IMPROVE QUALITY VIA QMS THROUGH QUALITY TOOLS

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ABSTRACT

Although Six Sigma has been widely implemented in the manufacturing industries, it is still a relatively new concept in construction sector. The aims of this study are to evaluate and improve the quality of ready mixed concrete plant of Al-Rasheed Company by using Six Sigma DMAIC improvement cycle. Six Sigma is a disciplined business strategy, data-driven approach and methodology that having statistical base focusing on removing causes of defects in the product to improve business outputs which are of critical importance to customers. The fundamental objective is the implementation of a measurement-based strategy that focuses on process improvement and variation reduction to reach delighting customers and then suggesting a Quality Management System to improve the production.

A field survey includes open and close questionnaire that aimed to get data and information required for achieving the research where the answers of questionnaire sample have led, during the application of DMAIC cycle, to identifying the potential possible reasons that caused quality deviations. Two programs have been used: First, 'Calculating Sigma Level' which is formulated by the researcher to measure the components of the process performance. Second, 'QI Macros Lean Six Sigma SPC Software' which uses the statistical tools of DMAIC improvement cycle. According to the fieldwork, it is concluded that sigma level for the concrete works quality before applying the QMS was 2.41, 18.11% non-conformance production and 181,070 DPMO which are considered too bad as compared with current global competition.

Keywords: Six Sigma, DMAIC, QMS, Construction Management, Concrete, Statistical Tools.

1. INTRODUCTION

Over the last twenty years, Six Sigma has received wide acclaim as a methodology, process and vision to accomplish process improvement. It has been successfully implemented in many industries, from large manufacturing to small businesses beside, its effective role in construction and banks sector. As a data-driven, Six Sigma is a quantitative approach that aims to deliver near-zero defects as defined by customers for every product and process within an organization. In other words, it is a stronger emphasis on capturing 'the true voice of the customer' by clearly 'understanding the needs of customers' for today and tomorrow [1].
Al-Rasheed State Contracting Construction Company is G2 governmental self-financing company. (Note: contractors in Iraq are classified according to the Ministry of Planning in one of seven financial categories. These range from G11, the smallest, to G1 the largest financial category).

2. SIX SIGMA

For the concept of Six Sigma was initially proposed by Bill Smith, a senior engineer and scientist at Motorola’s Communications Division in the 1980s. In 1988, Motorola became the poster child for Six Sigma when they won the Malcom Baldrige National Quality Award. Six Sigma is a quantitative approach for improvement with the goal of eliminating defects from any process, specifically a numerical goal of 3.4 (DPMO) defects per million opportunities [2].

Chowdhury (2001) defined Six Sigma as a statistical measure and a management philosophy that teaches employees how to improve the way they do business, scientifically and fundamentally, and how to maintain their new performance level. It gives discipline, structure, and a foundation for solid decision-making based on simple statistics. Technically, sigma is a letter in the Greek alphabet. It is written as σ, and used both as a symbol and a metric of process variation [3].

3. APPLICATION OF DMAIC IMPROVEMENT CYCLE

Six Sigma is divided into sub-methodologies, DMADV, DFSS and DMAIC. DMAIC acronym refers to the terms: Define, Measure, Analyze, Improve, and Control. It is an improvement methodology focusing on improving existing processes and performance [4]. This research includes the application of Six Sigma DMAIC improvement cycle of Al-Rasheed ready mixed concrete plant.

3.1 Define Phase

In this step, defining problems that can be fixed is an important key. It is important to pick problems that are costing the company most or are giving you the most problems [5]. This research focuses on the problem of ‘poor quality of concrete mixtures and the consequent deviation in the quality of building’.

3.2 Measure Phase

In this step, the Black Belt calculates how many errors are made. In other words, measures the current performance of the process: yield, DPMO, sigma level, etc [5]. Six Sigma offers the following formulas to calculate percentage of yield and number of defects per million opportunities [6]. Table 1 shows the relationship between sigma level and these metrics values while eq. 1 and eq. 2 are the formulas of calculating the yield and DPMO [1].

