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Key Performance Indicator for Measuring and Improving Quality of Construction Projects

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Abstract - *Construction projects are a balance between cost, time and quality. It is possible to have high quality and low cost, but at the expense of time, and conversely to have high quality and a fast project, but at a cost. If both time and money are restricted, then quality is likely to suffer. High quality is not always the primary objective for the client; time or cost may be more important. It is only realistic to specify a very high standard of quality if the budget is available to achieve that standard. The need for Key Performance Indicators (KPI) in construction projects has increased considerably in recent times due to significant changes, advancements in technology and high expectation of the users. The KPI maintain uniformity in construction process and ensure more economical utilization of materials resulting in significant reduction in cost to the users. This type of study has become necessary when the construction industry is encountering a quality issues day by day. Critical parameters or key indicators are necessary to introduce at planning stage when PQP is preparing which divert us to concentrate for quality.*

In this project work, critical parameters are considered in the planning stage and study is carried out. The study is done by using questionnaire and Delphi techniques on quality of certain important activities. This study leads to know critical parameters or key indicators of an activity and their contribution. These indicators can be used for internal qualitative improvement which ultimately improves business, reputation.

Key Words: Construction Projects, Key Performance Indicators, PQP, Quality

1. INTRODUCTION

The construction industry has been struggling with quality issues for many years, and the cost to our economy is dramatic. The cost could potentially be reduced significantly if the industry were to embrace the concept of quality assurance that has been used with great success by many other sectors of the economy. The construction industry is unique, and therefore, the application of quality assurance requires an approach that meets the needs of the industry. Building owners also need to be educated as to what is quality assurance so that they can begin using their voice to encourage adaptation of this approach to protect their investments and reduce the cost of construction. The quality assurance and quality control is having broad meaning as per as various sectors are concerned. In general to understand this concept of quality, we formulate four questions as follows,

1. What is mean by Quality?
2. How it is achieved?
3. What is Quality Assurance?
4. What is Quality Control?

When we are talking about quality about anything, either it is service or any product; one word should come in mind as response i.e. YES or NO. There should not be any response to differentiate quality viz; fair quality, moderate quality, quite poor or quite good quality. Ultimately the presence of quality is important. So in general we can define the quality in different ways as follows,

1. Quality is conformance to requirements or specifications
2. Quality is fitness for use
3. Quality is the degree to which a set of inherent characteristics fulfills requirements

Considering the significance of construction, there are three-fold meaning in construction, which are getting job done on time, ensuring that the basic characteristics of the final product comply with the requirements and getting the job done within budget. It has been a merging dispute over clients' dissatisfaction towards Indian construction industry performance in terms of completing the project within budgeted cost and time frame given and foremost, the quality of the end product. There is an increasing demand towards high quality of construction constructed by Indian Construction Industry. The major indicator to measure and determine the quality of construction is high quality of workmanship where it determines the success of construction. In early 1980's, quality began to emerge as a

key management focus in United States. Indian construction industry has realized on the aggressive competition in both regional and international industry. To ensure their position in emerging international market, the construction industry must impose higher quality levels in trying to achieve internationally accepted quality levels.

In construction industry, quality should be implemented throughout the life cycle of the project as a preventive action. Quality issues also have to be taken into consideration in the construction project management in order to eliminate any unnecessary problems before it occurs or towards lean construction. Lean construction means to eliminate the unnecessary system or approaches and continually improvement.

2. KEY PERFORMANCE INDICATOR

What is a Key Performance Indicator? Key Performance Indicators (KPI) are compilations of data measures used to assess the performance of a construction operation. They are the methods management uses to evaluate quality of a particular task. These evaluations typically compare the actual and estimated performance in terms of effectiveness, efficiency, and quality in terms of both workmanship and product.

Generalized models exist for implementing and monitoring construction activities, but they fail to identify which indicators will accurately portray the changes in performance. Instead of reporting and disseminating every piece of information gathered on the job, a more simplified method should be used to gather only that data which directly predicts performance for the task to be measured.

