Six Sigma Within Construction Context
As A Quality Improver & Management Strategy

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Abstract – Six Sigma was developed in 1980s in manufacturing industry and became popular as a process improvement method. However, the adoption of this concept is new in construction industry and the aim of this study is to evaluate Six Sigma as a process improvement method within construction context. This thesis includes Literature Review and three interviews. Literature Review had discussed process improvement methods used in construction industry and analyzed the basic features and principles of Six Sigma. Three interviews were conducted about the basic principles of Six Sigma and Quality Concept. Interviewers are a Project Manager, Field and Cost Engineer. The approach of the interview to Six Sigma is based on quality, performance and management aspects. This study defends that there is no doubt about the positive effects of Six Sigma on construction projects. Particularly, Six Sigma can provide a broader quality concept, detailed performance measurement, coordinated and repeatable process/performance improvement. It has increased quality directly/indirectly and has positive effects on production efficiency. As a management approach, Six Sigma is discussable within construction context due to differences of manufacturing and construction industry. Since construction industry includes lots of unrepeatable tasks and different process design techniques, Six Sigma does not seem applicable as a whole management approach in construction industry.

Keywords - Quality Control; Construction industry;Construction management, DMAIC procedure

I. INTRODUCTION

Quality Management is defined as any approach used to achieve and sustain a high quality output by conforming to requirements and meeting customer satisfaction. Six sigma is a quantitative approach for improvement with the goal of eliminating defects from any process, specifically a numerical goal of 3.4 defects per million opportunities (DPMO). Six sigma is reportedly easier to apply than many other quality management programs because it provides information about the change needed and the programs to execute the change. The strategy it uses is a five-step improvement process: define, measure, analyze, improve and control (DMAIC). This process is deeply integrated with the overall goals of the organization and, as such, requires top down implementation. Six sigma is more intense, focused and detailed than any other quality improvement techniques. Six Sigma was first used in 1985 by Bill Smith of Motorola to decrease cost, increase quality by improving process and reduce the production time.

II. SIX SIGMA METHODOLOGIES

Six Sigma is a statistics based methodology and relies on the scientific method to make significant reductions in customer defined defect rates in an effort to eliminate defects from every product, process and transaction. The Six Sigma principle can be represented on a normally distributed product quality distribution curve. When the mean is located at the center of the normal distribution curve, the lower and upper limits are six times the standard deviation (sigma) from the center line. In other words the range of lower and upper limit defect is +/- 6 sigma from the mean.

Table 1 illustrates the rate of defects per million opportunities in different sigma levels.

<table>
<thead>
<tr>
<th>Yield=% of items without defect</th>
<th>DPMO(defect per million opportunities)</th>
<th>Sigma level</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.9</td>
<td>690 000</td>
<td>1</td>
</tr>
<tr>
<td>69.2</td>
<td>380 000</td>
<td>2</td>
</tr>
<tr>
<td>93.3</td>
<td>66 800</td>
<td>3</td>
</tr>
<tr>
<td>99.4</td>
<td>6 210</td>
<td>4</td>
</tr>
<tr>
<td>99.98</td>
<td>320</td>
<td>5</td>
</tr>
<tr>
<td>99,9997</td>
<td>3.4</td>
<td>6</td>
</tr>
</tbody>
</table>
III. BASIC FRAMEWORK OF SIX SIGMA PRINCIPLE - BASED MANAGEMENT

According to the paper presented by aboelmaged, m. G. 2010[1] named “six sigma quality: a Structured review and implications for future research” the six sigma principle concept can be applied to the construction process control within the basic framework of CTQ inputs, DMAIC procedures and output measures as shown in figure below,

**FIGURE 1: BASIC FRAMEWORK OF SIX SIGMA**

<table>
<thead>
<tr>
<th>Performance Indicators (Input CTQ)</th>
<th>Six Sigma Application Procedure DMAIC</th>
<th>Indices of Performance improvements (outputs)</th>
</tr>
</thead>
</table>

DMAIC Procedure

As per paper published by Muharrem Firat Yilmaz[3] named “Six Sigma within Construction Context” Six Sigma is a continuous improvement methodology which known as DMAIC (define, measure, analyze, improve, control) aims to enhance the efficiency of the existing processes and increase customer satisfaction through designed products and services. DMAIC framework is a integration of several techniques such as QFD (quality function deployment), SPC (statistical quality control), DOE (design of experiments), and FMEA (failure mode and effects analysis) in a logical direction. This approach is more suitable when the current design of the products, services and processes are correct and satisfactory regarding to the requirements, customers and business. This methodology offers structured framework in following steps to establish systematic continuous improvement.

