Quality Evaluation of Al-Rasheed Ready Concrete Mixture Plant By Using Six Sigma Approach

Ali Amer M. Hasan Karakhan & Dr. Angham E. Ali Alsaffar

Abstract

The objective of this research work is to evaluate the quality of central concrete plant of Al-Rasheed Company by using Six Sigma approach which is a measure of quality that strives for near elimination of defects using the statistical methods to improve outputs that are critical to customers. The fundamental objective of Six Sigma methodology is the implementation of a measurement-based strategy that focuses on process improvement and variation reduction to reach delighting customers, and then suggesting an improvement system to improve the production of concrete in Al-Rasheed State Contracting Construction Company.

A field survey includes two parts (open and close questionnaire) that aimed to get the data and information required for achieving the research where the answers of questionnaire sample have led, during the application of DMAIC improvement cycle, to identifying the potential possible reasons that caused quality deviations in concrete works. Two programs have been used: First, 'Sigma Level Calculator' which is formulated by the researcher to measure the components of the processes performance. Second, 'QI Macros Lean Six Sigma SPC Software 2011' which uses the statistical tools of Six Sigma DMAIC methodology for: identifying the root causes of defects, analyzing the data, determining capability and stability of process. It is concluded that the processes sigma level for the concrete works quality is 2.41 σ and 181,070 DPMO which is considered too bad as compared with the current global competition.

تقييم جودة أنتاج معمل الرشيد للخلاطات الخرسانية بأستخدام منهجية ستة سيغما

الخلاصة

ان غاية هذا البحث هو تقييم جودة أنتاج الخلاطة المركزية للخرسانة التابعة لشركة الرشيد بواسطة استخدام منهجية ستة سيغما والتي تمثل مقياس للجودة تكافح لتقيل وأزالة العيوب بواسطة توظيف الطرق الاحصائية لتحسين المخرجات التي يهتم بها الزبون (المخرجات الحاسمة للزبون) علما ان الهدف الاساسي من منهجية ستة سيغما هو تطبيق استيراتيجية اساسها القياس تهدف الى التحسين المستمر للعمليات وتقليل الانحرافات وبالتالي تحسين الجودة للوصول الى الرضاء الكلي للزبون من خلال تقديم ما يفوق توقعاته، ثم اقتراح نظام لتحسين جودة الأنتاج الخرساني في شركة الرشيد العامة للمقاولات الأنشائية.

تضمن المسح الميداني كلا" من الأستبيان المغلق والمفتوح والذي يهدف للوصول الى البيانات والمعلومات الضرورية التي تساهم في انجاز البحث حيث أدت اجوبة عينة الأستبيان، خلال تطبيق مراحل دورة التحسين (دمايك)، الى تمييز ابرز الاسباب المحتملة لتردي جودة الأعمال الخرسانية . كما تم استعمال برنامجين حاسوبيين: الاول Sigma Level Calculation والمعد من قبل الباحث لقياس مكونات فعالية أداء العمليات الانتاجية. الثاني QI Macros Lean Six Sigma SPC Software 2011 والذي يستخدم الادوات الاحصائية لدورة دمايك في منهجية ستة سيغما للأغراض التالية: تمييز الأسباب الجذرية للعيوب فضلا عن تحليل البيانات بالاضافة الى تحديد مقدرة وثبات العملية الانتاجية. حيث تبين ان مستوى سيغما لعمليات جودة الإنتاج للاعمال الخرسانية كان 2.41 سيغما و 181070 عيب لكل مليون فرصة والذي يعد قليل مقارنة" بمقاييس المنافسة العالمية الحالية.

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, from financial services, insurance industry to healthcare systems beside, its effective role in the construction and banks sector. Six Sigma means a business management process that provides tangible business results to the bottom line by continuous process improvement and variation reduction. As a data-driven, statistically-based approach, Six Sigma aims to deliver near-zero defects (as defined by the customers) for every product, process, and transaction within an organization. In other words, it is a practical approach to running a business with the involvement of each resource at all levels. It is a stronger emphasis on capturing 'the true voice of the customer' by clearly 'understanding the needs and demands of customers' for today and tomorrow (Hasan, 2011).

2. Research Objectives

The objectives of this research are represented in the following points:

1. Implementing Six Sigma DMAIC improvement cycle to evaluate and analyze quality of central concrete plant at Al-Nahrain University (the Case Study).
2. Preparing a program named 'Sigma Level Calculator' to calculate the sigma level, DPMO, and percentage of yield which help measuring the actual performance during the Measure Phase of DMAIC cycle.
3. Proposing a suggested improvement system to improve and control the production of concrete in Al-Rasheed Company.
4. Proposing an organizational structure of Quality Improvement Department for Al-Rasheed Company.

3. Six Sigma

In 1980s, Motorola's top leaders conceded that the quality of its products was awful. As a Result, the managers started to think of a new approach to improve quality (Chen et al., 2006).

In 1987, Robert Galvin, at that time CEO at Motorola, together with Bill Smith, Mikel Harry and Richard Schroeder created a new improvement program that was named Six Sigma. The program was inspired by Japanese work and strongly influenced by Juran's thoughts (Klefsjö et al., 2007).

Due to Six Sigma, Motorola managed to reduce their costs and variation in many process and won the Malcolm Baldrige National Quality Award in 1988 (Kessler & Padula, 2005).

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" (Pheng & Hui, 2004).

The principles of Six Sigma can be distilled into the following themes (Tehrani, 2010):

1. Genuine focus on the customer. While profits and statistical tools get the most publicity, the emphasis on customers is the most remarkable element of Six Sigma.
2. Data and fact-driven management or metrics (i.e., numbers) for decision making. It takes the concept of 'management by facts' instead of basing on assumptions in building up key measures to calculate the success of an organization.
3. Process focus, management, and improvement. Six Sigma positions process as the key vehicle of success, measure the success and improve the efficiency, effectiveness and customer satisfaction, etc.
4. Proactive management. It means focus on eliminating the root causes of defects before their occurrence instead of trying to manage them after it has occurred.
5. Boundless collaboration. It means working to break down barriers and improve teamwork.

