementing monitoring and response plans for sustaining improvements, spread out the outcome and the methodology for the whole organization, insure the establishment of a new culture within the organization. Moreover, operating standards and procedures are documented and published in the Control phase.

Lean and Six Sigma have been implemented successfully in the manufacturing and service sectors to optimize different performance measures. Both lean and Six Sigma methodologies have proven over that last twenty years that it is possible to achieve dramatic improvements in cost, quality, and production time by focusing on process performance. Linderman et al. (2003) pointed out that Six Sigma could be implemented to the processes of producing manufacturing goods, business trade, executive management, and services. Recent research papers include improving operational safety [5], reducing amount of waste [8], improving quality for surveillance cameras to diminish related excess costs [10], enhancing the assembly efficiency of military products [4], increasing customer loyalty in the banking sector for Bank of America and Citigroup [21, 22], reducing patients' waiting time and length of stay [3, 17, 29], reducing length of stay for Ophthalmology Day Case Surgery [16], reducing lead-time [1], enhancing staff satisfaction [7], reducing clinical errors [20], process improvement for both the radiology department and medication administration process [15], and process design of compressor-housing machining process [25]. Others include [2, 6, 11, 12, 18, 19, 24, 26, 28, 29].

As a summary, both lean and six sigma methodologies have proven over that last twenty years that it is possible to achieve dramatic improvements in cost, quality, and production time by focusing on process performance. In this paper, a customized lean Six Sigma methodology is deployed at a local paper manufacturing company to increase production rate, minimize waste and increase Overall Equipment Effectiveness (OEE). The two tools have been used as complementary to each other, wherein DMAIC's roadmap has been used as a general framework for process improvement and lean tools have been embedded within these phases. Furthermore, the research focuses on employee involvement and motivation that are imperative to advance a new culture [9].

2. Problem Statement

The environment for most of the manufacturing companies is very challenging these days under the massive global market competition, therefore companies are looking for systematic ways to cut production cost, improving production rate, and increasing production quality. Managers at the local paper manufacturing company under investigation expect that they could improve their current production rate without increasing the existing resources. Moreover, managers noticed that their production processes are not running efficiently; in the first quarter of 2009, only 77% of customer orders were delivered on time. Furthermore, they decided that employees should be involved in improvement projects to build up a new culture and guarantee sustainability. The reason behind this attitude is that many manufacturing companies have implemented different process improvement tools without creating the underlying culture, so they end up with poor follow-up, lack of interest, diminishing productivity, and no ownership of improvements. So few years after the termination of their projects, company returns to the previous status and in some cases to a poorer state.

3. Research Methodology

The improvement team starts to recognize in broad scope the major problems that the company currently have. The scanning approach took different perspectives through direct observations, interview, and data analysis. The direct observations show that the operation process currently contains different types of wastes, which has not been identified and classified correctly. Afterward, different set of general interviews have been carried out with the plant manager, operation manager, quality manager, and maintenance manager. These interviews emphasized that the production processes could run more effectively if all types of wastes have been identified and eliminated. The last technique is data analysis, in this technique the production reports have been reviewed for the year 2008 in addition to the first quarter of 2009. The results confirmed that the average Overall Equipment Effectiveness (OEE) for the whole production line is lower than 33.5% where it should be around 85% as indicated by the top managers based upon the best practice for similar manufacturing companies. These results could explain the reason behind the incapability of the company to meet customer requirements. So there is a need to identify these wastes, analyze it, and develop action plans to lean them. The following subsections illustrate how the DMAIC cycle is used to increase the Overall Equipment Effectiveness in the paper manufacturing company.

3.1. Define Phase:

In the define phase, the project outlines, metrics, and objectives must be clearly identified. The project charter is a helpful tool in this context; it describes the project scope, goals, performance measures, significant risk, and anticipated benefits. Project charter is typically one of the most challenging steps in the DMAIC cycle, as it defines the expected delivery for the project and it may help to complete the project as proper as possible. To identify the scope of the project, a high-level process map is used as shown in Figure 1. The map shows that the main production operations that affect the performance of the production process. The operations are printing, cutting, window, and the gluing. The study was then limited to bottleneck operations of printing and cutting. Hence, a team is formed for the corresponding production processes including the authors (project champion), operators, quality personnel, production engineers, and management. Afterward, a set of brainstorming sessions are held to identify the main components of the project charter.