Define. In this step it is necessary to define customer requirements and any things do not meet those requirements known as defect, determine key processes, key roles and team charter, define project goals and scope, and estimate the risks and financial impact.

Measure. Identify and collect the appropriate data which are relevant to the defects and the processes need improvement. Measure the processes performance and establish the measurement system based on Six Sigma techniques and tools.

Analyze. Study and analyze the data collected in previous step to find out the root causes of the defects and unsatisfactory performance.

Improve. Identify alternative solutions and methods based on the knowledge derived from analyze step, study and assess the potential solutions to distinguish the most successful improvement solution. Implement that successful method.

Control. Establish a control plan to ensure that expected improvement has been achieved, and the knowledge and experiences have been documented and shared to remain at attained high level performance.

IV. DEPLOYING & IMPLEMENTATION

The twenty key lessons learned from the deployment of Six Sigma Six Sigma is very popular since its concept includes the combination of competitive pressures and management recognition of Cost. Various tools are present at each step of DMAIC procedure depending upon the difficulty level. In this paper we shall use the following tools at each step of DMAIC methodology.

| Define – SIPOC – Suppliers Input Process Output Customer |
| Measure – Pareto Diagrams |
| Analysis – Cause and Effect Diagram |
| Improvement – Corrective Action |
| Control – Control Plan |

Implementation of Six Sigma requires effective project communication in order to be successful. (Hahn, 2005) and (Antony and Banuelas, 2002) showed this relation in their study.

That’s why: Interviews emphasize the importance of project communication in this part. All of the interviewers emphasized the importance of collaboration & communication between different departments and disciplines for the success of process improvement. Also, (Antony and Banuelas, 2002) evaluated project communication as a key success factor for Six Sigma implementation.

**TABLE::2 COLLABORATION PRIORITIZATION DURING PERFORMANCE MEASUREMENT**

<table>
<thead>
<tr>
<th>Team members</th>
<th>priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Manager</td>
<td>1</td>
</tr>
<tr>
<td>Project Control Department</td>
<td>2</td>
</tr>
</tbody>
</table>
Another prioritization question asked to DPM was about the
low performance of site operations. If the site departments
show unexpected low performance which increase the costs
and reduce quality, DPM said that he will contact firstly with
Construction Manager (or Department Manager), secondly
Project Control (or Business Manager) and thirdly Quality
Control department in order to get some explanations or
reasoning.

TABLE: 3 COLLABORATION PRIORITIZATION
CONSIDERING LOW PERFORMANCE

<table>
<thead>
<tr>
<th>Team Members</th>
<th>priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project control (or Business manager)</td>
<td>2</td>
</tr>
<tr>
<td>Construction Manager (or Department Manager)</td>
<td>1</td>
</tr>
<tr>
<td>Site Engineers of the responsible department</td>
<td>4</td>
</tr>
<tr>
<td>Quality Control Department</td>
<td>3</td>
</tr>
<tr>
<td>The previous/next responsible department of the process</td>
<td>5</td>
</tr>
</tbody>
</table>

V. BENEFITS OF SIX SIGMA

The expected benefits of process improvement can be
different regarding industry types. That’s why; this part of
interviews deliberates on definition of an ideal process
improvement and expected benefits from it for construction
industry.

CE thinks that an ideal process/performance improvement
method should have different outputs based on financial,
technical and quality aspects:

- Financial aspect: an ideal process improvement method
  should decrease the cost and increase efficiency.
- Technical aspect: an ideal process improvement
  method may lead to more effective researches on
  engineering issues.
- Quality aspect: an ideal process improvement should make final
  product better and satisfy the customer expectations.