6. Drive for perfection, tolerate failure. Although these ideas sound contradictory, they are actually complementary. i.e., despite striving for perfection, failure is allowable, to manage them properly.

4. Six Sigma Dmaic Methodology

Six Sigma is divided into two methodologies, DMAIC and DFSS/DMADV. DMAIC (which is an acronym for Define, Measure, Analyze, Improve, and Control) focuses on improving existing processes and performance (Ferrin et al., 2002).

4.1 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 (Chowdhury, 2001).

Besides, define the customers, their requirements, the team charter, and the key processes that affect the customers. Goals and/or objectives of a certain process are then set based on the customer's requirements (Pheng & Hui, 2004).

SIPOC perspective (which stands for Suppliers–Inputs–Processes–Outputs–Customers) can be used in the define phase to solicit the Voice of the Customer (VOC) and determine not only the wrongs of a particular product, or service but also to identify the important inputs which lead to the outputs through a series of processes (Klefsjö et al., 2007). SIPOC diagram is a conceptual model used to help define the boundaries and critical elements of a process without getting into so much detail (Pande & Holpp, 2002).

4.2 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) (Chowdhury, 2001).

Six Sigma offers the following formulas to calculate percentage of yield and number of defects per million opportunities (DPMO) (Tehrani, 2010). **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.

Yield= (correct items / opportunities) (1)

DPMO= (defects / opportunities) X 10^6 (2)

Table (1): Relationship among sigma level, defect rate and yield (Park, 2003)

Sigma Level	DPMO	Yield (%)
2σ	308 770	69.1230
3σ	66 811	93.3189
4σ	6 210	99.3790
5σ	233	99.9767
6σ	3.4	99.99966

4.3 Analyze 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 (Pheng & Hui, 2004).

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 (Tehrani, 2010).

4.4 Improve Phase

In this step, Six Sigma project aims to eliminate the identified defects through the knowledge derived from analyze phase. Motivating the team and effective coordination of the different processes and activities and their interface are required to improve the entire construction project (Tehrani, 2010).

4.5 Control Phase

In this step, after finding root causes, alternatives for improvement are considered and improvements made. Then, further data is collected to ensure that improvements have occurred and control plan is put in place to ensure the changes are permanent. In a nutshell, this step ensures that the process improvement is not lost over time (Schroeder, 2008).

The ideal members of Six Sigma team, from top manager to entire involved people are shown in details in (Pheng & Hui, 2004) and (Tehrani, 2010) sources.

5. Field Survey

For the purpose of achieving the goal of this research, it is necessary to work in the open and close questionnaire method as follows:

5.1 Open Questionnaire

This step is considered the following processes which are: literature survey, field visits and personal interviews to help designing the questionnaire form.

The literature survey of the research helped much in the preparation of the questionnaire form. In addition, information was obtained from surveying various literatures and researchers in the field of controlling the concrete quality.

Some sites, for manufacturing concrete, have been visited in order to know the basic stages of producing concrete on the site.

Interviews were also made with a selected number of well-experienced personnel in the field of construction to know the most common current problems related to quality failure during the processes of producing concrete.

5.2 Close Questionnaire

The formulations of the questionnaire form were directed to accomplish the objectives of the research and it was formed of four axes:

1. First Axis: named 'General Information' which covers the personal information such as: name of the firm they work for, academic degree, specialization, current position and years of experience.
2. Second Axis: named ‘Quality and Six Sigma’ contains an introduction illustrating the concept of Six Sigma (generally and statistically), besides questions covers the quality improvement systems, statistical tools and mathematical methods.
3. Third Axis: named ‘Concrete Mixtures’ that covers all factors affecting the quality of concrete mixture.
4. Fourth Axis: shows the most common causes of deviations in the quality of concrete mixtures as shown later in Pareto.

6. Application of Dmaic Improvement Cycle

The Six Sigma process improvement strategy ‘DMAIC cycle’ (which stands for Define, Measure, Analyze, Improve and Control) aims at bringing process improvement by eliminating defects. This research includes the application of DMAIC improvement cycle Six Sigma at Al-Rasheed Company Project at Al-Nahrain University Campus (the case study).

The sequential five steps of DMAIC are primarily based on the application of statistical process control, quality tools, and both process capability and stability analyses.

6.1 Define Phase

In this phase, defining the problems should be specific and complete as possible. Problems are often initially identified very qualitatively, without much detail.

This research focuses on the problem of ‘poor quality of concrete mixtures and the consequent deviation in the quality of building’ whereas the business owner expects a high strength of cubes that can easily pass the compressive strength test because any defect could lead to: customer’s dissatisfaction; extra labor and equipment to accelerate constructing; extra days and payment the penalty for delay.

6.2 Measure Phase

In this phase, after gathering data, the Six Sigma team has to decide what to measure and how do they measure it.

The defect is defined, according to the technical specifications of C30 mixture for foundations in the project of the case 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 products, only 199 have passed, which means there are 44 defects’.

After having both the number of correct items and defects, Sigma Level Calculator would be used to calculate the current performance level as shown in **Fig. 1** while **Table 2** illustrates all the outputs and calculations of sigma process level performance.

