



# Quality Improvement by using Quality Control Indicators in High Rise Building

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**Abstract:** Three important parameters such as time, cost and quality are essentially necessary for successful completion of construction projects. Quality is the real parameter that is responsible for safety and overall health of construction projects. Maximum defect occurs during execution phase only due to non-compliance of desired specifications. It is observed that, on many sites, executors are not aware about quality control checklist and its significance. This is the reason why defects occur in even newly constructed structures. To overcome this, Android application, have been developed for Quality Control Indicator by using the Six-sigma process. The Six Sigma processes that are generally used in manufacturing plants, however its implementation has started in the construction industry. In the Android application, quality control checklist prepared by a construction company had taken for reference. Project authorities can apply quality control checklist on the activities and can give their remarks about the performance of particular construction activity such as Satisfactory (S), Unsatisfactory (US) and Not Available (NA). If any defect occurs in the activity and if it is not mitigated by site engineer or supervisor then the higher authority may take appropriate corrective action. By using this, Quality Control Indicator Application time required for lengthy conventional quality control process can be considerably reduced. Through this application, six sigma levels for particular performance are obtained immediately as well as cause s and effects of particular defect is also recorded in the application. Hence, this study covers the entire process of quality control indicators and android application for obtaining six sigma levels of various activities of the project. This study focusses on use to quality control indicator for various construction activities. QC Indicators indicates the quality status of the activity for facilitating the application of remedial measures in order to improve quality.

**Keywords:** Quality control indicators; six sigma; checklist; corrective action

## I. Introduction

In the construction industry, quality is as important as time and cost. Quality creates the difference in the product of the same item. Quality in construction is defined as „meeting or exceeding the requirement of client/owners. In the construction industry, quality is used in different every than the product industry. Quality in construction employed with conformity with which specifications are met. The consultant or Architect Designer gives the desire grade of concrete the contractor has to use desire grade of ingredient to achieve the desire grade of concrete. There are many popular theories about quality such as Total Quality Management (TQM), just in time, lean production and Six Sigma etc. have been used as a principle of efficiency to produce dramatically improved results in the manufacturing sector. (Hernandez and Aspinwill 2007) Many construction companies due to lack in quality, they are losing their reputation. In absence of desired quality, cost of construction reduces and thereby repair cost increases in future. Now a day we are using modern technology in our day-to-day life. Use of android is common for purpose of communication. The android application easily used by a human being. It also saves time and thereby cost considerably. In this study, the checklist is prepared by using six sigma levels. By doing so defects also can be measure and remove it accordingly.

## II. BRIEF REVIEW OF THE LITERATURE

In construction industry several troublesome challenges take place such as productivity down, litigation is up, delays and common expenses due to lacking in quality. A quality performance tracking system (QPTS) has been developed to provide the quantitative analysis of certain related aspects of projects. It systematically collects and classifies costs of quality. It consists correcting deviation. There are two types of quality cost that is a) the Quality of conformance cost b) Quality of non conformance cost of in the construction industry. It Provides quality assurance and quality control required an expenditure that has been reported to in the range of 1-5% of total project costs (Hays 1983) and construction direct cost incurred for rework alone (Deviation) to be greater than 1%. QPTS have three premises, conformance to the requirement, (not as a degree of goodness and excellence), the requirement for the design and construction are clearly stated and adequate work break has done structure cost and schedule system as in the plan.