According to CE, an ideal process improvement method
for construction projects should have two main targets:

- Cost Efficiency
- Effective research about engineering applications

DPM think that an ideal process improvement method
should have three main targets:

- Reducing of product cost (process cost)
- Increasing the quality of final products
- Increasing the quantity of site production

FE emphasized that there is a risk of making process less
efficient after the implementation of wrong process
improvement tool. That’s why; an ideal process
improvement method must be very less risky. Additionally, he
thinks that process improvement can be realized in the tasks
such as:

- Precast Construction Elements
- Structural Rebar Installation
- Concrete Plants & Manufacturing
- Asphalt Plants & Manufacturing
- Equipment Utilization and Efficiency

FE emphasized the importance of Site Engineers during process
improvement. He thinks that the support of site engineers is a
crucial for the success of Six Sigma and implementers of Six
Sigma should be mainly site engineers due to their specialized
knowledge on site process. FE thinks that although
Construction Management and Six Sigma have different roots
and historical background, Six Sigma can be implemented as a
management strategy. Moreover, FE expressed that Six Sigma
methods must be adjusted for the unrepeatable construction site
operations.

VI. SIX SIGMA AS A QUALITY INITIATIVE

Interviewers’ definition of quality shows that quality concept of
construction industry is smaller than manufacturing industry.
Construction professionals (especially site engineers) perceive
the quality as a technical issue and their expectations are to
fulfil the requirements of technical regulations and methods
statement agreed by both of the employer & contractor.

Evidently, all of the interviewers do not consider Quality
Control department as one of the key actors of process
improvement. It can be said that Six Sigma as a quality
initiative might be useful in order to extend quality concept to

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more efficient form and create a new quality framework which includes financial parameters of construction industry. According to (Harry and Schroeder, 2000), the new quality concept includes not only technical specifications but also economic value for the company & customer and highest quality can be realized when the products meets the customer requirements with lowest costs in Six Sigma approach.

VII. SIX SIGMA AS A PERFORMANCE INDICATOR

All interviewers expect the performance increase from an ideal process improvement method. DPM emphasized the importance of increasing quality & quantity for performance improvement and CE mentioned that the effective research about engineering applications should be in the scope of process improvement (Benefits of Six Sigma). Moreover, (Han et al., 2008) mentioned that Six Sigma can be used also as a performance indicator by project managers and evaluation of project performance level can be done nearly perfectly by several steps.

Obviously, performance/process improvement is almost impossible without having a solid methodology, data procurement/collection system and measurements techniques. According to (Han et al., 2008), measurement of project performance had been done after project completion, so performance improvement might be difficult due to lack of a definite methodology. That’s why; one of the prerequisite of process improvement (Six Sigma) is to measure project performance. Evidently, all of the interviewers support the existence of continuous data collection system (Benefits of Six Sigma) for the performance measurement.

VIII. SIX SIGMA AS A MANAGEMENT STRATEGY

Mostly, social sciences made contributions to management theory, However, Six Sigma is based on statistic and statisticians and Six Sigma are improved by companies such as Motorola, GE and IBM. So, one of the difference of Six Sigma is to be improved by companies and professionals. It makes Six Sigma very practical compared to others process improvement methods which developed in the scientific environments. However, none of the developer companies and professionals has construction industry experience. It makes Six Sigma quite questionable as a management strategy for construction industry. The adoption of Six Sigma to the construction industry requires the integration of SixSigma to the existing quality management strategy of the companies.

There are different views about the relation of Total Quality Management and SixSigma. DPM evaluates Six Sigma as a “sub-management strategy” which can be applicable if it is integrated to the existing management procedures and he thinks that Six Sigma is very useful for the construction projects which include lots of repeatable tasks (Benefits of Six Sigma). CE mentioned that Six Sigma is too new within construction context and construction professionals are not ready to implement it to the whole project phases (Benefits of Six Sigma). FE emphasized the importance of project control and site engineers collaborations. Also, he thinks that the proper adoption of Six Sigma is not completed totally and it should be improved and adjusted considering characteristics of construction industry (Benefits of Six Sigma).

CONCLUSION

Six Sigma can be very useful to broaden quality concept of construction industry to a more efficient form which should include financial parameters. Obviously, past researches and applications show that Six Sigma increase quality directly/indirectly considering technical and financial aspects in the construction industry even though it is not adapted properly. Briefly, Six Sigma, as a quality initiative, aims to reduce defects and variations in processes using statistical measurements, process design and quality control analysis in order to increase (external/internal) customer satisfaction. Six Sigma has provided an exact methodology, continuous data collection system and measurement techniques for performance/process efficiency measurement as a prerequisite. Additionally, the integration of Six Sigma approach to the existing procedures of Project Control department makes the collaboration of Site and Office department more efficient. Six Sigma methodologies make the benefits of process improvement repeatable and coordinated which are very important for the sustainable

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