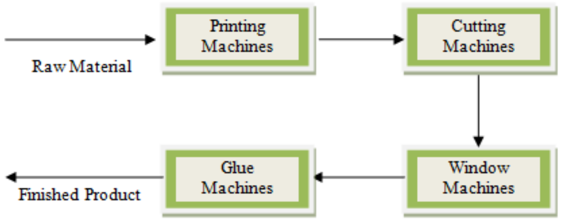

Figure 1: High-level Process Map.

To identify the project scope, ABC analysis is performed using historical data and revealed that four main products are the most frequent products manufactured at the company, these four products contributed to more than 80% from the total production rate. Performance measures are identified as production volume (ton), production rate (sheets/hour), percentage of wastes, and Overall Equipment Effectiveness (OEE). Targets are set to increase the production rate for the cutting machines from 4400 sheets/hour to 4700sheets/hour, to minimize cutting wastes from 0.25% to 0.15%, to increase the production rate for the printing machines from 6500 sheets/hour to 6750 sheets/hour, and to minimize printing wastes from 3.07% to 2.00%. The significant risks have also been identified as machine accident stoppage and shortage in the raw material required to produce the above four products. The project charter was reviewed and approved by top management team. This approval gives full support to the team to achieve the required goal and offers a clear and well-organized vision.

To develop a new culture, the project champion spread a good baseline about lean manufacturing and Six Sigma through two extensive awareness and training sessions. Moreover, the eight types of wastes are explained clearly to the team members to insure collecting the correct data during the measurement phase. Furthermore, posters were distributed within the whole organization in order to deepen the understanding of how to approach a lean and Six Sigma culture.

3.2. Measure Phase:

To start the measurement phase a standard form has been designed and distributed to the DMAIC team, the from contains the necessary information that should be gathered to be analyzed at the next phase, these information comprise from product type, raw materials type, machine parameters, type of wastes combined with general comments. Afterward, a set of pilot runs are carried out under the supervision of the project champion. During these experiments, the team starts to understand clearly how the data should be collected. Furthermore, a uniform team is formed to minimize personal errors (repeatability) and the error within the team (reproducibility). Machine operators are advised about the reasons behind collected data to enhance collaboration and to spread out the knowledge further. Data are collected over a period of three months; a sample from the collected data for the printing machine is shown in Table 1.

Table 1: Sample from the Waste Time for the Printing Machine.

Machine Name	Printing	Area	Printing	Date	16-June-09
Number of Operators	2	Product Type	XXX	Day	Thursday
Raw Materials Used					
Type	Supplier Name	Storage Day	General Comments		
Carton: A	MM	27-March-09	None		
Ink	MMM	1-March-09	None		
Machine Parameters					
Time	Number of Operators	Speed Parameters	General Comments		
8:30	2	4616	The operators don’t try to reach to the maximum speed since there is a problem in the gearbox for unit number five.		
9:20	2	4500			
10:30	2	4570			
Types of Wastes					
Stoppage			Transportation		
Activity Type	Time (Minutes)	Comments	Activity Type	Time (Minutes)	Comments
Carton stoppage	00:30	This problem has been repeated five times during five hours and a half	Internal shortage on carton	00:40	
Feeder problem	2:10	Feeder problems include: 1- Feeder adjustment. 2- Evacuate stoppage. 3- Sheet guide problem.	Internal shortage on carton	00:50	
Feeder problem	1:30		Insert alcohol	1:00	
Feeder problem	7:40				
Carton jam	00:30				
Clean and adjust blanket varnish	4:57				

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Cut blanket varnish side	3:40				
Varnish roller bearing problem	120:30				
Waiting Time (Minutes)			Moving Time (Minutes)		
Waiting until the carton rearranged and fed to the main Feeder	1:30	The carton came from the warehouse not in a proper way, so the operator have to rearrange it to minimize the time	Bring tools to cut parts from the varnish blankets	3:40	
Waiting until the carton rearranged and fed to the main Feeder	1:00				
Waiting until the carton rearranged and fed to the main Feeder	4:00				
General Observations					
1- There is no homogeneity between the ink, water, and alcohol so from time to time there is an accumulation in the varnish roll.					