QPTS is developing to handle the major issues in deviation, which are described in this study. Nine important question should be answered which are connected with deviation which task is defined, what factor affected, when it will be detected, what are the causes, Is QM involved, what type of cost of quality, what will be response, what class and how much does it cost. The QPTS plan will define the quality of conformance which is required and it will maintain related cost. Quality cost is a combination of management effort and correcting deviation. WBS cost coding system can be adapted for breaking down of deviation. (Davis and James 1989). This study discusses that Six-sigma, underline the explicit recognition of the root causes of defect and statistical process control to sustain continuous improvement. It also suggests six sigma principle application and research opportunities reduce the variability in lean construction (Celep et.al. 2012). The future research is needed to investigate the implementation of six sigma methods in lean construction. Six Sigma is a great tool for problems that are “hard to find but easy to fix”. Lean tools are great for “easy to find but hard to fix problems”, (Abdulhamid, 2003). The survey conducted in the Mexico City and UK construction industry in which they collected the various quality indicator in the group. Which are in form of gathering customer needs and the organizing customer needs. Formal method, planning tools, quality control, measure the performance and technology. This survey concluded that the technology, quality control, and performance measurement is most common tools group used in the construction industry. (Harnandez et al., 2007). The six-sigma principle is an effective statics - based methodology to measure the defect rate in order to maintain a high standard quality level, particularly in construction material. Six-sigma principle, not only use in construction operation but also construction material such as barometer to measure, evaluate and improve construction performance etc. In this study, performance indicator is six sigma. The project manager can use it to establish an explicit goal as well as to evaluate the level of project performance nearly perfect. (Abdelhamid, 2003). The six-sigma principle as one of the concept to increase productivity in the construction industry, which is focused on reducing cycle time and eliminating any defects occur in the processes. In this study, six sigma principle concepts can be applied to the construction process control within the basic framework of CTQ (Critical to Quality) inputs, DMAIC (Define-Measure-Analysis -Improve-Control) procedures and output measure. In this study the case study is done that shows process reliability in terms of variation in cycle time in enhanced as the sigma level of the CTQ improved. This implied that the defect rate in minimized to attain a reliable workflow and performance improvement. (Han et.al 2008) The study shows that the comparative analyses of the existing methods for performance improvement and identified the benefits of the six-sigma principle to overcome on traditional technique. The six-sigma principle provided more benefits by obtaining the optimized solution sets from performance indices. Future research concentrates on developing detailed guidelines on critical total quality control of target factors based on the diverse character of many different companies because the customization of the six-sigma principle strategy facilities construction firms to achieve their own process evaluation paradigm. (Han et.al., 2008) In this study concluded that defect from builder and residential developments are classify to their location, subcontract, and element. The research reveals that the most common defects identified by customers at handover were incomplete tile grouting and incorrect fixtures and fittings in toilets. In areas such as fixtures, fittings, and finishes were of a similar nature, the kitchen and bathroom, defect always occur. Determining the location, subcontract, an element where defects arise in residential buildings can provide very useful knowledge about areas where builders are likely to make errors or to take shortcuts during construction. (Nuria et al., 2013) The case study of Taiwan in s seismically active zone because it is located in the earthquake pacific ring. The crack in lightweight partition walls caused by frequent earthquake decrease customer satisfaction and increase the repair cost in the company. Six-sigma team can determine and improve the key input variables affecting the cracks in lightweight partition walls. In that analysis, he used C&E (Cause and effect) matrix highly correlated input variables, Failure modes and effects analysis (FMEA) to identify causes of the cracks. The result showed that a 1 cm preset spacing between the board and the main structure substantially reduces cracks caused by the earthquake by using the control plans. (Lee and Yang 2013). The analysis revealed that the majority of defects during execution are located in „general areas“ (roof, façades, foundations, structures, and installations) which cannot be attributed to a specific flat because they are concerned with the whole functioning of the building. The analysis of sixty - eight residential developments the most common defects identified during execution was „inappropriate installation“, surface/appearance“ and „affected functionality“. Inappropriate installation“ includes materials, elements or items not well positioned, mainly in foundations and structures this defects during construction (24.29%) and at handover (16.00%) were relatively similar. Typical „surface/appearance“ defects detected during construction include honeycombs in concrete elements mainly caused by poor workmanship. These defects during construction (15.95%) are similar to those detected during post-handover (19.95%). „Affected functionality“ defects were mainly related to M&E and P&S systems and to pillars and stairs. The maximum of defects observed during the execution stage is related to the functionality and installation caused by poor workmanship, not to the materials or products used (Nuria et.al.2014). Six Sigma is quality improvement technique is implemented in manufacture industry very successfully it is new construction industry. In this case study of a residential building in which six sigma methodologies have been adopted to improve the quality and checked against the sigma level. Finding suggests that some changes in current work procedure will improve the quality and ultimately customer satisfaction, which is of prime importance. (Sneha and Smita, 2014) Defects are the nonconformity of the object. There are many types of defect in the construction industry such as design defect, construction defect structural defect, etc. Construction defects are very common and frequently arising in the construction project, which are poor workmanship, poor project