A KPI is a measure of a factor critical to success. The existent literature on Key Performance Indicators in Construction Industry focuses primarily on performance measurement systems.

David Arditi and H. Murat Gunaydin(March 1999) investigated the differences in the perceptions of entry-level professionals and long-time practitioners with regard to process quality in building projects with Delphi process and a questionnaire survey are conducted.[4]

Robert F. Cox; Raja R. A. Issa, M.ASCE; and Dar Ahrens(April 2003) Studied that there is a great need in the construction industry for identifying a set of common indicators to be used by construction executive and project managers in measuring construction performance at the project level.[17]

K. N. JHA & K. C. IYER (November 2006) examined the factors that adversely affected the quality performances of projects were: conflict among project participants; hostile socio-economic environment; harsh climatic condition; PM's ignorance & lack of knowledge; faulty project conceptualization; and aggressive competition during tendering.[11]

Mirosław J. Skibniewski and Saumyendu Ghosh(October 2009)explored that the identification of key performance indicators (KPIs) is an essential first step in developing a proper performance measurement framework.[9]

3. PROJECT QUALITY PLAN

"Project Quality Plan" can be defined as a set of activities planned at the beginning of the project that helps achieve quality objectives. It is a live document that is used and updated regularly throughout the project life or contract period. It must comply with ISO 9001 standards and specifications of the project.

- The PQP clearly defines
- Project or contract objectives.
- Resources to be used i.e. organizational structure.
- Personnel responsibilities and authorities

Process controls to be used to deal with work and risks involved, including quality procedures, and ITP‟s and associated checklists, with method statement. Methods to be used to monitor and audit implementation. Methods to be used to identify nonconformities, and implement corrective and preventive actions. Methods to be used for document control and records management including maintaining, securing/protecting/storing, identifying, retrieving and otherwise controlling records for the periods required and then their disposal.

4. RESEARCH GAP

1. Critical activities are identified in the project. Necessary actions are defined.
2. But, the key factors which are affecting to quality of activity is not identified
3. This may lead to the achieving less quality and time spent, resources require for correction. Key performance indicators are necessary to know for any activity before it starts.

5. SCOPE OF WORK

1. Setting out objectives
2. Literature survey
3. Site Visits
4. Identification of critical activities and factors affecting to it
5. Finding importance of factor in terms of grade Corrective actions for respective key factor

6. METHODOLOGY

Methodology adopted for this study is shown in flow chart:

Fig-1: Methodology in Primary Stage

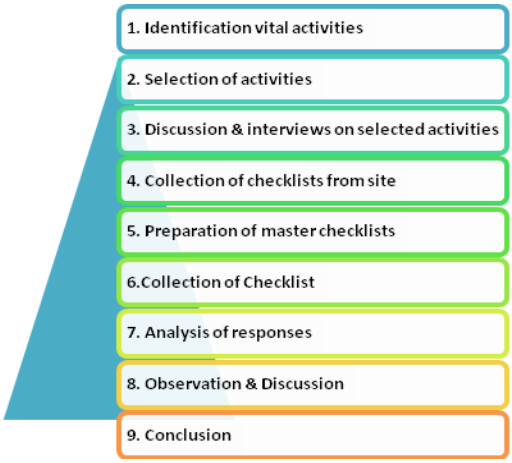

Fig-2: Methodology for Study

Following activities are selected for this study:

Activities listed below are the major contributors towards quality, aesthetics and cost. This is the main reason for their selection. Negligence in executing these activities may be a serious threat to the structure.

Selected Activities Are,

1. Planning
2. Excavation Work
3. Plinth Filling Work
4. Reinforcement Work
5. Concrete And Masonry Work
6. Footing Work
7. Brickwork Masonry Work
8. Formwork
9. Painting Work
10. Plastering Work
11. Plumbing and Sewerages Work
12. Electrical Work

6.1 Planning

6.1.1 Planning and Site Organization

Careful forethought and planning are required for sound site organization. Consideration must be given to the efficient use of available space at the site during building operations in order to ensure that all building activities move smoothly with minimal interference or delay. The proper choice of suppliers and subcontractors plays an important part in achieving desired quality and efficiency.

