

A Thesis on

ASSESSMENT OF FACTORS AFFECTING COST OF QUALITY IN CONSTRUCTION PROJECT

Submitted in partial fulfillment of the requirements for the award of the degree of

**MASTER OF TECHNOLOGY
CONSTRUCTION TECHNOLOGY AND MANAGEMENT**

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DECLARATION

I declare that the research thesis entitled “**ASSESSMENT OF FACTORS AFFECTING COST OF QUALITY IN CONSTRUCTION PROJECT**” is the bonafide research work carried out by me, under the guidance of **MR. ZISHAN RAZA KHAN, (Associate Professor)**, Department of Civil Engineering, Integral University, Lucknow. Further I declare that this has not previously formed the basis of award of any degree, diploma, associate-ship or other similar degrees or diplomas, and has not been submitted anywhere else.

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CERTIFICATE

Certified that the thesis entitled “ASSESSMENT OF FACTORS AFFECTING COST OF QUALITY IN CONSTRUCTION PROJECT” is being submitted by Mr. TUSHAR SARKARI (1901103021) in partial fulfillment of the requirement for the award of degree of Master of Technology (CONSTRUCTION TECHNOLOGY AND MANAGEMENT) of Integral University, Lucknow, is a record of candidate’s own work carried out by him/her under my supervision and guidance.

The results presented in this thesis have not been submitted to any other university or institute for the award of any other degree or diploma.

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ABSTRACT

Quality management is one of the most important consideration in any infrastructure construction project. Cost of Quality is one of the most significant parameter for analysing the quality performance of any construction Project.

It becomes increasingly necessary to pay attention to measurement of cost of Quality and optimizing it. Quality costs may be regarded as a criterion of quality performance but only if valid comparisons can be made between different sets of cost data. Clearly the comparability of sets of data is dependent on the definitions of the categories and elements used in compiling them.

Regardless of the varied different costing methods, the concept of identifying the value of quality encompasses one primary idea which is to link all areas of improvement to a price or customer expectation that's quantifiable, and thereby sufficiently actionable to scale back the general cost of quality

This research deals with identifying the major types of cost of quality and the prime factors which affect this. The data was collected through Questionnaire survey by identifying the top 24 factors which affect the cost of Quality. Data analysis was done through Relative Importance Index Method and Pareto Analysis to obtain the desired results. The field survey showed that the Internal Failure cost have the utmost impact on the Cost of Quality. Prevention and Appraisal cost also provide huge Impact on Cost of Quality as compared to External Failure Costs. Based on these results, several points of Optimizing Cost of Quality have been suggested.

CHAPTER 1

INTRODUCTION

1.1 Introduction:

Due to the development of the economy in the developed countries, competition has led to the survival of the fittest. Due to increased competition in the market, there is an increasing obligation on the construction companies to improve their internal quality and strengthen management. It specifically means that companies need to improve quality control in order to satisfy the needs of quality assurance of customers. (Cao, 2010)

Quality is a quite wide word that has a lot of meanings and for different people often means different things. Quality control and safety represent increasingly important concerns for project managers. (Amit A Mahadik, 2014) Defects or failures in constructed facilities can result in very large costs. Even with minor defects, reconstruction may be required and facility operations impaired. Increased costs and delays are the results (Ogwueleka, 2013). In the worst case, failures may cause personal injuries or fatalities. Accidents during the construction process can similarly result in personal injuries and large costs. Indirect costs of insurance, inspection and regulation are increasing rapidly due to these increased direct costs. Good project managers try to ensure that the job is done right the first time and that no major accidents occur on the project. (S. Senaratne, 2015)

As with cost control, the most important decisions regarding the quality of a completed facility are made during the design and planning stages rather than during construction. It is during these preliminary stages that component configurations, material specifications and functional performance are decided. Quality control during construction consists largely of insuring *conformance* to these original design and planning decisions. Total quality management is also an effective management technique which is followed by several organisations to improve productivity. (Dickson Sam J Danam, 2019)

Defects within new buildings are areas of non-compliance with the code of India, various Indian Standards and published acceptable tolerances and standards. Defective building construction not only contributes to the ultimate cost of the merchandise but also to the value of maintenance, which may be substantial. Defective construction may lead to the complete failure of a structure (Vishal Patil)

1.2 Quality costs:

Quality costs may be regarded as a criterion of quality performance but only if valid comparisons can be made between different sets of cost data. Clearly the comparability of sets of data is dependent on the definitions of the categories and elements used in compiling them.