management in the site construction. Defect impact on the cost, quality. Time overruns. To minimize defect in future work numerous analytical or statistical method are available analyzing impact selection the proper method depends upon various data available. The various consequences of defect dissatisfied customer, an extra cost born by a company, delay in completion and reduced productivity. 32% of all defect costs originated from client and design, 45% from site management and approximately 20% from material and machine. Most of the defect due human factors were caused by “forgetfulness and carelessness” (Josephson and Hammarlund 1999). The reason for defects is very common in everywhere i.e. Workmanship, quality of material, lack of supervision wrong construction method, lack of inspection after construction etc. (Bagdiya and Shrutti 2015).

#### A. STATEMENT OF THE PROBLEM

From literature survey following Problem are observed and discussed,

1. Until date, no easy, quick and efficient tool is used to improve quality of individual activity during execution.
2. Construction activities not being measured separately using six-sigma level.
3. Normally the site engineer forgets to take action during the activity execution. To remember the important things of activity or to confirm the quality of the activity checklist is prepare.

Based on the literature survey, the following statement of the problem formulated:

In the construction industry, until the date, performance measurement and quality control techniques have been used. Maximum defects used to occur during execution only, to avoid such defects; implementation of a checklist on each activity is a must. Hence, an objective of this study is to use the checklist for carrying out each activity and that is by using android app, named as Quality control indicator (QCI).

### III. AIM AND OBJECTIVES

The steps followed in this study are as follows,

- 1) Selecting most suitable site of high-rise building.
- 2) Note down the activities, which are in the progress.
- 3) Prepare and Apply checklist on activities and note down the six-sigma level of each activity.
- 4) Find the causes and effect occur of the activity of the structure.

It will help,

1. To improve the quality of specific activity.
2. To identify the vital checks required for quality.
3. To find the causes and effect of the defect in the construction industry in each activity.
4. To find the six-sigma rating in the construction activity.
5. To find the corrective action of any defect of the activity those, which are unsatisfactory.
7. Development of Android Application in order to save time and to make friendlier user in construction

### IV. GAPS AND FINDING

In view of the aforementioned problem as specified from the literature review, following gaps and finding is outlined for the present investigation.

1. Initialize using technology to control the quality of the project in the construction industry.
2. Determine the quality of the project in the six-sigma level indicator.
3. Find the cause and effect of the activity in the construction industry.
4. Keep the record of the construction activity in the construction industry.
5. Take the preventive action after the unsatisfactory point happens in the recording manner.
6. Remove the study used in the construction industry it will be the environment-friendly.

### V. EXPERIMENTAL PROGRAMME

A. The flow of the experimental Programme is as mention below.

1. Selection of construction site (High Rise Building)
2. Collection of Activities checklist
3. Preparation of Activities Master Checklist
4. Apply six-sigma process on Each Activities
5. Preparation of Android Application
6. Application apply on site

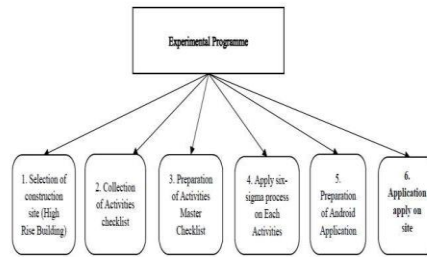


Fig 1. Experimental Programme

7. Selection of construction site (High Rise Building)

8. Collection of Activities checklist

9. Preparation of Activities Master Checklist

10. Apply six-sigma process on Each Activities

11. Preparation of Android Application

12. Application apply on site

B. Detailed Methodology of the Experimental Programme:

1. Selection of construction Site

The proposed model and hypotheses were tested by using data collected from well-known construction firms. Then survey-covered companies chosen from construction sector from that every site selected high Rise Building.