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\text{Yield} = \frac{\text{correct items}}{\text{opportunities}} \quad \text{(1)}
\]

\[
\text{DPMO} = \frac{\text{defects}}{\text{opportunities}} \times 10^6 \quad \text{(2)}
\]

<table>
<thead>
<tr>
<th>Sigma Level</th>
<th>DPMO Rate</th>
<th>Yield %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2σ</td>
<td>308 770</td>
<td>69.1230</td>
</tr>
<tr>
<td>3σ</td>
<td>66 811</td>
<td>93.3189</td>
</tr>
<tr>
<td>4σ</td>
<td>6 210</td>
<td>99.3790</td>
</tr>
<tr>
<td>5σ</td>
<td>233</td>
<td>99.9767</td>
</tr>
<tr>
<td>6σ</td>
<td>3.4</td>
<td>99.9996</td>
</tr>
</tbody>
</table>

**Table. 1 Relationship among Six Sigma Metrics**
On the ground, defect is defined according to the technical specifications of C30 mixture for foundations in this study as all concrete cubes have not passed the compressive strength test based on the American Specification (ACI-318). Accordingly, it is noticed that from 243 cubes, only 199 have passed, which means there are 44 defects.

After having both the number of correct items and defects, ‘Calculating Sigma Level’ program (which is created by the researcher) have been used to calculate the current performance level as shown in Figure 1. Practically, the current process performance for the quality of concrete works was 2.41 sigma level with 181,070 DPMO which consider a high defective rate within the company and requires an immediate treatment for improving quality process yield and rising up level of sigma as much as possible to limit the numbers of defect. For example, 3.4 sigma level can be chosen as a target for this case to eliminate the number of defects from 44 to only 7. In other words, the non-conformance production can be reduced from 18.11 % to only 2.88 % if the improvement applied correctly which would definitely bring better quality and more revenues as well as saving costs.

Fig. 1 Sigma Level Calculations

3.3 Analyse Phase

In this step, understand and analyze the data collected by using simple statistical tools as well as the process to determine the root causes of the problem that need improvement [3]. In construction, the main task is to identify when, where and why the defects occur in the project, which includes actual and potential problems by using Six Sigma tools [6].

a. Capability Analysis (Variability)

Histograms are used in Six Sigma to establish variability or deviation from the center line of the target value in a bell shape. They are a way of doing a capability study [1]. Histogram is a graphical representation, showing a visual impression of the distribution of measured or counted data [7]. Figure 2 shows histogram and process capability curve which is drawn by using the QI Macros.

There is a couple of index called Cp and Cpk which help to determine whether a process is capable or not. A \( \text{Cp} \geq 1 \) means the process fits between the upper and lower specification limits; whereas \( \text{Cpk} \geq 1 \) means the process is centered between these limits. Also, there are many other calculations shown in histogram [8]. According to the values presented, the process is not capable (Cp and Cpk < 1) and the histogram is moderately skewed to the left while many points are located outside the lower specification limit (LSL).
b. **Stability Analysis (Predictability)**

Control charts are a way of measuring stability [1]. Control charts are the appropriate tool to monitor processes. They are useful to find unusual sources for variation. Samples falling outside the control limits are a signal for unusual sources and an investigation should be made to find the causes behind. The appropriate response to the signal is to stop the process at once and preventing defects [9].

There are so many different control charts that estimate $\mu$ and $\sigma$ using the average and range of samples. The formulas to do this vary depending on the type of data (variable data such as time, cost, length, weight, etc. or attribute data such as number of percent defective) and the sample size. Each control chart’s formulas are designed for these varying conditions. In variable charts, the XmR uses a sample size of 1, XbarR [2-10] and XbarS [11-25] [8]. Accordingly, the right control chart for this study is the XbarR charts which can effectively help evaluating the stability of processes for the values of compressive strength testing as shown in Figure 3 which is drawn by the QI Macros but values seem scattered and out of statistical control. Therefore the process is not stable (unpredictable trends).

![Histogram and Capability Analysis](image1)

**Fig. 2** Histogram and Capability Analysis

![X bar-control Chart for Testing Results](image2)

**Fig. 3** X bar-control Chart for Testing Results
Also, it can be noticed that the values start to drop down with the passage of time especially in the second half of the year.