6.1.2 The Construction Process and Supervision

Reliable standards must be maintained throughout the whole construction process in order to ensure that the built work is durable, is functionally sound and aesthetically satisfying. Simple time-tested methods that have proved effective in ensuring quality can be employed to make sure that problems do not develop later, which can be expensive and difficult to rectify. Close supervision of craftsmen and workers employed by the main contractor on the site is essential to make certain that all the elements that make up the building conform to acceptable standards of quality. The work of sub contractors too requires planning and supervision to ensure quality is maintained in all aspects of construction, including services.

6.1.3 Health and Safety

Health and safety are factors that must be pursued with as much vigorous other management objectives. Ensuring the well-being and safety of all workers or visitors at construction sites will improve performance; minimize accidents and illness which in turn will reduce disruption of work as well as consequent expenses.

The following checklist is prepared so that building contractors and supervisors can make sure that essential steps are taken to ensure maintenance of quality control throughout the building process.

Note: In checking out the Yes/No response to each question, it is important that if the answer is No, follow-up corrective action is needed.

6.2 Excavation Work

The process of removing rock or earth from a solid, broken, or unconsolidated layer of soil by means of an excavator, bulldozer, scrapper or any similar type of machine refers to the term excavation. In construction industry, earthwork is broad term used for excavation which includes the entire work cycle from digging, transportation and dumping of earth from construction site to the dumping area.

6.3 Plinth Filling Work

The sides of concrete and masonry in foundation trenches or in the column pits should be filled with suitable excavated material. Filling should be done in layers, and compacted with steel rammer or with wooden logs. The approved excavated material, which has been stocked, shall be cleaned of all rubbish, large size stone, vegetation etc.

Filling should be done in layers each layer being of 15cm to 20cm.Each layer is watered and compacted with heavy rammers of wooden logs or steel. If the area of refilling is large then either electric operated or fuel operated compactors are used to compact the filling material.

The process of filling in plinth, watering and compaction shall be carried out till the required level is reached so as to form a thoroughly compacted base. While compacting due care is taken to protect the foundation columns, plinth walls, etc., which are already constructed.

If the depth of filling exceeds more than 1m then for economy purpose building rabbit may be allowed as a filling material for further depth, the procedure being the same. Under no circumstances black cotton soil shall be used for filling in plinth and footing pits.

6.4 Column, Slab & Beam and Footing

6.4.1 Reinforcement

Concrete has good compression strength but has low tensile strength and ductility. To counterbalance this, concrete is reinforced with steel bars to increase its tensile strength and ductility. Reinforcement is provided basically in all structural members which contributes towards strength of structure mainly slabs, walls, beams, columns, foundations, frames and more.

As per IS 456:2000, the structure can be under reinforced or balanced but cannot be over reinforced. In case of over reinforced, the structure may fail without any signs of cracks and hence should be avoided. Maintaining a quality becomes crucial for stability of structure.

Master checklist of the above activity was prepared on the basis of Checklists collected from Construction firms and few from online portals.

6.4.2 Concreting

A hard, strong construction material consisting of sand, grav el, pebbles, broken stone, or slag in a mortar or cement matrix.

Portland cement - The cement and water form a paste that coats the aggregate and sand in the mix. The paste hardens and binds the aggregates and sand together.

Water- Water is needed to chemically react with the cement (hydration) and too provide workability with the concrete. The amount of water in the mix in pounds compared with the amount of cement is called the water/cement ratio. The lower is the w/c ratio, the stronger the concrete. (Higher strength, less permeability).

Aggregates- Sand is the fine aggregate. Gravel or crushed stone is the coarse aggregate in most mixes.