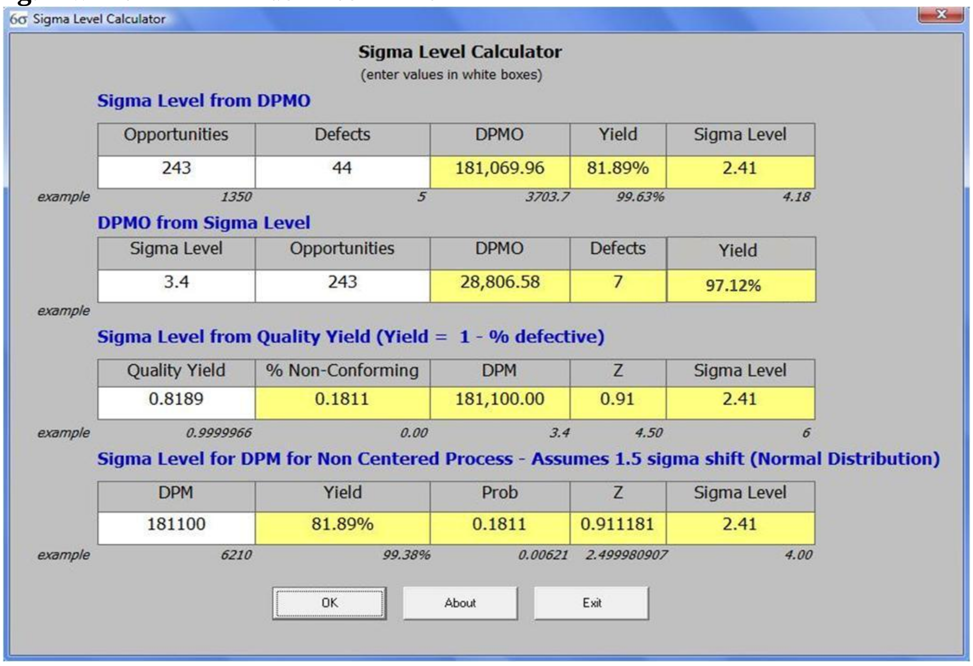

Figure (1) 'Sigma Level Calculator' Program

Table (2): Sigma Level Calculations

Evaluate and Improve Quality of Concrete (central mix plant process yield)			
Current (outputs)		Target	
Yield	Sigma level	Yield	Sigma level
81.89 %	2.41	97.12 %	3.4
DPMO		DPMO	
181,069.96		28,806.58	

6.3 Analyze Phase

In this phase, not only studying and analyzing the data statistically, but also identifying key process variables that cause failures and understanding root cause's behavior of why failures occurs as follows:

6.3.1 SIPOC Diagram

SIPOC diagram is kind of a high level process flow from Suppliers and their Inputs through the Process to the Outputs and Customers both internal and external. It is a graphic representation of how work flows through the company and show the sequence of processes.

SIPOC diagram forms the basis for understanding what actually happens in a process; so, issues can be identified and process can be improved. This is possible only if the preparation of SIPOC is managed correctly where it is noticed that the most common problems faced SIPOC's user is either putting in too much or too little details. **Table 3** shows the P part of SIPOC dia. which illustrates the sequence of processes during the stages of producing concrete on the site.

Table (3): P part of SIPOC Diagram

S I	P	O C
	Process	
	Start:	
	Mix design then issued the check request	
	High-Level Process Description:	
	First, batching the materials; Next, mixing; Then, handling & transporting; Also, taking samples for testing; After that, casting; Following, compacting; Finally, finishing.	
	End:	
	Curing and removing forms	

6.3.2 Scatter Diagram

Scatter diagram is one of the most useful tools used to determine the correlation (relationship) between two variables. Correlations may be positive (rising), negative (falling), or null (uncorrelated) (Stevenson, 2005).

The values of compressive strength for concrete samples verses the date of casting are plotted on the vertical and horizontal axes respectively to show the kind of relationship between variables in a scatter diagram which is drawn by using the QI Macros as shown in **Fig. 2**.

According to the scatter diagram, the pattern of dots slopes from upper left to lower right and seem scattering rather than centering. Therefore, the relationship is a 'weak negative correlation'. The diagram also shows that the strength values are deceasing with the passage of time where it is noticed that in the beginning, most results are high while in the end of the year they go down; i.e. the quality control of concrete production has been decreased with the passage of time.

6.3.3 Histogram

Histogram is a graphical representation, showing a visual impression of the distribution of data. It consists of tabular frequencies that represent a frequency distribution and rectangles whose areas are proportional to the corresponding frequencies (Schroeder, 2008)

Histograms are used in Six Sigma to establish variability or deviation from the center line of the target value in a bell shape; also, they are a way of doing a 'capability' studies. **Fig. 3** shows 'histogram with Cp and Cpk' which 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 $Cp \geq 1$ means the process fits between the upper and lower specification limits; whereas $Cpk \geq 1$ means the process is centered between these limits. Also, there are many other calculations shown in histogram (Hasan, 2011).

According to the values presented, the process is not capable (based on Cp and Cpk) and the histogram is moderately skewed to the left while many point are located outside the lower specification limit (LSL).

6.3.4 Control Chart

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 (Nyrén, 2007).