2. Collection of checklist

The Collection of the checklist from well-known construction firms. Selected activities are Excavation, Reinforcement, Formwork, Concreting, Block/brick masonry, Flooring, Plastering, PCC, plum, concreting, slab and beam reinforcement, false ceiling work, terrace waterproofing, firehouse cabinet, tiling, piling foundation, painting etc. Which is based on major cost contribution, quantity, aesthetics and safety.

3. Preparation of master checklist

The formation of Master Checklist based on all points are importance and critical activity which most essential during construction period its effect on overall quality of the project and gives expertise direction. Prepare the model of a checklist of each activity and remove a defect in construction activity using the six-sigma DMAIC process.

Identify the various defects occur in the construction activity and suggest the how to remove unsatisfactory from the present in the activity by using the checklist of Activity.

4. Applying six sigma Process on Each Activity

Each activity of high-rise Building Checklist Prepared and Activities applied DMAIC process to estimate and remove the quality defect in that activity. The following DMAIC process for each Activity.

a) Define SIPOC (supplier input process output customers): - Any activity has pointed to understand the process to the improvement of the activity. SIPOC helps us to agree on the boundaries of what we will be working. All the activity has the points in which is distributed in the as per nature of existence we read point and gives the three types of the rating

1) satisfactory 2) Unsatisfactory 3) Not Available points in the project

b) Measure: - After that given, the comment on the points it

will automatically calculate six-sigma level on that basis of the comment by using the sigma level on the DPMO.

$DPMO = \frac{\text{No. of „X“ in data collection sheet}}{\text{No. of Opportunities of defects} \times \text{No. Of Units}} \times 1,000,000$

TABLE 1: OVERVIEW OF SIGMA LEVELS &amp; DPMO

Yield	DPMO	Sigma level
30.9	6,90,000	1
69.2	3,08,000	2
93.3	66,800	3
99.4	6,210	4
99.98	320	5
99.9997	3.4	6

c) Analyze - By using, the cause and effect diagram helps us to see in a graphical manner the outcome and various factors that influence that outcome. The influence factors are mitigated by the taking the corrective action on the activity.

This diagram is sometimes called a “Fishbone Diagram” because of the way it looks.



d) Improve (Corrective Action): - As per the “preventive and corrective action guidelines” given by Baldwin the corrective

action is defined as a term that encompasses the process of reacting to product problem, customer complaint or other nonconformities and fixing them

The process includes:

- Reviewing and defining the problem or nonconformity  Finding the cause of the problem
- Developing an action plan to correct the problem and prevent a recurrence
- Implementing the plan
- Evaluating the effectiveness of the correction.

e) Images of the site Effect: -

Take the images of the site, which is unsatisfactory of that activity for proof of the document in the construction industry which parameter, not apply in the construction industry

f) Control

Control the quality various parameter are enlisted in the quality checklist, which is prepared by the quality control department in the construction industry, which is shown the SIPOC process. That basis analyses whole the project determines the quality of the project.

#### 5. Development of Android application

Based on observation android application are developed. The site engineer, Supervisor, and client to check the quality of every activity will use it easily. They can send the quality to the official website site to performance measure easily on construction site.

Software used For Android Application Development

- a) MS Excel
- b) Android Studio, Eclipse, SDK, JDK

Requirement to use the android application on the site

- a) Android Mobile
- b) WPS office Version 10.5
- c) Above KitKat Level Android Version

6. Android Application apply on Activities of Various site

## VI. RESULT AND DISCUSSION

The Quality Control Indicator (QCI) is apply on the three sites. This all Building are residential project. The project 1, project 2 and project 3 progress activity of project are given with Their sigma level and causes and effect in **Table 2**.