6.5 Brick Masonry Work

The common materials of masonry construction are brick, stone, marble, granite, limestone, cast stone, concrete block, glass block, stucco, tile, and cob. Brick is the most commonly used material in masonry work around the world. The materials used, the quality of the mortar and workmanship, and the pattern in which the bricks are assembled can significantly affect the durability of the overall masonry construction.

Different methods of lying of Brick masonry is followed around the world which is as follows:

- English bond,
- Flemish bond,
- Stretching bond,
- Heading bond,
- Garden wall bond,
- Facing bond,
- Raking bond,
- Dutch bond,
- English cross-bond,
- Zig-Zag bond,
- Silver lock's bond **Formwork**

6.6 Formwork

Formwork is a temporary structure of mold into which reinforcement bars are placed and concrete is poured. It is upheld in position till concrete sets and removed / dismantled after it. Formwork systems used concrete frame construction have continued to develop significantly. The major innovations have focused on on-site efficiency of production, health and safety, and environmental issues, driving the concrete construction industry towards ever-increasing efficiency.

The modern formwork systems listed above are mostly modular, which are designed for speed and efficiency. They are designed to provide increased accuracy and minimize waste in construction and most have enhanced health and

safety features built-in Formwork is also responsible for its aesthetical value as it going take the shape of the mold and should be placed with intense care.

Master checklist of the above activity was prepared on the basis of Checklists collected from Construction firms and few from online portals.

6.7 Painting Work

Painting is the practice of applying paint, pigment, color or other medium to a surface (support base). The medium is commonly applied to the base with a brush. Preparing your walls with primer before you paint is the best way to ensure a lasting finish. Priming not only adds to the durability of the paint job it also saves you time, especially if you have the primer tinted the same color as the finish coat. There are also several new interior paint options that now include paint and primer in one, saving you time by hiding and sealing previously painted and uncoated surfaces without the use of a separate primer.

Tinting primer improves the color of your paint and reduces the number of coats needed to achieve the truest color or hue. Primer is formulated to adhere to a variety of surfaces and seals them to prevent stains and discoloration from bleeding through the final coat. The finish coat sticks more effectively to a primed surface than it does to plaster, wood or an earlier coat of paint.

6.8 Plastering Work

Plasterwork refers to construction or ornamentation done with plaster, such as a layer of plaster on an interior or exterior wall structure, or plaster decorative moldings on ceilings or walls. This is also sometimes called pargeting. The process of creating plasterwork, called plastering or rendering, has been used in building construction for centuries.

6.9 Plumbing and Sewerages Work

Proper pipe work for sewerage and plumbing work ensures hygienic conditions in any building. All connections with main or branch pipes should be arranged in a way that can prevent cross flow from one appliance to another. Soil, waste and building sewer pipes should be of sufficient diameter in the direction of flow. Keep in following tips while designing and executing layout of sanitary pipes for the drainage of a building.

- In sewer line minimum gradient should be 1 in 57 for 100 mm diameter pipe and 1 in 100 for 150 mm diameter.
- Pipe works and appliances should be arranged in a way that allows close grouping of connections with water closet near main soil pipe.
- Branch pipes should be kept short to reduce noise.
- When washbasin and bathroom are at some distance from stack, it may be cheaper and simpler to combine their waste pipe in to one pipe.
- Any bend in waste pipe should be of large radius.
- Pipe works in branch connections should be arranged to allow free drainage of system.
- Connections with main or branch pipes should be arranged in a way that can prevent cross flow from one appliance to another.
- Branch connections should be of large radius along the invert.
- Minimum diameter of soil and waste stacks should be 100 and 75 mm respectively.
- Covered pipes or hard to find pipes along internal face of walls should be of cast iron.
- On ground floor all pipes including those laid on external face of the wall should be of cast iron also.
- Sufficient condition should be made to access all pipe works.
- Embedding of joints in walls should be avoided.
- All appliances connected to stack should be trapped directly.
- The soil, waste and building sewer pipes should not be reduced in diameter in the direction of flow.
- Cast iron fittings and branches for waste pipes should be of same quality.