Therefore, the control chart, as shown in Figure 4, is divided into two parts: ‘before Summer’ and ‘in Summer’ where it is noticed that before Summer the process is almost stable while in Summer the values slope down and become unstable. Thereby, it can be said that the reason for this deviation may return to the high temperatures in that period of year in Iraq.

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\text{Fig. 4 Process Change of X bar-control Chart}
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c. Root Cause Analysis

The goal is to identify root causes for the defects in processes that keep organizations from providing customers with the consistent quality. Two statistical tools are used in this stage: Pareto chart and Fishbone diagram.

Pareto analysis is a technique for focusing attention on the most important problem areas. The Pareto concept, named after the nineteenth-century by Italian economist Vilfredo Pareto, is that a relatively few factors generally account for a large percentage of the total cases. The idea is to classify the cases according to degree of importance, and focus on resolving the most important, leaving the less important [10]. Figure 5 presents ranking of the main causes of deviation in the quality of concrete mixtures depending on the responses of respondents for the close questionnaire form which is drawn by the QI Macros software.

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\text{Fig. 5 Pareto Diagram of Causes of Deviation in Concrete Works}
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Fig. 6 Fishbone Diagram for Causes of Deviation in the Quality of Concrete Mixture

Cause and effect diagram is known as a fishbone diagram because it looks like that. This tool is a facility that helps organizing ideas or a way of capturing root causes in Six Sigma [1]. According to the results of close questionnaire, field visits to the concrete plant, and interviews with both: key project participants and engineers, the major causes of deviation in the quality of concrete mixtures have found and pictured in Figure 6.

3.4 Improve and Control Phases
The main task in these phases is the elimination of root causes of problems and developed process requirements that minimize the likelihood of the failures based on the knowledge and information obtained in previous phase or from the questionnaire forms and interviews. Therefore, these two phases have been replaced by proposing a Quality Management System (QMS) based on Six Sigma to improve performance as shown later in this research.

4. PLANNING OF PROGRAM

In order to apply the proposed QMS, the company has to rearrange its organizational structure by establishing a ‘Quality Improvement Department’ (QI Dpt.) and a ‘Steering Committee’ in Al-Rasheed Company instead of the small Quality Division that established since 2008 with keeping the rest of departments as they are. This rearrangement and additions will play a pivotal role in implementing the QMS.

4.1 Quality Improvement Department
The organizational structure of QI Dpt. has included five divisions, as illustrated in Figure 7, which are:

1. Six Sigma Division which aims to promote Six Sigma principles and practices the five phases of DMAIC. As well as, supports training programs by providing plans and ensures that everybody knows the reason of adopting Six Sigma;
2. Training Division where the term training refers to the acquisition of knowledge, skills, and competencies as a result of teaching. Training topics typically include quality awareness, teamwork, leadership, interpersonal communication, job-related technical skills, and problem
solving techniques. In addition, quality improvement teams often receive instructions as a unit. Among the essential tools for the successful application of Six Sigma are: flowcharting, brainstorming, capability analysis, control-charts, Pareto chart, and cause-effect diagrams;

3. Documentation Division where documentation of variation causes, progress of work, result of testing, quality reports, and how improvements were carried must be conducted manually and electronically;

4. Quality Control Division which is responsible for testing products, calibrating equipments, finding defects, checkpoint review, issuing reports; and

5. Quality Assurance Division which is responsible for inspection raw materials, quality audit, selection of tools, preventing defects, proactive actions and defining process.

4.2 Steering Committee
In order to achieve quality objectives for the company, a steering committee chaired by top manager has established to meet regularly once every two weeks to break down any barriers among engineers, project managers, technicians, and accountants. The committee members represent the chief executive officer and the department head managers. The steering committee is responsible for:

1. Establishing policies for every area that needs guidance in the quality effort;
2. Paying particular attention to revise the undergoing projects and solve any problems arising between different departments;
3. Preparation of quality manuals covering all company wide applications;
4. Development of an action plan for implementing the program;
5. Selection of initial quality improvement teams;
6. Establishment of a system to get accurate feedback on the program success; and
7. Being visible and available to all employees.