TABLE 2: SIGMA LEVEL AND CAUSES AND EFFECT OF PROGRESS ACTIVITY IN PROJECT 1, 2 AND 3

SI No	Site	Activities	Six Sigma	Causes and Effect
1	Project 1 (siddhi project)	Block work	1.85	Water-cement ratio not proper, DPC layer not provided, RCC stiffener (patli) not provided, joint between RCC frame and brick masonry not provide, tooled joint not provided,
		RCC	Pre 2.88	Hook not bend at 135 degrees, joggling not done (1in 6), pin props min 12mm not provided
			During 2.9	Extra diesel pump not available of vibration
			Post 6	
		formwork	3.27	Pin props min 12mm dia not provided
		gypsum plaster(Punning)	2.848	Application of chicken mesh not provided on RCC joints, Leakage not test before plastering, Leakage observed on the surface of gypsum
		toilet/bathroom	3.31	Mix proportion is not proper



		waterproofing		
		plastering	Internal 2.99	Chicken mesh RCC masonry joint, all electrical boxes protected by plastic sheet
2project 2(majestic project)	3	Block work	1.97	DPC Course Not Provided, mix proportion not proper, metal packing not done at junction of RCC & masonry, toothed joint not provided, Date of masonry not display
		Gypsum plaster/punning	2.27	Electrical boxes not fit proper level, plaster bag not fix on electric boxes, straight line not available on gypsum plaster surface,
3project (lodha project)	3	Block work	6	No cause and defect as per checklist because the checklist check by 3 people client, contractor, consultant and client
		Reinforcement	6	
		Concreting	6	
		Gypsum plaster	6	
		Electrical work	6	
		Formwork	6	

In siddhi project Activity Block work is going on that time apply QCI on activity. The work causes and Effect are given in Fig 2 by using Ishikawa Diagram

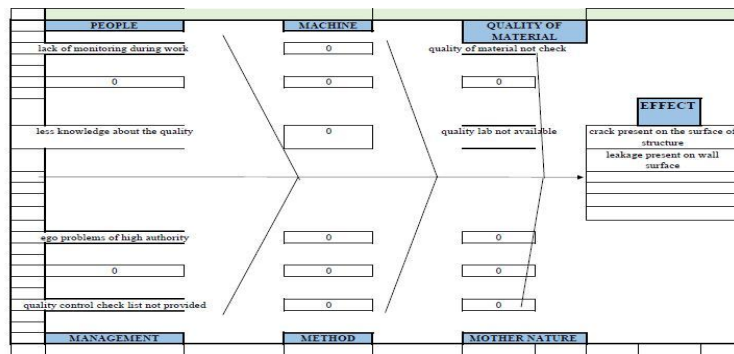


Fig 2 Ishikawa Diagram (Cause and Effect Diagram) for activity of block work if siddhi Project

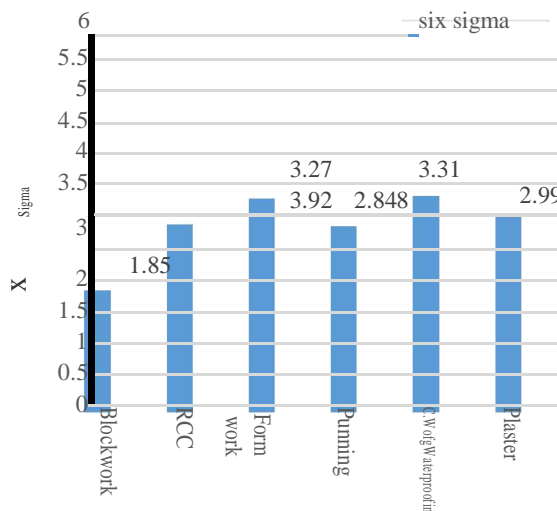
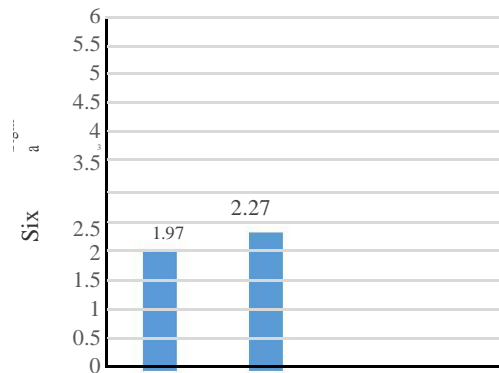


Fig 3: Project 1 Sigma level of activities in Siddhi group Blockwork Punning Activities



The fishbone diagram, or the cause and effect diagram, is a simple graphic presentation that displays all the possible Causes of a problem. It is also referred to as Ishikawa diagram. Here is a fishbone diagram example of brick work displaying the causes of low quality in construction share from six perspectives: people, machine, quality of material, management, method and Mother Nature( Masoud H. 2011). The QCI (Quality Control Indicator) Apply on various activity as Shown in **Table 1**. Those Activity Sigma level shown in the **Fig 1, Fig 2 and Fig 3** as shown in below.