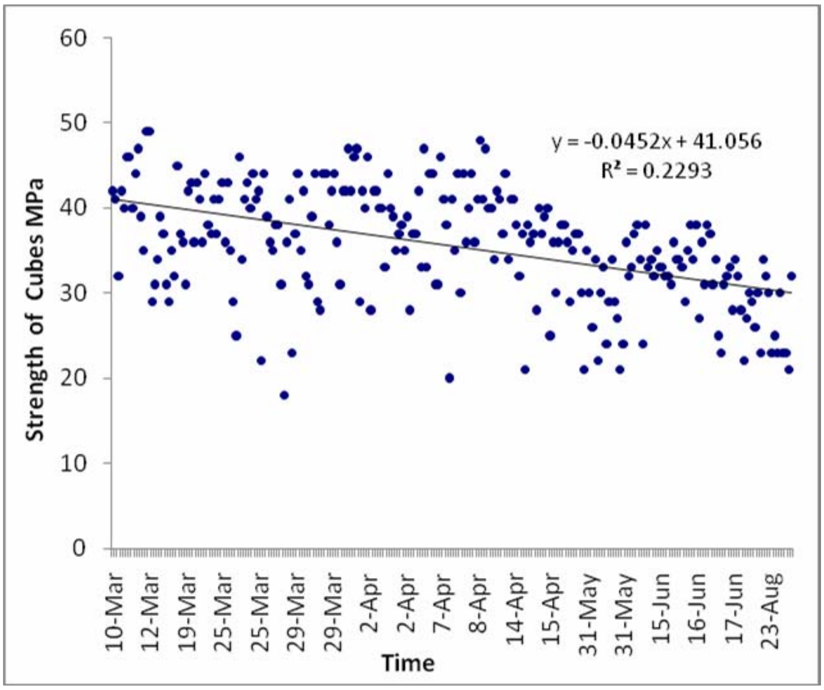

Figure (2) Scatter Diagram

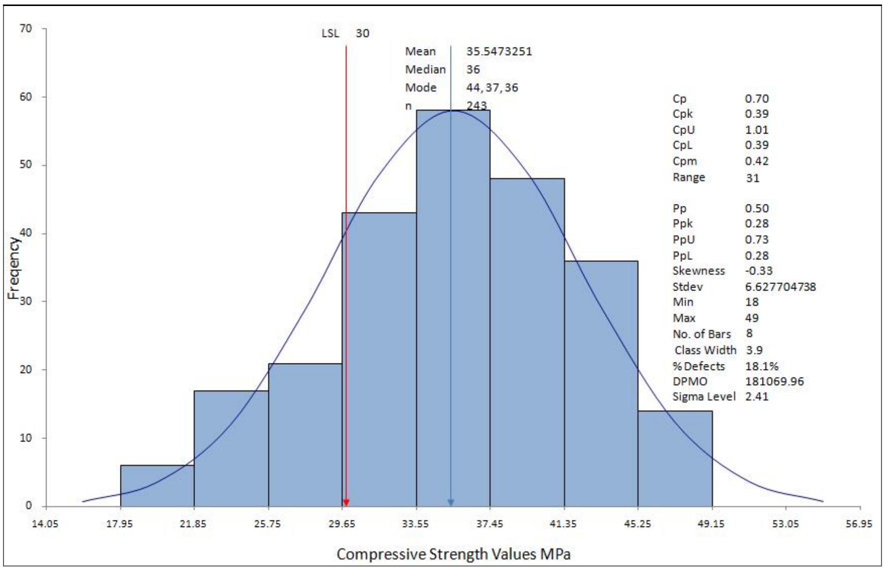

Figure (3) Histogram

There are so many different control charts that estimate μ and σ 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). In attributed charts, the c and np charts use small samples and fixed populations; the u and p charts use varying populations (Arthur, 2004).

Accordingly, the right control chart for the data of this study is the XbarR charts which can effectively help evaluating the stability of processes. In other words, it helps evaluating if the trend of process is predictable or not.

Fig. 4 and **Fig. 5** show X bar - control chart and R - control chart respectively of the values of compressive strength testing. The 'QI Macros' has been used in drawing these charts. From these two figures, the values seem scattered and out of statistical control. Therefore the process is 'not stable' (unpredictable).