This committee will be directly linked to the following parties as shown in Figure 7:

‘Quality Circle’ work group which consists usually of (5-10 persons) one as a chairman of circle (president), one person of each division of the proposed QI Dpt. besides foreman and worker to met periodically (an hour a week) to discuss quality issues, the progress of improvement measures, corrective actions and find appropriate solutions. Then, submitting preliminary reports to the QI Dpt. through the steering committee. And ‘External Consultant’ where this study is believed that hiring an external consultant experienced with quality programs will accelerate the company transformation toward high quality production via Six Sigma philosophy.

5. NEW PROPOSED MODEL OF QUALITY MANAGEMENT SYSTEM

In accordance to the research findings, a formulated model has created to be followed in Al-Rasheed Company in order to improve the quality of production specially the concrete works. This model consists of the following steps: (1) input control; (2) process control; and (3) output control by FISH cycle.

5.1 Input Control
Input such as raw materials, devices, equipments, machineries and specialized technical staff are used by the process to produce the output.

a. Raw Materials Control
The most prominent procedures that must be included in this stage are:

1. According to ‘Contract Condition for Civil Engineering Works [11]’ (clause 37). It is suggested to send a team of experienced engineers to the headquarters of manufacturing, prior to purchase the raw materials, to perform tests and evaluate the quality of materials
before buying and shipping them to the site in order to overcome wasting of time and effort on transporting invalid materials;
2. Registration of the entrance of the material from suppliers in software used for this purpose and saved in computer as a permanent document which can help evaluating the efficiency of suppliers; and
3. Determining the required material; then, buying the right amount after deep studies; next, providing an appropriate storage for materials; after that, testing the materials; finally, documentation of all information.
These responsibilities must be managed by: quality assurance division, documentation division and quality improvement department.

b. Devices and Machines Control
Organizations need to purchase or hire items in order to conduct their business. The proposed system aims to guarantee the continuity of work equipment to achieve the purpose of their existence which is introduced the best performance at the lowest cost and highest degrees of safety through adopting the procedures of preventive and predictive maintenance instead of the remedial maintenance.
The main goals of this stage are:
1. Selecting the right acquisition policy; where equipment may be purchased, hired or hired with an option to purchase later;
2. Providing a convenient place for equipments;
3. Reducing periods of breakdown to a minimum and improving the productivity of equipments to a maximum;
4. Complying with safety regulations to ensure staff safety; and
5. Reducing number of spare parts, unless it is necessary, to avoid freezing of capital.

Fig. 7 Proposed Organization Structure of QI Department and Steering Committee to Al-Rasheed Company

The following parties should be responsible for adjusting equipments work: maintenance unit, stores division, purchasing department, financial affairs department, QC division under the supervision of QI Dpt.

c. Personnel Control
The field survey have reflected that most of the workers in construction projects are temporary labour and have not had enough efficiency that can qualify them to work on sites. Therefore, two important functions are suggested to solve the problem referred to above which are:
1. Establishing a new system for hiring personnel permanently instead of depending on the temporary labours;
2. Now, after having a permanent staff, the company must be sure that new employees receive the proper indoctrination by offering *training courses* to develop their skills and increase knowledge of Six Sigma to accomplish mutually beneficial relationship between organization and employees; and
3. Training should not be directed only to site engineers. Therefore, it must be included the middle and top managers.
   These responsibilities should be managed by: training division, Six Sigma division, human resources department, and quality improvement department.

**5.2 Process Control**
Organizations must remember that process control and producing high-quality products may ensure customer satisfaction. This stage should control:

**a. Examination and Inspection**
Testing and inspection are usually used to determine whether the item or activity is in line with the targets or not. The next stations of examination and inspection must be achieved during the process of concrete production:

1. Suggested station for testing and inspection of the raw materials at the provision sources by sending committees from the purchasing department and quality control division to assure quality of materials ‘before’ buying them to the site;
2. Station of testing the received raw materials, from provision sources, on the site;
3. Suggested station for inspecting during the process of concrete production inside the concrete plant by a permanent representative from each of QC division, OA division and resident eng. office in order to verify concrete quality;
4. Suggested station for testing the fresh concrete in the field by QC division as recommended from the American Concrete Institute (ACI) specially the Slump and Temperature tests which can immediately and effectively detect deviations in the quality of concrete mixtures;
5. Station of the compressive strength testing for concrete cubes by QC division; and
6. Suggested station of inspection ‘during the casting process’ to assure high production for both specimens and hardened concrete.