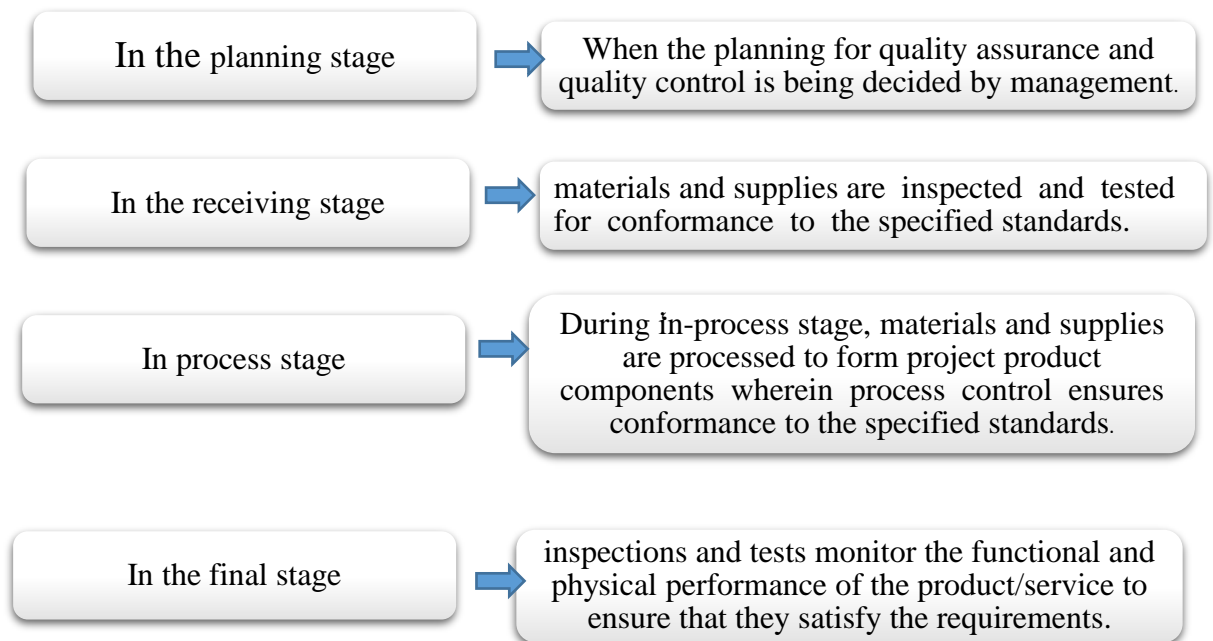
Quality is one of the most important and significant dimension of any construction project. From the inception to completion of any activity involved in construction, quality is one parameter which is kept on constant check at every stage. (Christine Hattar, 2016) There are different standards and procedures for checking the quality at each and every stage which involves different kinds and types of costing required. Quality costs generally refers to the cost involved or incorporated in maintaining and adhering to the necessary specific standards and desirable outcomes. (Vishal Patil)

Regardless of the varied different costing methods, the concept of identifying the value of quality encompasses one primary idea which is to link all areas of improvement to a price or customer expectation that's quantifiable, and thereby sufficiently actionable to scale back the general cost of quality

No matter which quality costing approach is employed, the most idea behind the Cost of Quality analysis is the linking of improvement activities with associated costs and customer expectations, thus allowing targeted action for reducing quality costs and increasing quality improvement benefits. Therefore, a sensible estimate of Cost of Quality, which is that the appropriate trade-off between the amount of conformance and non-conformance costs, should be considered an important element of any quality initiative and an important issue for any manager. Variety of organizations

are now seeking both theoretical advice and practical evidence about quality related costs and therefore the implementation of quality costing systems. (James, 2006)

Cost of quality depends on several factors and parameters at every stage of construction. There are mainly for stages of construction in which different activities are pursued. We could see identify the activities at each stage which have significant impact on quality in construction.



1.3 Major Categories of Quality Costs

1.3.1 Internal Failure Costs

Internal failure costs are incurred because products and services do not conform to specifications or Client needs.

- ▶ Scrap
- ▶ Rework
- ▶ Downtime (defect-related)
- ▶ Re inspection
- ▶ Retesting
- ▶ Design changes
- ▶ Repairs

1.3.2 External Failure Costs

External failure costs are incurred because products and services fail to conform to requirements or satisfy customer needs after being delivered to Client.

- ▶ Lost sales (performance-related)
- ▶ Returns/allowances
- ▶ Warranties
- ▶ Discounts due to defects
- ▶ Product liability
- ▶ Complaint adjustment
- ▶ Recalls

1.3.3 Prevention Cost

Prevention costs are incurred to prevent poor quality in the products or services being produced.

- ▶ Quality engineering
- ▶ Quality training
- ▶ Recruiting
- ▶ Quality audits
- ▶ Design reviews
- ▶ Quality circles

- ▶ Marketing research

1.3.4 Appraisal Costs

Appraisal costs are incurred to determine whether outcomes are conforming to their requirements or Client needs.

- ▶ Inspection of materials
- ▶ Packaging inspection
- ▶ Product acceptance
- ▶ Process acceptance
- ▶ Field testing
- ▶ Continuing supplier verification

1.4 Reasons for Increased Cost of Quality in Construction:

❖ Lack Of Project Management System:

A project management system determines the perfect intervals for testing the work completed thus far for errors and omissions. Without a management system or plan for internal control and assurance, most construction firms wait far too long to perform essential checks on their work.

❖ Damaged and Low-Quality Materials:

Too much water or sand during a concrete mix, lumber cut from undersized trees and improperly graded steel can all end in widespread construction quality issues. Not only do these materials fail early, they also create construction safety more risky by reacting unpredictably during the building process.

Ordering only from trusted suppliers and assigning a top quality control officer to see every shipment of materials is the only way to verify a project is correctly supplied.

❖ Ignored Audits and Testing:

Some construction companies stick strictly to their third-party testing and auditing plans, yet ignore the results of the tests and continue on with flawed designs or existing quality issues. This often leads to a scarcity of proper designation for internal control, causing reports to bounce from project manager to steer engineer without a transparent workflow for addressing the fabric.

❖ **Scope Creep:**

.Construction projects often start out much simpler, smaller and with less prospects than the finished project.