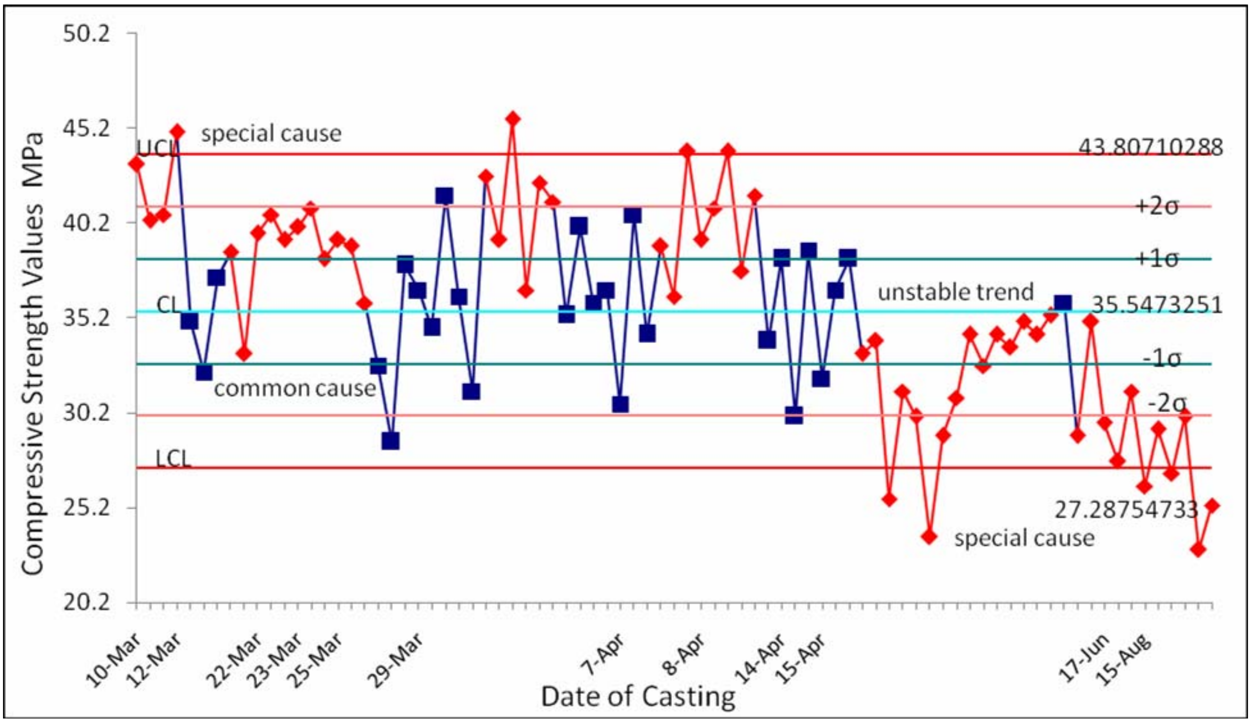

Figure (4) X bar - Control Chart for the Compressive Strength Testing

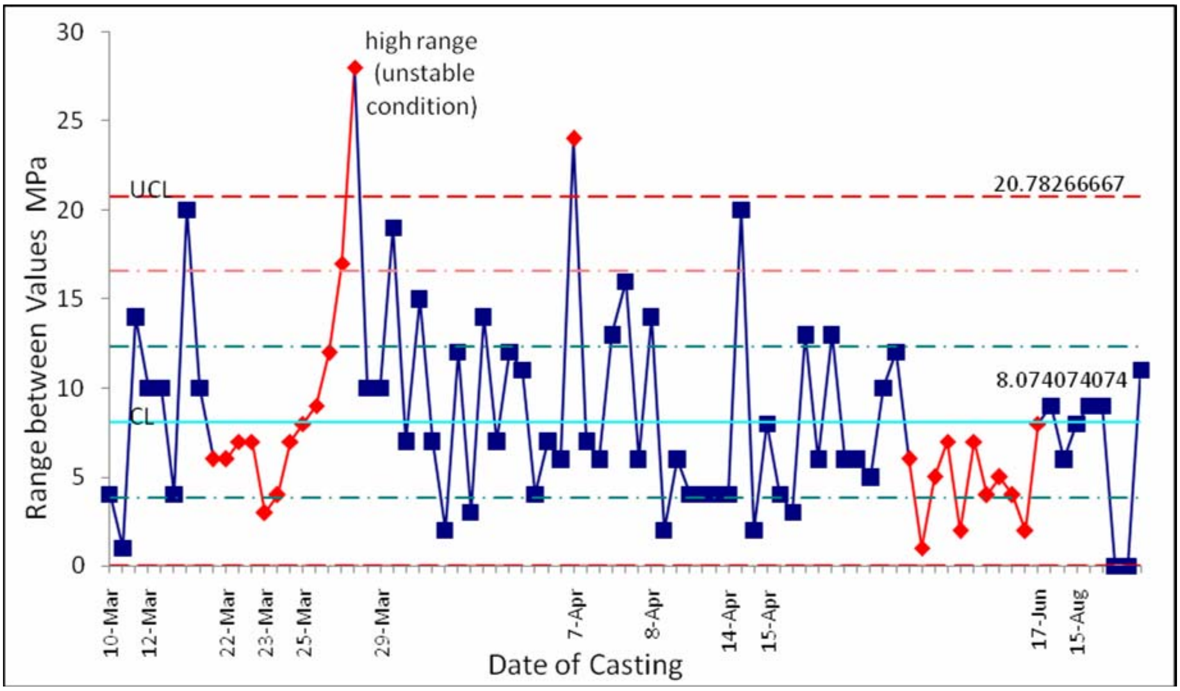

Figure (5) R - Control Chart for the Compressive Strength Testing

Additionally, it can be noticed that the values start to drop down with the passage of time especially since 31st May. Therefore, the control chart, as shown in **Fig. 6**, 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 is concluded that the main reason for this deviation may return to the 'high temperatures' in that period of year.

Histograms are a way of determining capability (does the process meet customer specification?), while control charts are a way of measuring stability (is the output of process predictable and consistent?). Specification limits

are set by customers and used in histograms whereas the upper and lower control chart limits (UCL and LCL) are calculated based on the data. The process of this study is neither capable nor stable which means improvement must be accomplished.

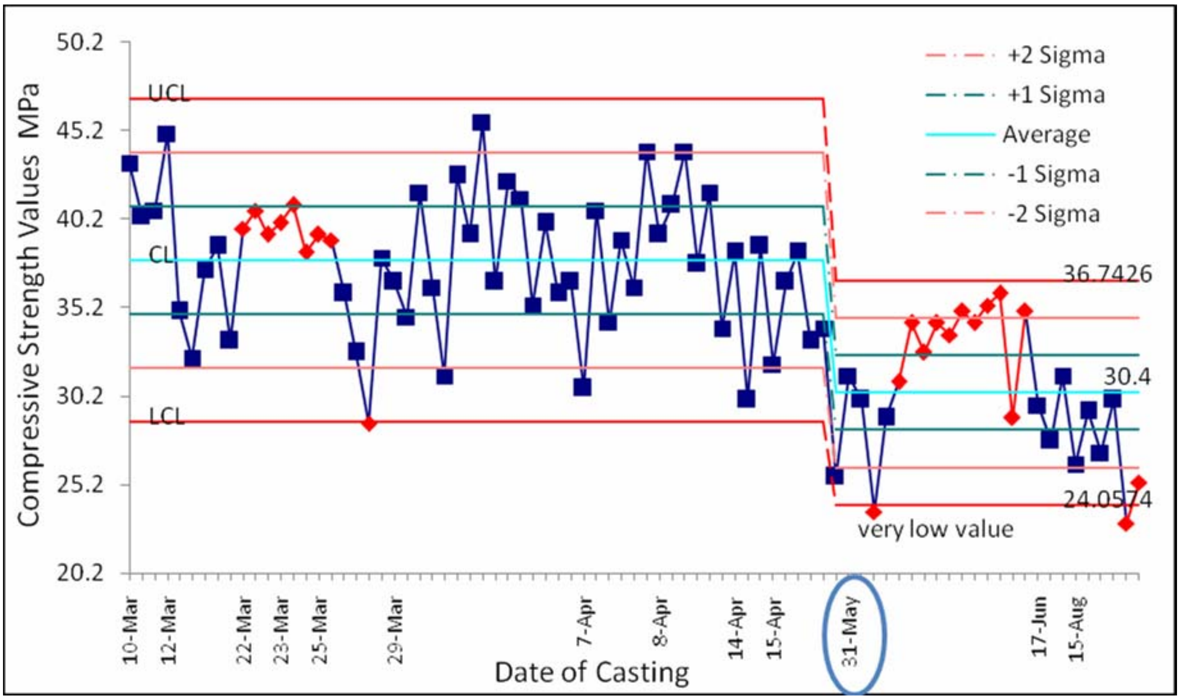

Figure (6) Process Change of the X bar - Control Chart for Compressive Strength Testing

6.3.5 Pareto 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 (e.g., complaints, defects, and problems). The idea is to classify the cases according to degree of importance, and focus on resolving the most important, leaving the less important (Stevenson, 2005).

The bars are placed from left to right in descending order to illustrate the most common causes of deviation in the quality of concrete mixtures according to the responses of respondents for the close questionnaire as shown in **Fig. 7** which is drawn by using QI Macros software.

6.4 Improve and Control Phases

The main task in these two phases is the elimination of the 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 lists and interviews. The team members should generate ideas for improving processes; then, evaluate these ideas to select the best potential solutions to implement them. These phases have been replaced by proposing an improvement system as shown later in this research.

