APPLICATION OF LEAN SIX SIGMA METHODOLOGY ON CONSTRUCTION FIELD – PART 1: DEFINE PHASE

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ABSTRACT

This aim of this study was to apply Lean Six Sigma methodology through the famous DMAIC (Define, Measure, Analyze, Improve and Control) approach to improve the efficiency of construction activities. Lean manufacturing concept is based on increasing the efficiency by eliminating non-added value (waste) activities. Six Sigma is a statistically-based process improvement methodology that aims to reduce defects to a rate of 3.4 defects per million defect opportunities. Lean (with its roots in the Toyota Production System) and Six Sigma (with its roots in the Motorola Quality System) is essentially the combination of two strategies, cultures, methodologies and tool sets with overlapping themes but are also uniquely different value propositions. Six Sigma is limited to process quality tools and does not have the process speed tools. Similarly, Lean does not possess the tools to bring a process under statistical control, nor does it define a sustaining infrastructure or emphasize customer focus as does Six Sigma. Thus, achieving the goals of enterprise requires both Lean and Six Sigma.

Keywords: *Lean Six Sigma, DMAIC, Lean manufacturing*

INTRODUCTION

The construction industry is the largest industry in the world. It is more of a service than a manufacturing industry. Growth in this industry in fact is an indicator of the economic conditions of a country. This is because the construction industry consumes a wide employment circle of labor. What differentiate the construction industry from other industries is that its projects are large, built on-site, and generally unique. Time, money, labor, equipment, and, materials are all examples of the kinds of resources that are consumed by the project (Brussee, 2004). Lean manufacturing is a comprehensive term referring to manufacturing methodologies based on maximizing value and minimizing waste in the manufacturing process (George, 2003). Value is defined as an item or feature for which a customer is willing to pay. All other aspects of the manufacturing process are deemed waste. Lean manufacturing is used as a tool to focus resources and energies on producing the value-added features while identifying and eliminating non value added activities. Lean manufacturing techniques are based on the application of five principles to guide management's actions toward success:

1) Value: The foundation for the value stream that defines what the customer is willing to pay for. 2) The Value Stream: The mapping and identifying of all the specific actions required to eliminate the non-value activities from design concept to customer usage. 3) Flow: The elimination of all process stoppages to make the value stream "flow" without interruptions. 4) Pull: The ability to streamline products and processes from concept through customer usage. 5) Perfection: The ability to advocate doing things right the first time through the application of continuous improvement efforts (Harris, 2002).

The story of Six Sigma was presented by Pyzdek (2010), when Motorola engineer William Smith, known as the father of Six Sigma, created the term Six Sigma in 1988, while he worked on the concepts for many years prior. Essential Six Sigma tools were presented by Pande, (2000) as illustrated in the figure (1).

The DMAIC methodology is central to Six Sigma process improvement projects. Pyzdek (2010) provided a problem- solving process in which specific tools are employed to turn a practical problem into a statistical problem, generate a statistical solution and then convert that back into a practical solution. 1) Define phase: the purpose of the Define phase is to clearly identify the problem, the requirements of the project and the objectives of the project. The objectives of the project should focus on critical issues which are aligned with the company's business strategy and the customer's requirements. 2) Measure phase: the purpose of the Measure phase is to fully understand the current performance by identifying how to best measure current performance and to start measuring it.