While it's natural for all projects to vary with time as new facts are discovered about costs, time constraints, and site limitations, the matter comes when the expansion in scope results in cutting corners to stretch a limited budget and time-frame.

❖ **Supplier and Vendor Failures:**

Even when the materials themselves aren't responsible for a top quality issue, problems with suppliers and vendors can raise costs and lower quality levels. Replacing the requested building supplies with other brands and materials that don't offer an equivalent quality may result in unhappy clients and time-consuming rework requests. Finding new vendors may desire a distraction within the middle of a construction project, but it can significantly improve construction quality management.

❖ **Failure to Document Changes and Practices:**

Some quality issues aren't directly associated with an error or design change, but rather to the shortage of documentation of the change. If a cloth is substituted for an additional with a totally different maintenance and replacement cycle, failure to update the ultimate documents may result in improper handling from the upkeep team.

1.4 Research problem

Numerous researches have been done till now keeping in view the quality aspect of construction. Researches are mainly focused on the parameters and gaps important for quality management in construction.

A comprehensive and precise integration of quality management facet is somewhat lacking as per the knowledge gathered through literature review.

Very few studies have highlighted the cost related extent of quality.

Factor Based Cost analysis of QA/QC system is needed to be assessed to get a better understanding on quality aspects in construction.

There is a research space in the domain of quality which is linked to its different types of cost and their significances as well as the points which everyone construction stakeholder should know for cost optimization.

1.5 OBJECTIVES OF STUDY

To sum up the objectives in points, we could write them as:

- Assessment of factors affecting Cost of QA/ QC system implementation for a project site.
- To establish the ranking of most crucial factors impacting the Cost of Quality.

1.4 Benefits:

- **Continuous improvement:**

Identification of the crucial factors and most vital factors would lead to focussing more energy on these aspects and prioritising them. This would eventually help in continual improvement in an organization with less time taken and with more efficacy.

- **Operational Efficiency:**

Inconsistent and in effective operations are the major roadblock in the quality management process which in due course results into a hefty increase in quality costs. Factor identification would ultimately help in providing better quality performance at less costs.

- **Improved decision making:**

Evidence-based deciding can benefit the organization by removing subjectivity from leadership. The real-time use of knowledge can facilitate continuous improvement toward strategic goals. The data analysis done in this dissertation could provide value-added decision making to the construction organization.

- **Less expenditure on quality**

Since the main aim of this dissertation is to find out the main factors impacting cost of quality in construction project so it would benefit the major stakeholders or managers to recognize the major issues of quality.

Quality expenditures could be minimised by detecting the most crucial factors and giving more importance to them,

- **Higher Liquidity:**

Less cost would be incurred on productivity and quality therefore more liquidity would be available to the firm which would ultimately lead to more efficient use of resources

1.5 Limitations of study:

- Data collected is regarding cost of Quality only and factors are selected keeping in view the Cost of Quality only.
- The analysis techniques are on the basis of relevant literature reviewed and the type of outcome to be found out.
- This study would not be applicable for unplanned construction Projects.
- The study parameters would not be applicable for works which are not contractual type of small construction Projects.
- This would be not be applicable for small scale projects where procurement is done on smaller scale.
- This study would not be applicable for low budget construction Projects.

CHAPTER 2

LITERATURE REVIEW

Since the dawn of any civilization, the need to live in a safe and closed space has been the crux of human needs. This led to the construction activities being started with quality not defined in terms of language still existing in the minds of people. During middle ages, a little or very less significant evidence is found about the scriptures related to quality. During the middle of 18th century when the industrial revolution started, inspection activities and skill inspection were the activities getting the limelight. During the beginning of 20th century, a new technique of quality control i.e. statistical process control was introduced by Stewart. After the mid of 20th century, several other notable persons such as B G Dale, Crosby and Juran gave some phenomenal concepts about quality assurance, quality control and Total Quality Management.

Since the onset of the 21st century much debate is about how to improve quality with minimal effect on other parameters such as time, cost, etc. Many researchers focused on this aspect of construction and tried to carve out new inferences and conclusions which would be beneficial for the academic sector as well as the industrial sector.

Several strategies are formed keeping in view the leadership aspect of Quality. Paul Schiltz focussed on the effect of leadership on quality in an organization. This research demonstrates that what type of leadership characteristics best support the quality management function. The author provides valuable insights into questions concerning which leadership characteristics best support the leadership prescribed by Deming, Juran and others concerned with quality. **(Paul D Hirtz, 2007)**. Peter Hoonakker discussed the difficulties in construction industry for defining quality, determined benefits quality implementation, and at barriers to implementation of quality in construction. They collected data with the help of questionnaire. They showed development which may help to overcome failure. From the finding they stated that contractors do know the value of quality but there are obstacles for implementation. **(Peter Hoonakker)**

Professional ethics also has an effect on quality in construction which are depicted in this study. Hamzah Abdul Rehman highlights a very important topic related to quality which is generally not given the due importance. He explores on how the professional ethics impact construction quality. He demonstrates the current level of professional ethics in construction industry and how ethics influences the construction project. The findings indicate that unethical conducts have a direct and negative impact on the quality of construction. The author concludes that professional ethics is a pre-requisite to attaining sustained and acceptable quality in construction and suggests several approaches to enhance professionalism among construction professionals to improve quality in construction. (**Hamza Abdul Rehman, 2011**)

Mohamad Kamal (2013) focused implementation of the quality management work process in ship construction industry and for this survey qualitative method was selected as the most appropriate research method among those available. The main purpose was to succeed in the quality management implementation in ship construction project.