6.10 Electrical Work

All electrical works shall be carried out by adequately skilled and licensed supervisors and trained technicians. Primary attention shall be given to safety of the installation and conformity to prevailing regulations. Particular attention shall be given to the neatness in the appearance of the installation which is to be achieved by judicious planning of runs and cables, the locations of light fittings, fans, switches, socket outlets etc. and making good any surfaces, framework or other elements in the building in the process of execution of electrical installation.

Master checklist of the above activity was prepared on the basis of Checklists collected from Construction firms and few from online portals.

6.11 Master Check List

Master checklists are prepared from collected checklists from site, expert views & interviews. Following checklists are prepared for further study.

7. Data Collection

To determine and analyze the set of perceived Key Performance Indicators (KPIs) utilized by construction executives and project managers in the construction industry, 40 construction sites were targeted with the intention of determining KPIs among construction industry. Differences in the perceived importance of performance indicators were also determined according to the number of years of construction experience each respondent possessed.

The approaches used for data collection are direct interviews or filling questionnaires, discussions with implementation consultants and representatives from selected construction sites. Data were collected from construction projects sites with annual construction volumes ranging from 20Cr to 200 Cr.

8. Result and Discussions

After collecting data from 40 sites data recorded into a excel sheet so that to assess in matlab. For all major activity which gives major contribution in quality are recorded and analyzed using matlab and some of the results & discussion (sample) are shown as under.

Table-1: Results and Discussion

Sr. No.	Activity	Vital %	Important %	Needed %
1	Planning	54	41	5
2	Excavation	14	48	38
3	Plinth Filling	43	36	21
4	Reinforcement	18	55	27
5	Concreting	47	51	2
6	Footing	45	38	17
7	Brick Masonry	9	73	18
8	Formwork	39	44	17
9	Painting	46	47	7
10	Plastering	40	51	9
11	Plumbing	18	35	47
12	Electrical	25	63	13

8.1 Excavation

For Excavation, 14% activities are vital which are means while execution 48% checks are important to concentrate.

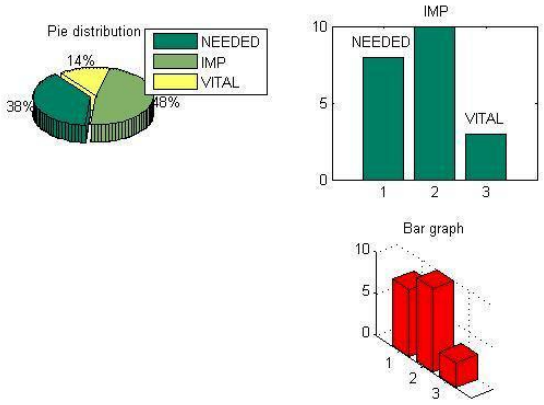

Fig-3: Excavation

9. CONCLUSIONS

1. This study indicates the correct testing procedure to maintain the quality for an activity. This gives related checks for overall quality.
2. This study gives an integrated checklist for an activity which is used at different site by different organization. This may leads to easiness in external quality audit.
3. PQP is most important document is rearranged with contents & key indicators for an activity & their importance.
4. This paper gives a key factors involved to improve a quality of an activity.
5. Relative comparison says the relative index within checks which is most important to concentrate on it.
6. Specified activities which are contributing to cost and aesthetic more are segregated and master checklist gives and general view to maintain quality of particular activity.
7. Responses collected from professionals rates checks gives the vitality of an individual check.
8. The vital checks require more concentration to improve quality, e.g. for excavation vital checks are inspection of site by concerned authority before starting of work, protection of employees from cave-ins while entry and exit of excavated area, etc.
9. This study gives a percentage contribution for every group of checks come under following heads.(Vital, Important, Needed).

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