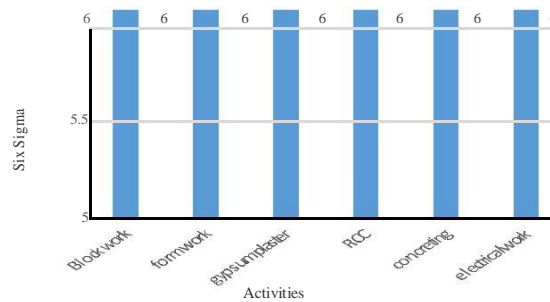


Fig 5: Project 3 Sigma level of activities in Lodha group

In most of construction projects in India, People don't apply checklist for the purpose of quality control, may be because they don't know the significance of checklist. By using QC Indicator, Performance of individual activity can be evaluated easily.

Project 1, 2, 3 shows that sigma level of the activity on blockwork sigma value is 1.85, 1.97 and 6 the value difference is due to the concrete patli not provided, DPC layer not apply, w/c ratio not proper etc. Due to this, the six-level differs. in Block work the concrete patli provide the strength to the 4-inch wall is also called the stiffener. Project 1, 2 and 3 the activity of gypsum plastering the value of six sigma is 2.828, 2.27 and 6 respectively. The value difference is due to the electric boxes in properly apply in wall, chicken mesh not apply on the joints, this not taken properly, external plaster not done before gypsum plaster start etc.

Project 1 and 3 the activity of formwork the value of six sigma is 3.27 and 6 the difference of the value is due to pin 12mm dia not provided. If less dia of bar provided in the props it may chance of failure of the formwork. This point is safety point of structure.

Project 1 and 3 the activity of reinforcement the value of six sigma is due to pre, during and post is 2.88, 2.9, 6 and 6, 6, 6 are due the diesel vibrator is not available during concreting, 1:6 crank is not provided in reinforcement etc. During the concreting may chances of electricity turn off from that diesel vibrator should available on site. On construction site beam and column, joint crank is provided because the steel goes simple in the column bar, and to reduce the width of beam in column junction.

Project 1 the activity of internal plastering value of six sigma is 2.99 issue the chicken mesh is not provided on the joint. Which will cause the leakage and bonding between the joint will occur properly.

Project 2 the activity of toilet waterproofing the value of six sigma is 3.37 respectively. The difference is due to the mix proportion is not proper which will affect the strength of the structure and leakage Proof.

## VII. CONCLUSION

This study focusses on use to quality control indicator for various construction activities. QC Indicators indicates the quality status of the activity for facilitating the application of remedial measures in order to improve quality Indicator are very much useful for rating the construction projects. It also will be helpful to reduce the defects in high rise building construction. In Addition, it covers advanced quality control checklist, quality assurance, testing procedures and reports etc.



### VIII. SUMMARY

This entire project is application of six sigma in order to reduce the adverse effects on project activity. Entire study in this project focuses on the causes and effect of activities during construction and correction action taken. By project manager to reduce the failure of the running project as well as the time and cost reduction in order to save money and time. All activities are monitored on an android based application developed. This android application takes care about cause and effect. Depending upon that it suggests the corrective action. It also has feature of developing the images and charts.

### IX. SCOPE FOR FUTURE WORK

The above studied model proved to be reasonable and feasible. It has following scopes in future,

- Initialize the using the technology to control the quality of the project in the construction industry.
- Can determine the quality of the project in six-sigma level using QIC.
- Easily find the causes and effect of the activity in the construction industry.
- Keep the record of the construction activity in the construction industry.
- Take the preventive action after the unsatisfactory point happens in the recording manner.
- Remove the study used in the construction industry it will be the environment-friendly.
- The used six-sigma level in the construction industry to improve the quality of the project.

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