This procedure should be applied to increase care and protection for each concrete and cubes by allocating particular inspectors and engineers from quality improvement department and resident eng. office to carry out periodical inspection.

**b. Devices and Equipments**
All devices and equipments used for testing and inspection must be ‘calibrated’ periodically, to prevent any deviation in their performance form ever getting out, by taking some procedures like: sending them to a third-party authorized to conduct calibration, and providing appropriate environmental conditions for storage.

**c. Documentation**
Document everything by adopting an electronic documentation system depending on software and manual documentation by hand; which include all kinds of reports such as: variation causes, purchase orders, quality reports (daily, weekly, and annually), supplier evaluation reports; results of testing, and progress reports.
The responsibilities of ‘process control’ stages must be executed and handled by: QC division, QA division, documentation division and stores division under the supervision of quality improvement department.

5.3 Output Control

This stage is adopted the sequential ‘FISH process cycle’, which stands for Focus, Improve, Sustain and Honor; to strengthen the suggested OMS as described in the following steps:

a. **Focusing on both: Reports and Product Delivery**
   
   This first step aims at: (1) narrowing the focus on performance control reports (variation causes reports) that issued by quality circle group or the quality improvement department and its divisions to provide top-management with the actual situation. Mainly, these reports aid managers by measuring deviations from standard plans and evaluating the actual performance according to the results of testing which would be subjected to audits and analysis by specialists to prepare recommendations for the corrective actions; and (2) focusing on service by making plans to the way the product should be delivered to the customers.

b. **Improving Performance**

   This second step seeks to make corrective actions that suggested by specialists in the previous step after fully agreement of top-management. In this step, some methods such as brainstorming, benchmarking, and quality circles might be used to generate and come up with new ideas that lead to the right corrective/preventive actions. In addition to establish a system to share information with employees by encouraging employees to speak out against policies that inhibit quality; and to submit their suggestions through a suggestion box; then, let them know that their suggestions are appreciated; next, reward them appropriately if the suggestion was acceptable and worked; or explain the reason if the suggestion was not feasible.

c. **Sustaining the Improvement**

   One of the most places where people fail down is actually sustaining the improvement whereby changes in the process cannot be detected with naked eyes, but with control charts and histograms it can. Therefore, it is necessary to teach employees how to use statistical process control SPC charts to monitor, manage and maintain the performance by training them how to use these tools.

d. **Honour the Work Team**

   It is significant to motivate the team members to be the owners of their work and strive for their own specific goal regarding their tasks beside the cooperation toward the common goal and overall success of the project. This can be done by providing health insurance, social security beside increasing allocations and monetary bonus or by giving financial loans to those who submitted distinct jobs.

6. **CONCLUSIONS**

   According to the field survey (open and close questionnaire), DMAIC cycle and research findings many conclusions have been made as follows:

   1. The current process performance for the quality of concrete works in this study are: 2.41 sigma level, 81.89% quality yield, 18.11% non-conformance production and 181,070 DPMO which are considered too bad as compared with the current global competition and need to be improved through the adoption of proposed Quality Management System (QMS).
2. Histograms are a way of determining capability while control charts are a way of measuring stability. Therefore, the values of compressive strength testing in this study were neither capable nor stable.

3. Pareto chart shows that the major causes of deviations in the quality of concrete mixture are: mix design then, bad quality of materials, truck mixer delay; after that, temperatures; next, lack of training which leads to inefficiency of labors and other reasons.

4. Based on the questionnaire, it is found that Al-Rasheed Company suffers from lack of interest in quality, because it believes that controlling quality costs too much!

7. **RECOMMENDATIONS**

In order to improve quality in construction industry, the company should adopt new reforms toward quality policies such as the application of proposed QMS and its components which are included many procedures for amendment the performance such as: establishing a professional system for hiring personnel permanently, adopting an electronic documentation system, offering training courses, and performing temperature and slump tests for the fresh concrete.

**REFERENCES**