3.3. Analysis Phase:

The analysis phase deals with identifying the critical factors embedded in the current operation that could be improved to minimize waste. Prior to starting this phase, the project champion reviewed the collected data to filter out any type of noise and disturbance. Data mining is then used to identify main types of wastes for each machine to perform the corrective actions. Data reveal that there are seven types of wastes at the cutting machines with jamming during sheet feeding, jamming at mold, adjust press and knife, and adjusting feeder contribute to more than 90% of the total waste. Table (2) presents times for each type of waste per 5.5 hours during 9 working days. Similarly, for the printing machine the main types of wastes include carton jam, feeder problems, and clean and adjust plate, and blanket for color and varnish.

Table 2: Main Types of Wastes for the Cutting Machine.

Report No.	Jam problem during sheet feeding	Feeder adjustment	Adjust side and front lays	Jam at mold	Adjust pressure at the pressing and cutting knifes	Motor problem	Adjust flagstone	Total Time	Percentage of waste in time (%)
1	25:00	11:30	5:02	7:00	4:12	0	0	53:44	13.3
2	19:17	7:14	0	5:55	0:00	3:20	0	35:56	8.9
3	18:35	3:20	0	15:45	21:09	0	0	58:49	14.5
4	24:40	2:22	0	5:04	4:32	0	0	36:38	9.1
5	16:12	0:00	0	0:00	9:23	0	0	25:35	6.3
6	27:50	3:09	0	4:30	0:00	0	2:30	35:29	9.4
7	17:20	10:30	0	0:00	45:25	0	0	73:15	18.1
8	20:30	0:00	0	32:53	2:00	0	0	55:23	13.7
9	19:40	0:00	0:45	6:54	0:00	0	0	27:19	6.8

Once the team has identified the main types of wastes for each machine a set of brainstorm meetings have been carried out to find the root causes for each problem, these sessions are organized after a training course conducted for the DMAIC team on problem solving and decision making tools. Figure (2) shows the main causes for the jamming problem in the cutting machine.

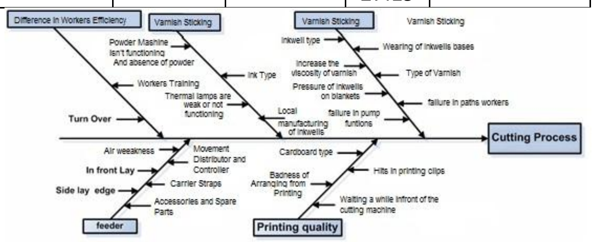

Figure 2: Cause and Effect Diagram for the Jamming Problem in the Cutting Machine.

3.4. Improve Phase:

Having identified and verified main types of wastes, the team proposed actions to minimize the probability of reoccurrence for these problems. Brainstorming sessions are held to generate solution alternatives. Each solution is evaluated with respect to cost, ease of implementation, and probability of accomplishment upon implementation. Sample from the proposed solutions for the cutting machine are summarized in Table (3).

At this stage, the DMAIC team has recognized clearly the main causes for each type of wastes, expected solutions, required actions, time interval, and others. Corrective actions are started immediately as requested by management. For example, investigations show that one of the main causes for the carton sticking problem is the wearing out for roller base, the action plan was to adjust the roller base instead of buying a new base because of the high cost of the roller base; by working on finishing surface, specify the wear parts, and fix.

To evaluate gains, data are collected over the three months period following the implementation of suggested solutions. Tables 4 and 5 summarize results for both the printing and the cutting machines respectively. Results confirm the achievements: production volume (ton) for printing and cutting machines increased by 24%. The production rate increment for printing machines by 5% and for the cutting machines by 10%. In addition, the OEE value is has increased by 21.5% and 48.44% for the printing and cutting machine respectively. Moreover, the order fulfillment rate increased by 11.43%.