7. Proposed Organizational Structure

An organizational structure of Quality Improvement Department has suggested to be adopted in Al-Rasheed Company instead of the small Quality Division that established since 2008. The Proposed Quality Improvement Department has a pivotal role as a second major party after the top-management in implementing the suggested improvement system. The organizational structure of Quality Improvement Department has included five divisions, as illustrated in **Fig. 8**, which are:

1. Six Sigma Division: which aims to promote Six Sigma principles and practices the five phases of DMAIC and offer opportunities for employees to increase

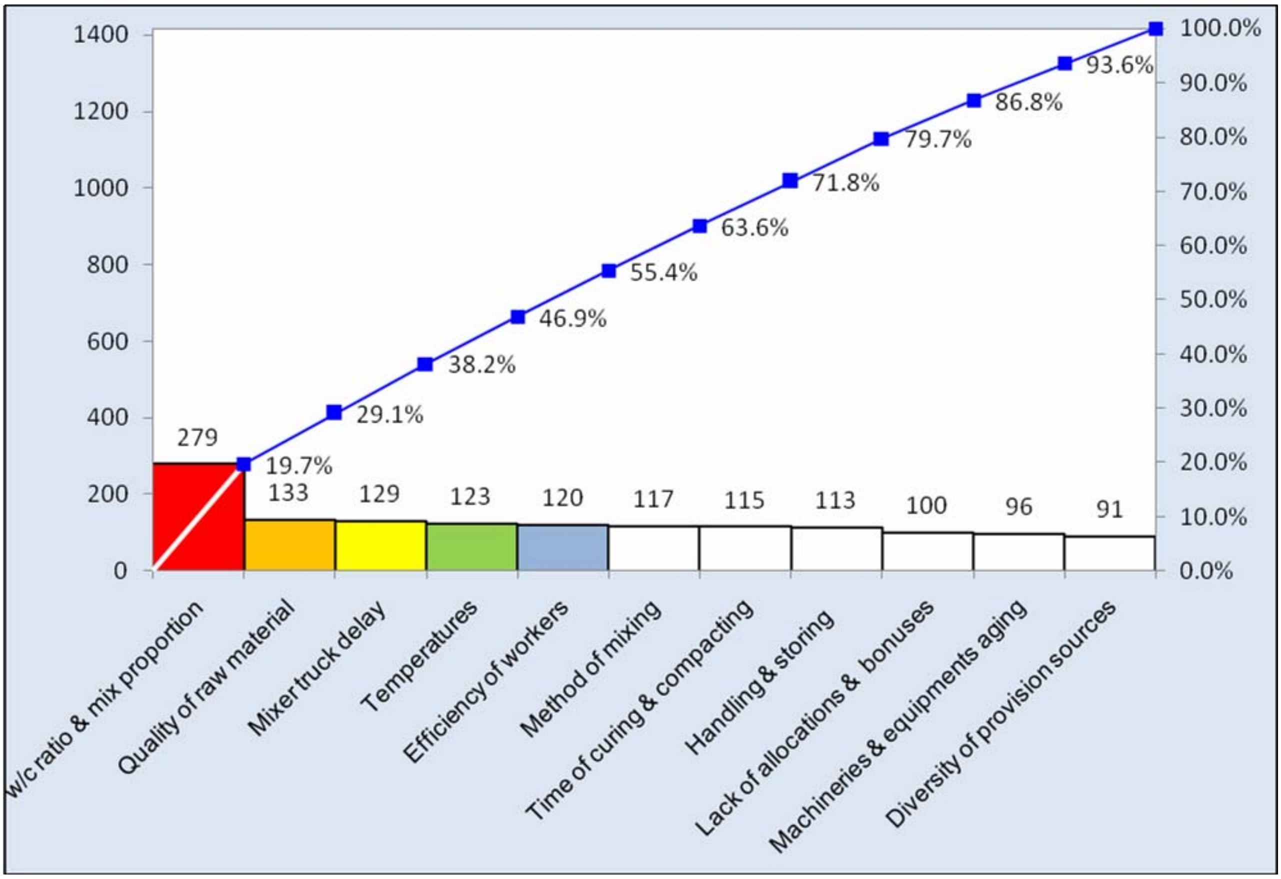

Figure (7) Pareto Diagram for Analyzing the Problems

Their knowledge of Six Sigma. As well as, supports training programs by providing plans and ensures that everybody on the company 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. The members of this division must prepare training schemes which can be divided into three categories. First is 'Six Sigma course' to all personnel which gives an orientation to the Six Sigma philosophy. Second is 'statistical course' to specific engineers who concerned in the application of the statistical tools. Third is 'manpower course' to all workers to develop their skills through the process of the concrete.
3. Documentation Division: this division deals with documenting everything (such as the progress of work, result of testing, quality reports, etc.) manually and electronically.
4. Design Division: this must be included numbers of well-experienced engineers to doing missions like: revising and verifying the design; cooperation to design specification limits; detecting deviation; and providing advice and guidance.

5. Examination and Inspection Division: this consists of engineers and technicians to perform: supervision of testing for each of raw materials, equipments and devices; and works skills as well as taking specimens and issuing reports.

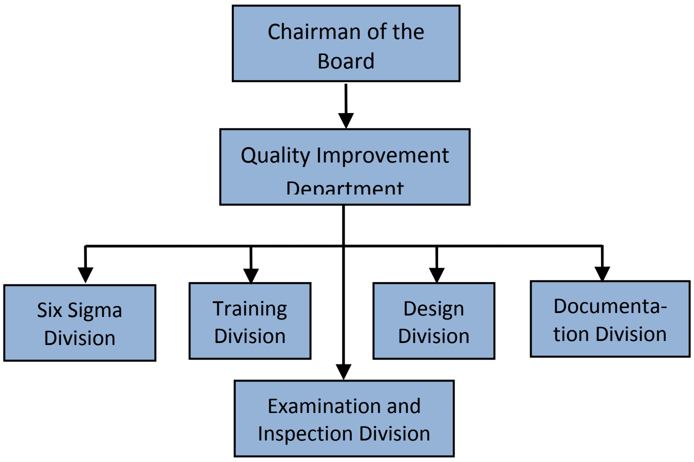

Figure (8) Proposed Organizational Structure of Quality Improvement Department to Al-Rasheed Company

8. Suggested Improvement System

In accordance to the results of the analyze phase, a formulated model has created to be adopted in Al-Rasheed Company in order to improve and control the quality of concrete production. The basic elements of the 'suggested improvement system' are summarized in the following items:

1. Input Control.
2. Processes Control.
3. Output Control by FISH Cycle.

8.1 Input Control

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

8.1.1 Raw Materials Control

The most prominent procedures that must be included in this stage are:

1. According to 'Contract Condition for Civil Engineering Works' (clause 37). It is suggested to send a team of experienced engineers to the headquarters of manufacturing, prior to complete the purchase of 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 the processes of transporting and storing 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.