The following study gives a strong issue in identifying the cost that is mutual between quality and safety. John Wanberg tries to establish an empirical relationship between construction safety and quality performance. The two main points concluded by the authors are that a poor quality performance has higher likelihood of injuries and the first aid rate is positively correlated to the number of defects. The author provides insights about how Total Quality Management could simultaneously improve both safety and quality in construction. (**John Wanberg, 2013**) . Another researcher D Ashok Kumar illustrates about the crucial role played by the quality in construction industry. The author analyses the major factors of hindrance and the cost variance due to quality defect in quality management. The author provides mainly five factors which serve as the main constraints for achieving quality in construction. There could be more than five factors which could affect the quality in construction therefore a more detailed approach needs to be followed. (**Kumar, 2014**)

The managerial approach which could have an effect on cost of Quality is defined by following researcher. Amit A Mahadik analyses quality as a managerial approach and views quality to be the result of integration of all organizational activities. He believes that quality will play an incomparable role in any business especially in construction field. The main conclusion of the author is that the implementation of the quality control in the construction site is crucial for low defects and efficient construction. **(Amit A Mahadik, 2014)**

Justin Fischgrund explores about the quality gaps in construction projects. The study critically examines about the major and vital gaps which are encountered during a projects life cycle. The findings of this study make a case for the need to define construction quality in the context of an expanded list of gaps in the client-firm service encounter, with a complementary list of the mitigating factors for practitioners. The author explains an exhaustive list of gaps, but rather that quality should be defined and evaluated in the context of these and other quality gaps inherent in the management of construction projects. **(Justin Fischgrund, 2014)** Dr. Jalindar R. Patil Stated about the quality management system which is an amalgamation of several factors and it is crucial factor for successful implementation of construction project. From the research, the author stated Customer satisfaction and checklist method of inspection plays an important role in maintaining quality at construction site. **(Pravin Mane, 2015)**

A researcher conducted an exploratory research which provides insights about quality practises, tools, techniques and management commitment towards quality implementation in construction. The author provides a few issues which are faced during quality implementation. However more factors could be added and a thorough research could be done on this. The author tells that more quality practises on site increases the paperwork on site and every project has a specific quality plan which should be followed strictly. **(Arun Kumar H, 2015)** S. Senaratne discusses the point that although high quality is not the core requirement of client yet it is extremely important to a successful project. They notice a very significant point about quality that a facility with good construction quality program and minimal defects is more likely to have smooth transitioning into the commissioning and qualification phase of a project. **(S. Senaratne, 2015)**

Christine Hattar expresses their viewpoints about quality in a different perspective. They defined quality as how closely the project conforms to the requirements according to the contractor, engineer, architect and owner itself. They found out that the major factor that affect quality is the human resource management and construction specifications. There is a scope of further research as these results are not in elaborative form. **(Christine Hattar, 2016)** D.Ambika studies about the factors affecting the quality in construction projects. The study revealed that the significant factors affecting quality are occurrence of meeting, environmental risks, working hours, material delay, and labour shortage, coordination, checking inventory level, resource delay, coordination and safety precautions. The author uses the questionnaire survey methodology to come to results. **(K.S.Shobana, 2016)**

Vishal Patil focussed on cost of poor quality in construction. The author tries to review the use of quality in construction industry. The author throws light on the issue that defective building construction not only contributes to added construction cost of the project but also the cost of maintenance, which can be substantial. According to research done by author, the cost of quality is equivalent to 1% of the total project cost. **(Vishal Patil)**

A.I. Romanova researches into creating a unified approach to the organization of the control system and the evaluation of the quality of construction at the facilities of the investment. The author specifies some particular problems related to quality and finds out the possible solutions related to quality in construction. The author tries to provide an approach which aims towards building a self-regulatory organization. **(Romaova, 2016)**

Monisha Manoharan states a very important point which is that an effective quality control has more economic benefits. The author conveys information that systematic planning of quality for each construction process has more economic benefits with more effective quality control. Rational allocation of resources serve as make the construction project run in a timely manner and achieve better quality objectives. Hence it could be said that project management has an effect on quality in construction. (Manoharan, 2017)

Nasir Shafiq deeply investigates about the constraints towards effectiveness of quality planning in construction industry. The authors try to identify the basic problematic factors toward the implementation of quality in construction projects. He portrayed a very unique conclusion that clients are not driven towards a high quality approach on selection of a contractor. He concluded that better approach needs to be followed for educating the people involved in construction. **(Nasir Shafiq, 2017)**

Dickson sam J Danam says that in today's construction industry, quality and its concepts are vital. The authors are of the view that Total quality management principles and philosophy apply to construction industry. He emphasizes the total quality principles should be impregnated construction industry in an innovative manner. Several contradictions to this could be possible which need to be studied thoroughly. **(Dickson Sam J Danam, 2019)**

Maysoon Abdullah Mansor draws attention to the measurement and determination of cost of quality so as to identify qualitative problems and opportunity for improvement of work done. The author identifies the categories and item of cost of quality through theoretical literature then uses Pareto analysis to find the high impact categories and items on the cost of quality. The findings show that prevention and appraisal items have an important influence in minimizing the failure cost where the quality audit cost is of utmost importance. This research uses a very reliable technique such as pareto analysis for coming to conclusions. **(Mansoor, Studying and evaluating the cost of Quality in Construction Projects, 2020)**