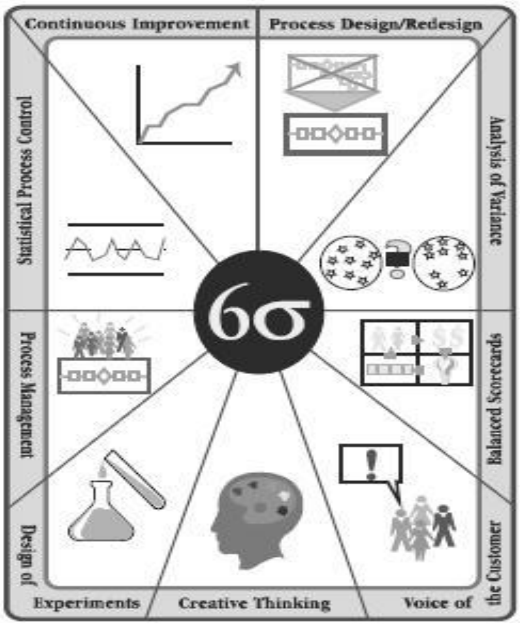

Figure 1. *Essential Six Sigma tools.*

The measurements used should be useful and relevant to identifying and measuring the source of variation. 3) Analyze phase: in the Analyze phase, the measurements collected in the Measure phase are analyzed so that hypotheses about the root causes of variations in the measurements can be generated and the hypothesis subsequently validated. It is at this stage that practical business problems are turned into statistical problems and analyzed as statistical problems. 4) Improve phase: the Improve phase focuses on developing ideas to remove root causes of variation, testing and standardizing those solutions. 5) Control phase: the Control phase aims to establish standard measures to maintain performance and to correct problems as needed, including problems with the measurement system. This part of the study will focus on only the first phase; define.

MATERIALS AND METHODS

The methodology of this research will follow the DMAIC approach as described by Pyzdek (2010). Minitab software was used for analysis to save time and efforts required to perform the complicated statistics. Six Sigma invented by Motorola in the 1986 and popularized by General Electric (GE) in the 1990's. Organizations including Honeywell, Citigroup, Motorola, Starwood Hotels, DuPont, Dow Chemical, American Standard, Kodak, Sony, IBM, Ford have implemented Six Sigma programs across diverse business operations ranging from highly industrial or high-tech manufacturing to service and financial operations. Six Sigma is a statistically-based process improvement methodology that aims to reduce defects to a rate of 3.4 defects per million defect opportunities by identifying and eliminating causes of variation in business processes. In defining defects, Six Sigma focuses on developing a very clear understanding of customer requirements and is therefore very customer focused. The Six Sigma methodology is based on a concept called DMAIC.

The DMAIC approach consists of five sequential phases:

1. **Define** the deficiency and its potential reasons
2. **Measure** the value of deficiency along with its potential reasons
3. **Analyze** measurements to identify root cause of deficiency
4. **Improve** the process performance to eliminate deficiency
5. **Control** the process to sustain the improvement gains

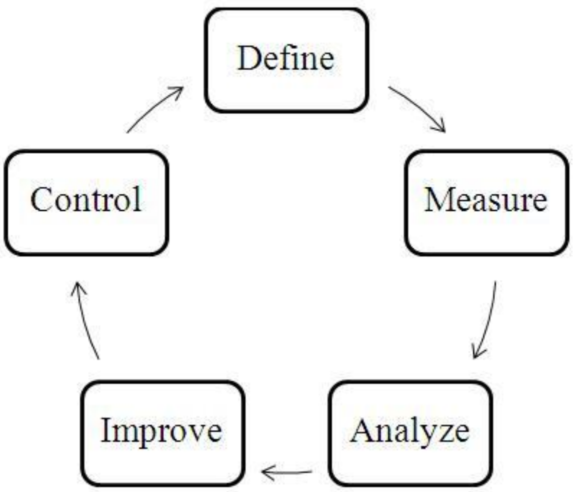

Figure 2. *Continuous Improvement through the DMAIC Approach.*

RESULTS AND DISCUSSION

Exploratory Study:

Initial information was gathered from one project site to confirm the existence of excessive reinforcement steel waste.

Reinforcement steel quantities were measured as follows:

• Reinforcement steel quantity used for construction was calculated as the diffrence between purchased and remaining quantities:

Quantity purchased - quantity remaining = 754.537 - 42.365 Quantity used for construction = 712.172 Tons.

• Reinforcement steel quantity delivered to client was obtained from project invoice approved by the client: Quantity delivered to client = 593.58 Tons.