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.

Purchasing the materials of high quality can help companies avoiding causes of deviation in the quality of concrete mixture as shown in the second bar of Pareto chart, **Fig. 7**.

8.1.2 Devices and Equipments 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.

5. Reducing the number of spare parts, unless they are necessary, to avoid freezing of capital.

The following parties are suggested to be responsible for adjusting the work of equipments:

1. Maintenance Unit and its workshops.
2. Stores Division.
3. Purchasing Department.
4. Financial Affairs Department.
5. Quality Improvement Department.

8.1.3 Personnel Control

The human resource is the master key to accomplish the quality requirements; therefore, it has become necessary to establish the concept that 'quality is everyone's responsibility'.

The field survey have reflected that most of the workers in construction projects are temporary labor 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. These procedures are:

1. Establishing a new system for hiring personnel permanently instead of depending on the temporary labors.

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.

These responsibilities should be managed by:

1. Training Division.
2. Six Sigma Divisions.
3. Human Resources Department.
4. Quality Improvement Department.

8.2 Processes Control

Organizations must remember that processes control and producing high-quality products may ensure customer satisfaction. This stage should control:

8.2.1 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 and Quality Improvement Department to assure quality of materials 'before' buying and shipping them to the site.

2. Station of testing and inspecting 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 reprehensive from each of Quality Improvement Department and Resident Eng. Office in order to verify and monitor the progress of concrete production in accordance to plans.

4. Suggested station for testing the fresh concrete in the field as recommended by 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 testing the hardened concrete by taking cubes of concrete for the compressive strength testing.

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.

8.2.2 Devices and Equipments

All devices and equipments used for examination 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, providing appropriate environmental conditions for storage, and documenting all the information in the achieve.

8.2.3 Documentation

Document everything by adopting an electronic documentation system depending on computer and manual documentation by hand; which include all kinds of reports such as: purchase orders, quality reports (daily, weekly, and annually), supplier evaluation reports; results of testing, and progress reports.

The responsibilities of 'processes control' stages must be executed and handled by:

1. Examination and Inspection Division.
2. Documentation Division.
3. Stores Division.
4. Quality Improvement Department.

8.3 Output Control (FISH Cycle)

This stage is adopted the sequential 'FISH processes cycle', which stands for Focus, Improve, Sustain and Honor; to strengthen the suggested improvement system as described in the following steps:

8.3.1 Focus on both Reports and Product Delivery

This first step aims at: First, narrowing the focus on performance control reports that issued by Quality Improvement Department to provide top-management with fairly broad range of outputs. Mainly, performance control reports aid managers by measuring deviations from standard plans and evaluating the actual performance according to the results of testing concrete mixtures and raw materials which should be subjected to audits and analysis by members of Quality Improvement Department to prepare recommendations for the corrective actions. Second, focusing on service by making plans to the way the product should be delivered to the customers.

8.3.2 Improve Performance

This second step seeks to make corrective actions that suggested by members of Quality Improvement Department 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. Therefore, the following two methods are recommended to generate ideas:

1. Quality Circles: by creating a work group usually consists of (5-10 persons): one person from Six Sigma Division as a chairman of circle (president), one person of each Design, Examination and Inspection, and Documentation divisions besides foreman and worker; who met periodically (an hour a week) to discuss quality issues, the progress of improvement measures, corrective actions and find appropriate solutions. They often use statistical tools.

2. 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 the 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.

8.3.3 Sustain 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.

8.3.4 Honor 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.

Fig. 9 pictures the practical side of this research in a flow chart.

9. Conclusions and Recommendations

Conclusions are presented next as a result of field study and DMAIC cycle. According to these conclusions, the research recommendations have been discussed to improve the quality of concrete production by implementing Six Sigma DMAIC methodology.

9.1 Conclusions

1. The current process performance for the quality of concrete works in the case 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.

2. Al-Rasheed Company has not had clear policy working toward improving quality of concrete production; and suffers from lack of interest in the quality, because it believes that controlling quality costs too much.

3. The absence of specialized departments for managing quality with a task of auditing processes, starting from the early stages of production to the end. Al-Rasheed Company even has not established 'Quality Department' in its organizational structure.

4. Decision-making in Al-Rasheed Company depends on experience and position instead of facts on the ground, despite facts are considered the primary tributary of decision-making in modern systems.

5. Al-Rasheed Company is not performing the testing of fresh concrete besides, limited

6. of examination and testing of the received raw materials from provision sources.

7. Six Sigma organization structure can be adopted with some modification to be in various divisions and departments in company, like replacing the ideal teamwork of Six Sigma (master black belts, black belts, green belts, etc.) by members of either quality circle or proposed Quality Improvement Department.

9.2 Recommendations

1. Any organization that wants to improve their quality of concrete mixture can use DMAIC cycle and the suggested improvement system; then, start by giving personnel a brief introduction on modern management techniques of quality control because they are the base of Six Sigma.

2. Adopting the predictive and preventive maintenance instead of the remedial maintenance can reduce occurrence of defects and breakdowns.

3. Creating Quality Circles to provide corrective and preventive actions taking into consideration information that comes from employee suggestion box.

4. Al-Rasheed Company should start building up an electronic documentation system by using computers to document reports and testing results etc.