Sahil sanjeev salvi focussed on the point that the construction industry faces a huge economic loss due to loss of quality in construction projects. He emphasized on internal quality control and quality assurance as the key two factors which would greatly impact the quality on construction site. He argues about the point that there are several contradictions to quality which needs to be monitored. **(Sahil Sanjeev Salvi, 2020)**

Based, following on above review, following key points or the inferences could be carved out. It has been understood that Quality aspects are generally being studied with reference to Quality management systems in a quantitative manner or the qualitative manner. Other inferences observed were that cost of Quality needs to be studied in a more detailed as well as in ore comprehensive manner.

A facility with good construction quality program and minimal defects is more likely to have smooth transitioning into the commissioning and qualification phase of a project.

As pre the review done of different papers, the cost of quality is equivalent to ***1% of the total project cost.***

Another main inference is that total quality principles should be impregnated construction industry in an innovative manner to optimize cost and increase efficiency.

*One of the main inferences drawn from the survey are **measurement and determination of cost of quality** so as to identify qualitative problems and opportunity for improvement of work done*

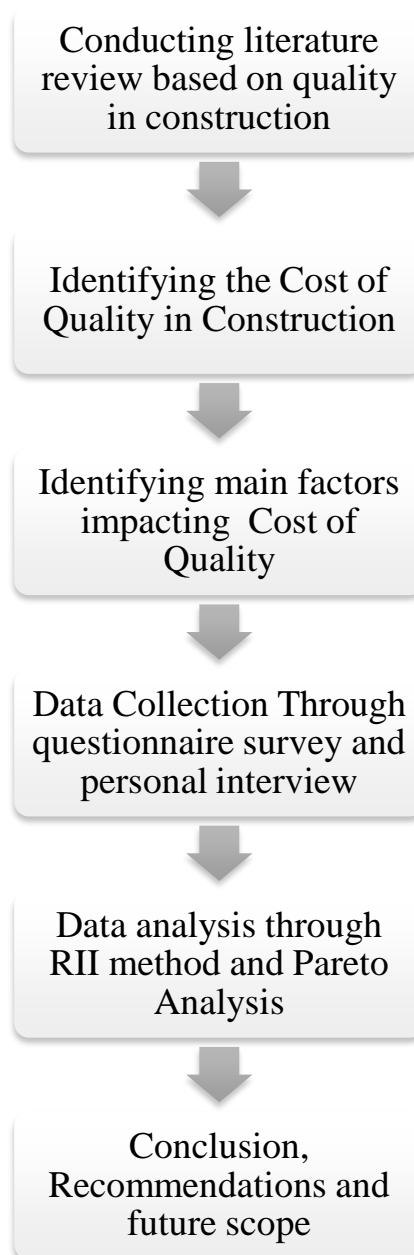
From the literature review, it is highlighted that there is a need to pursue a study on factors which affect the cost of Quality as well as analyse them to provide the best possible outcome for construction projects.

CHAPTER 3

RESEARCH METHODOLOGY

A research methodology should be such that it gives the most accurate results. Through studying the literature and other material, questionnaire survey method seems to be the most suitable and viable option for pursuing the required objectives. The data is collected using the above chosen approach from different stake holders of construction.

Following steps are chosen for conducting the research:



The following is the questionnaire survey prepared for conducting the dissertation survey:

M TECH DISSERTATION SURVEY

Dear Respondent,

This questionnaire has been designed to study quality costs in construction and how they could be minimized. The study is being conducted by the student pursuing M.Tech program at Integral University.

It's a kind request to fill this survey.

This questionnaire survey has been designed for academic purpose and the responses will be used for academic activity only.

Kindly ensure that none of the questions is missed and you answer them to the best of your knowledge

Your participation would be highly appreciated.

Thanking you.

TUSHAR SARKARI

❖ NAME *

Your answer

❖ What is your Designation? *

- Supervision engineer
- Site Engineer
- Project Manager
- QA/QC Engineer
- Contractor
- Other

- ❖ Would you mention your years of experience in construction industry/business?
 - Less than 5
 - 5 to 10
 - 10 or above

- ❖ Do you think there is a dire need of quality improvement in construction?
 - Yes
 - No
 - Maybe

- ❖ Quality is Best defined as
 - Best Fit for Purpose Being served
 - Having zero defects in system
 - High conformance to standards and specifications

- ❖ Do you think Quality could be traded off with time, cost, etc.?
 - Yes
 - No
 - Maybe

- ❖ Documentation of quality aspects for further use should be minimized or not so as to have less money levied on quality expenditure?
 - Yes
 - No
 - Maybe

- ❖ According to you, which is the most crucial stage for quality management in construction? (In terms of cost of Quality)
 - Designing stage
 - Planning Stage
 - Execution Stage
 - Monitoring and Controlling stage

❖ Which cost has the maximum effect on quality in construction?

- Internal Failure Costs
- External Failure Costs
- Appraisal Costs
- Prevention Cost

❖ Impacts of Different parameters on Cost of Quality

This section consists of major points and their impact on cost of Quality.