Table 3: Sample from the Summarized Corrective Actions for the Cutting Machine.

No	Machine	Stoppage	Action	Required time	Notes
2	Cutting	Varnished carton sheets sticking			
2.1		Wearing out roller base	Fixing the roller	4 hr	Monthly maintenance
2.2		Varnish Type	Perform more test on varnish to check the conformance to the specification	Acknowledgment of receiving committee comment	checked once samples are received
2.3		Lack of accuracy of the adjustment works	The adjustment should be done by the most skilled operator or printing supervisor	1 hr	Monitoring
2.4		Roller type and manufacturing accuracy	Stop buying from local supplier		Regularly
2.5		High varnish viscosity	Adjust the viscosity sensor	0.5 hr	Circularly
2.6		Roller pressure on blanket	Continuous checking on roller rotating accuracy	0.5 hr	During assembly of rollers
2.7		Low efficiency of the pumps because of impure dirty varnish	Installing filters for dust and rotating brush to homogenize varnish	2 hr	Monthly maintenance

Table 4: Summarized Performance Measures for the Printing Machine.

Printing Department	Before	After	Financial
Production (ton)	672 ton	1143 ton	147894 JD
Production Rate	6500 sheets/hr	6850 sheets/hr	-
Waste%	3.45%	2.67%	4500 JD
OEE	27.70	33.67	-
Total			152394 JD

Table 5: Summarized Performance Measures for the Cutting Machine.

Cutting Department	Before	After	Financial
Production (ton)	638 ton	1086 ton	-
Production Rate	4550 sheets/hr	4850 sheets/hr	3265.92 JD
Waste%	2.50%	2.50%	-
OEE	29.27	43.45	-
Total			3265.92 JD

3.5. Control Phase:

In order to sustain the achieved results and to prevent degradation in the machines' performance, a sustainability plan is formed including checklists. A sample from the sustain plan for the cutting machine is presented in Table (6).

Before the termination of this project and during the control phase, the outcomes of this research are spread out for the whole organization using posters and seminars. In addition, operating standards and procedures are documented and published. Moreover, the study helped the organization build a new culture of continuous improvement. They decided to start a 5-S project for the whole organization. 5-S is a strategy for creating and maintaining an exceptionally clean, orderly, and safe work environment. 5-S creates a clean environment, eliminates many types of wastes, creates a tone of enthusiasm, and prepares workplace for further improvements.

Table 6: Sustain Plan for the Cutting Machine.

Machine name: Cutting Machine operation Name:			Date / /				
	Description	Task	Period	checked by	fixed by	Approved By	Action Plan
1	Ink Roller Varnish	Cleaning	Each Sunday				
		Change bearing	Each Sunday				
		Lubrication	Monthly				
2	General Situation	Cleaning	Each Sunday				
		Lubrication	monthly				
4	Foundation and Bearing	Cleaning	Each Sunday				
		General Status	Each Sunday				
5	Varnish	Cleaning	Each Sunday				
		Lubrication	monthly				
		Check bearing	Each Sunday				
6	Roller Provision	Availability	Each two month				

4. Conclusions

The paper presents a lean Six Sigma procedure to enhance the performance of the cutting and printing machines at a local paper manufacturing company. The scope of the study is to identify, analyze, and minimize all types of wastes, based upon customer and management request. Thorough investigations revealed various causes that contributed largely to minimize production rate, increase wastes, and minimize Overall Equipment Effectiveness (OEE). Following a DMAIC procedure, various improvement opportunities are suggested and implemented. As a result, the OEE for the printing and cutting machines has increased by 21.6% and 48.45% respectively. Furthermore, to ensure the control of the achieved results a sustain plan has been prepared in addition to a new working procedure. To achieve long-term benefits of the lean Six Sigma approach, awareness and training sessions are carried out to start a culture change focusing on individuals rather than only results. This target has also been achieved once management decided to start a 5-S project for the whole organization.

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