• Reinforcement steel waste was calculated as the difference between the used and delivered quantities: Waste = Used – Delivered = 712.172 - 593.58

Waste = 118.592 Tons.

• Waste Percentage was calculated as the ratio between waste and quantity delivered to client:

Waste Percentage = Difference ÷ Delivered = 118.592 ÷ 593.58 = 19.98 %

• Process yield was calculated as the complementary of waste percentage: Process Yield = 100 - 19.98 = 80.02 %.

• Current process sigma level was obtained using process yield using "sigma level calculator" software. Current Process Sigma Level = 2.342.

SIPOC Analysis:

SIPOC (Suppliers Inputs Process Outputs and Customers) analysis was performed to illustrate details of process.

Table 1. *SIPOC analysis*

Suppliers	Inputs	Process	Outputs	Customers
Site Engineer	Work Order	Transportation	Waste due to movements	
Warehouse	Steel		Delivered steel to work shop	Cutting workshop
	Fork left			
	Cranes	Cutting	cutoff steel bars	Forming Workshop
	Labor		short steel bars	
	Measuring devices		Waste due to incorrect cutting	
	Fork left	Forming	Formed Steel bars	Steel Fixer
	Labor		Waste due to incorrect forming	
	Hand tools			
	Labor	Delivery	Formed Steel bars in site	Site Engineer

Research Variable Identification:

By the end of the define phase we can identify input and process variables, which should be measured during the measure phase. These variables are obtained from the following IPO analysis

***Table 1.** IPO analysis.*

Inputs	Process	Outputs	Measurable characteristic
Steel	Transportation		Steel Diameter Used Steel Weight
Fork left		Delivered steel to work shop	Number of equipment
Engineer	Cutting	cutoff steel bars	Number of engineers Engineers experience
Labor		short steel bars	Number of labors Labors experience Labors weight Labors length
measuring devices		Waste due to incorrect cutting	
Labor	Forming	Formed Steel bars	Steel QC comments
Supervisor		Waste due to incorrect forming	Number of supervisors supervisors experience
Fork left	Delivery		
Labor		Formed Steel bars in site	

As a result of IPO analysis, ten factors were identified as potential influence of significant impact on the "reinforcement steel waste percentage". Prior to the commencement of data collection, meeting was conducted with project team in order to agree the operation definitions and approve the method used to record the necessary data.

These ten factors are:

1. Total Steel Used (kg): Total Steel Used is measured by the total amount of reinforcement steel consumed in the project site in kilogram.
2. Total Steel QC comments: Total Steel QC comment is measured by the total comments of quality control on reinforcement steel in project site by numbers.
3. Number of Labors: Number of Labors is measured by the total count of labor working in cutting and forming of reinforcement steel.
4. Labors Weight (kg): Labor weight is measured by kilogram to represent labor physical fitness.
5. Labor Years of Experience: Labor years of experience are measured by number of years the labor spent in the reinforcement steel field.
6. Number of Supervisors: Number of supervisor is measured by the total count of supervisor controlling the labor working in cutting and forming of reinforcement steel.
7. Supervisors Experience: Supervisor Experience is measured by number of years the supervisor spent in the reinforcement steel field.
8. Number of Engineers: Number of Engineers is measured by the total count of Engineers managing cutting and forming of reinforcement steel.
9. Engineers Experience: Engineers Experience is measured by number of years the Engineers spent in the reinforcement steel field.
10. Number of Equipment: Number of Equipment is measured by the total forklift working in the transforming of reinforcement steel.

CONCLUSION

The existing problem was identified as "High percentage of reinforcement steel waste" and potential influencing factors are:

x1. Total Steel Used (kg)
x2. Total Steel QC comments
x3. Number of Labors
x4. Labors Weight (kg)
x5. Labors Years of Experience
x6. Number of Supervisors
x7. Supervisors Experience
x8. Number of Engineers
x9. Engineers Experienc
x10. Number of Equipment

ACKNOWLEDGEMENTS

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