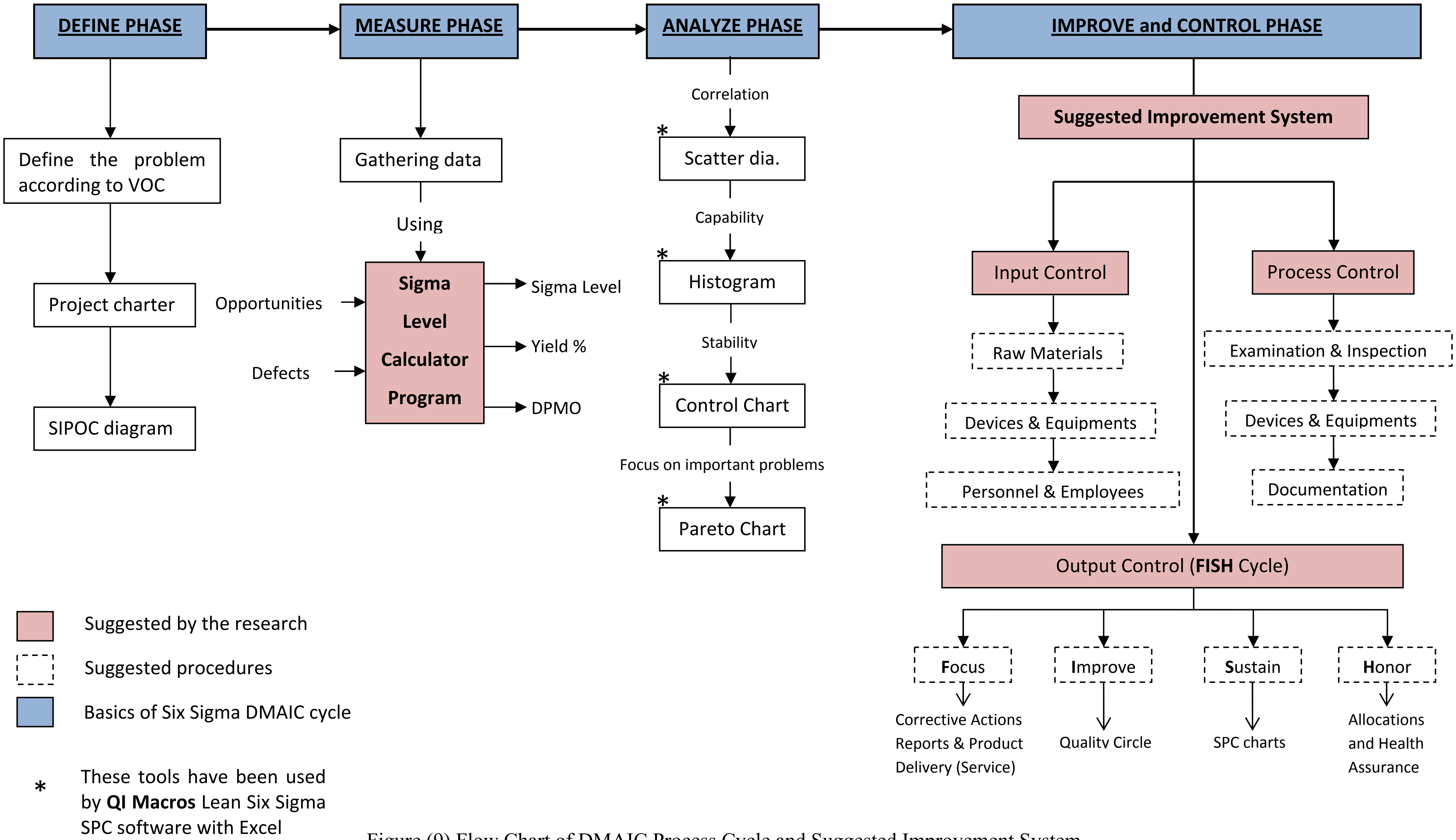

Figure (9) Flow Chart of DMAIC Process Cycle and Suggested Improvement System

10. References

Arthur, Jay, (2004), "Six Sigma Simplified", Third Edition, LifeStar Publishing, USA.

Chen, K. S.; Hsu, C. H.; and Ouyang, L. Y., (2006)," Applied Product Capability Analysis Chart in Measure Step of Six Sigma", Quality and Quantity, Vol. 41, No. 3, pp. 387-400, Springer.

Chowdhury, Subir, (2001), "The Power of Six Sigma", First Edition, Dearborn Trade Publishing, USA.

Contract Conditions, (2005), "The First and Second Parts of Contract Conditions for Civil Engineering Works", Legal Office, Ministry of Planning, Baghdad, Iraq.

Ferrin, D.; Miller, D.; and Muthler, M., (2002), "Six Sigma and Simulation, so What is the Correlation", Proceedings of the 2002 Winter Simulation Conference.

Hasan, Ali, Amer, M., (2011), "Quality Evaluation of Construction Factories by Using Six Sigma Approach", MSc Thesis Submitted to the Civil Department, College of Engineering, University of Baghdad.

Kessler, Rafael, Motta; and Padula, Antonio, Domingos, (2005), "The Implementation of Six Sigma in Manufacturing Organizations: Motivations and Results Achieved", Brazilian Journal for Business and Management, Vol. 4, No. 2, pp. 11-20, FUMEC University, Brazil.

Klefsjö, B.; Bergquist, B.; and Edgeman, R.L., (2007), "Six Sigma and Total Quality Management: Different Day, Same Soup", International Journal of Six Sigma and Competitive Advantage, Vol. 2, No. 2, pp. 162-178, Copyright: Inderscience Enterprises Ltd.

Nyrén, Gustav, (2007), "Product Development According to Six Sigma and the DMAIC Improvement Cycle", MSc Thesis Submitted to the Department of Business Administration and Social Sciences, Industrial Business Administration, Leleå University of Technology.

Pande, Pete; and Holpp, Larry, (2002), "What is Six Sigma", McGraw-Hill company, Inc., USA.

Park, Sung, H., (2003), "Six Sigma for Quality and Productivity Promotion", Asian Productivity Organization APO, Tokyo, Japan.

Pheng, Low, Sui; and Hui, Mok, Sze, (2004), "Implementing and Applying Six Sigma in Construction", Journal of Construction Engineering and Management, Vol. 130. No. 4, pp. 482-489, ASCE.

Schroeder, Roger, (2008), "Operation Management: Contemporary Concepts and Cases", Third Edition, McGraw-Hill company, Inc.

Stevenson, William J., (2005), "Operation Management", Eighth Edition, McGraw-Hill Irwin companies Inc., NY, USA.

Tehrani, Maryam, Dabbaghi, (2010), "Performance Improvement in Construction Project based on Six Sigma Principles", MSc Thesis Submitted to the Department of Quality and Environmental Management, Industrial Engineering, University of Borås, Sweden.