1. Internal Failure Cost

- Downtime (defect-related)

Very Low 1 2 3 4 5 Very High
 ○ ○ ○ ○ ○

- Re inspection of activity

Very Low 1 2 3 4 5 Very High
 ○ ○ ○ ○ ○

- Design changes

Very Low 1 2 3 4 5 Very High
 ○ ○ ○ ○ ○

- Repair of work

Very Low 1 2 3 4 5 Very High
 ○ ○ ○ ○ ○

- Rework

Very Low 1 2 3 4 5 Very High
 ○ ○ ○ ○ ○

- Scrap of work

Very Low 1 2 3 4 5 Very High

2. External Failure Cost

- Grievance Redressal

Very Low 1 2 3 4 5 Very High

- Warranty Costs i.e. cost of Re checking on Clients complaint

Very Low 1 2 3 4 5 Very High

- Scope Creep i.e. changes in scope due to clients change of mind

Very Low 1 2 3 4 5 Very High

- Cost of Claims i.e. liability to bear defects

Very Low 1 2 3 4 5 Very High

- Returns: investigation of rejected structures.

Very Low 1 2 3 4 5 Very High

- Hidden costs i.e. repair cost after commissioning of project

Very Low 1 2 3 4 5 Very High

3. Prevention Cost

- Quality Strategy i.e. quality plans, Quality records, etc.



- Process monitoring i.e. Quality checks, documentation, quality test scheduling, process reviews etc.



- Quality circles i.e. employees who meet regularly to consider ways of resolving problems



- Supplier Quality Assurance i.e. Procurement, supplier evaluation, etc.



- Quality Audits i.e. Internal Audit, Third Party Audit, etc.



- Quality Training Programmes i.e. Quality improvement training, Quality assurance workshops, etc.



4. Appraisal Cost

- Inspection costs i.e., stock assessment, site inspection, etc.



- Quality tests such as laboratory equipment, materials, etc.



- Maintenance of inspection and measuring equipment



- Quality of product inspection i.e. wages of inspectors, etc.



- Field Testing of Quality



- Maintenance of Quality records and documents



CHAPTER 4

DATA ANALYSIS

4.1 INTRODUCTION:

Data collection was done through questionnaire survey. Data collected through survey is analysed using the following techniques.

In this thesis work the excel software was used to calculate and analyse the statistical data which was collected by the questionnaire survey other than that complete statistical tests can also perform in that software. The collected data from the questionnaire survey will be analysed by using excel software so as to carry out the data analysis in this research.

4.2 RII INDEX METHOD:

It is used determine the relative importance of the various set of factors.

Data of all these tables were examined by a RII Index was calculated for each type of claims as follows;

$$\text{RII Index} = \Sigma W / (A \times N)$$

Where, W = weight given to each factor by the respondents, ranges from 1 to 5,

A = highest weight (i.e. 5 in this case) and

N = total number of respondents

Total 37 responses have been gathered for data collected from different stakeholders of construction. These responses are now being analysed using RII Method:

❖ For Internal failure Costs:

Table 1 RII index for Internal Failure Costs

Factors	Very Low (1)	Low (2)	Average (3)	High (4)	Very High (4)	Weighting	Rank
Downtime (defect-related)	1	1	9	16	10	144	0.78
Re inspection of activity	2	4	14	14	3	123	0.65
Design changes	1	4	7	7	18	148	0.8
Repair of work	0	3	11	11	12	143	0.77
Rework	1	1	10	10	15	148	0.8
Scrap of work	1	8	13	10	5	121	0.65

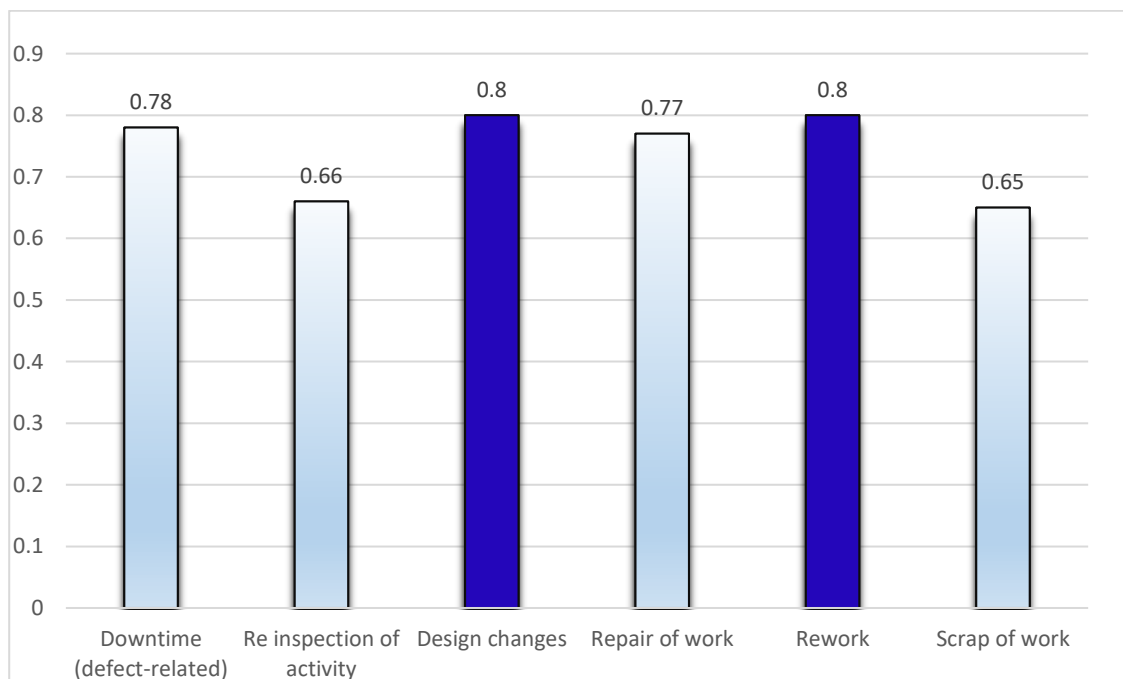


Figure 1

❖ For External failure Costs:

Table 2 RII Index for External Failure Costs

Factors	Very Low (1)	Low (2)	Average (3)	High (4)	Very High (5)	Weighting	Rank
Grievance Redressal	7	13	9	7	1	93	0.50
Warranty Costs i.e. cost of Re checking on Clients complaint	3	11	12	7	4	109	0.59
Scope Creep i.e. changes in scope due to clients change of mind	1	4	10	8	15	146	0.79
Cost of Claims i.e. liability to bear defects	3	9	18	3	4	107	0.57
Returns: investigation of rejected structures	2	9	13	11	2	113	0.61
Hidden costs i.e. repair cost after commissioning of project	1	10	15	4	7	117	0.63

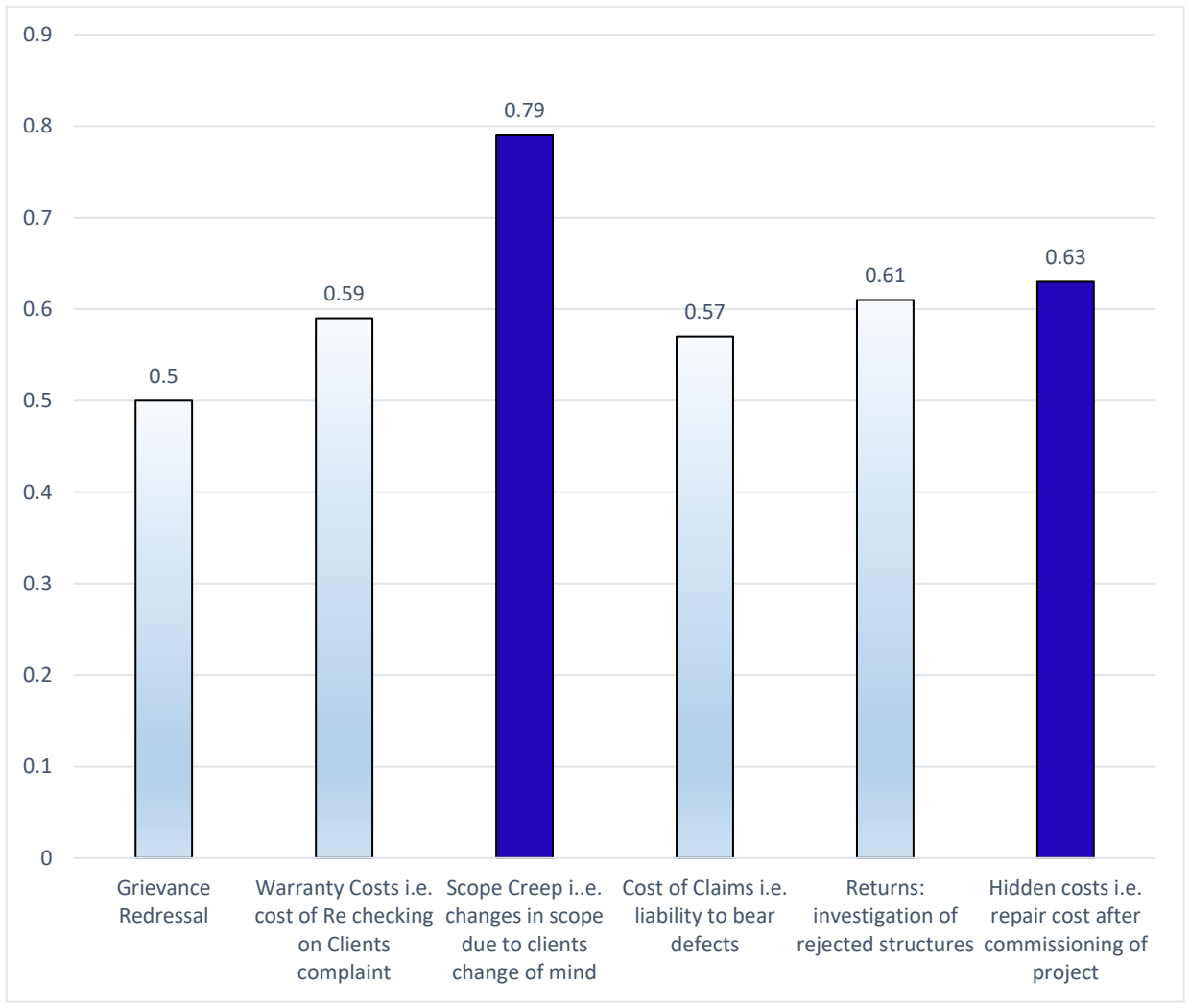


Figure 2

❖ For Prevention Costs:

Table 3 RII Index for Prevention Costs

Factors	Very Low (1)	Low (2)	Average (3)	High (4)	Very High (5)	Weighting	Rank
Quality Strategy i.e. quality plans, Quality records, etc.	2	9	14	9	3	113	0.61
Process Monitoring i.e. Quality checks, documentation, quality test scheduling, process reviews etc.	1	7	11	9	9	129	0.70
Quality circles i.e. employees who meet regularly to consider ways of resolving problems	5	8	13	7	4	108	0.58
Supplier Quality Assurance i.e. Procurement, supplier evaluation, etc.	2	4	15	9	7	126	0.68
Quality Audits i.e. Internal Audit, Third Party Audit, etc.	1	6	11	8	11	133	0.72
Quality Training Programmes i.e. Quality improvement training,etc	1	11	12	9	4	115	0.62

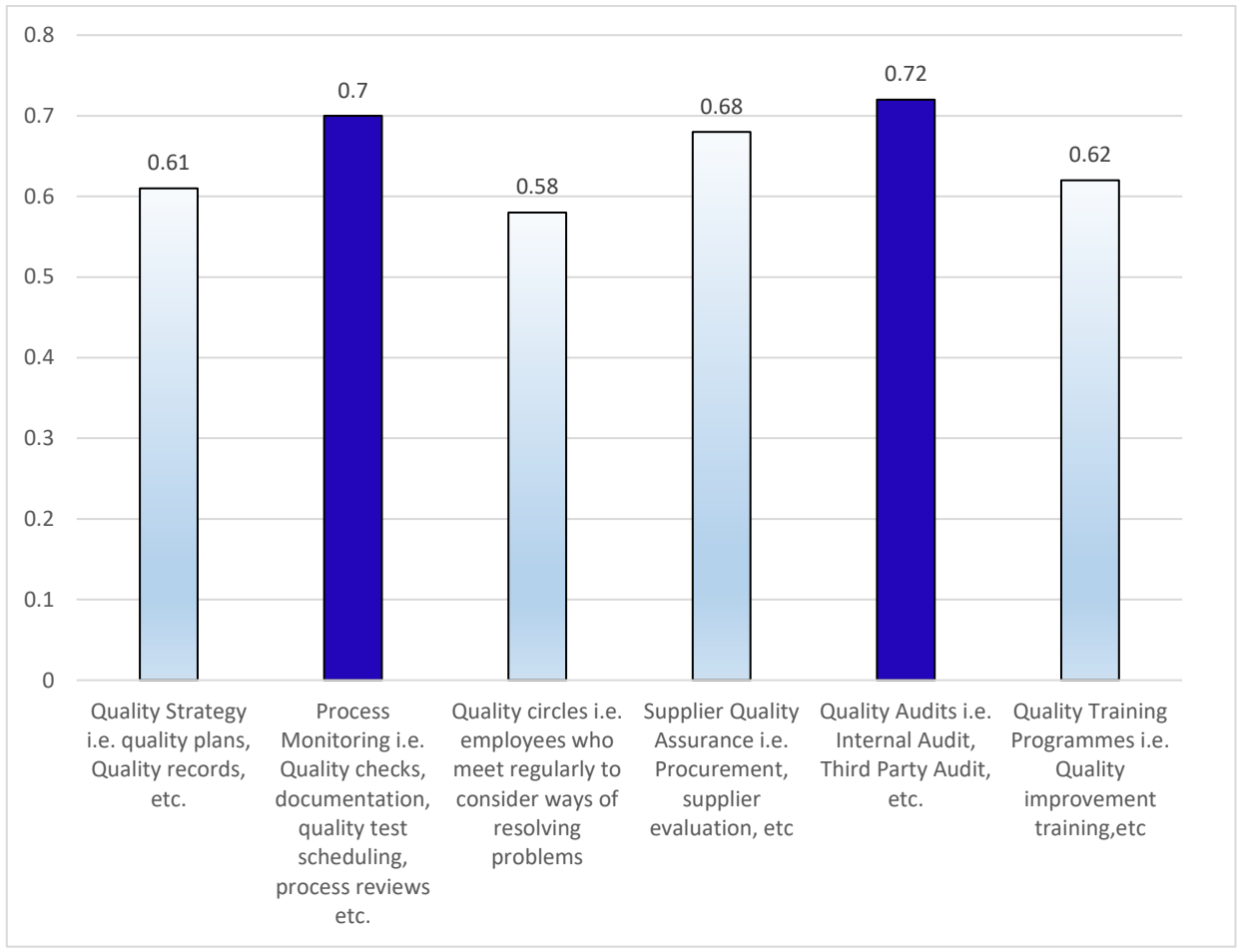


Figure 3

❖ For Appraisal Costs:

Table 4 RII Index For Appraisal Cots

Factors	Very Low (1)	Low (2)	Average (3)	High (4)	Very High (5)	Weighting	Rank
Inspection costs i.e., stock assessment, site inspection, etc.	2	8	15	8	4	114	0.61
Quality tests such as laboratory equipment, materials, etc.	0	3	15	14	5	132	0.71
Maintenance of inspection and measuring equipment	0	12	11	12	2	115	0.62
Quality of product inspection i.e. wages of inspectors, etc.	4	5	18	4	6	114	0.61
Field Testing of Quality	0	2	13	11	11	144	0.78
Maintenance of Quality records and documents	1	7	16	4	9	124	0.67

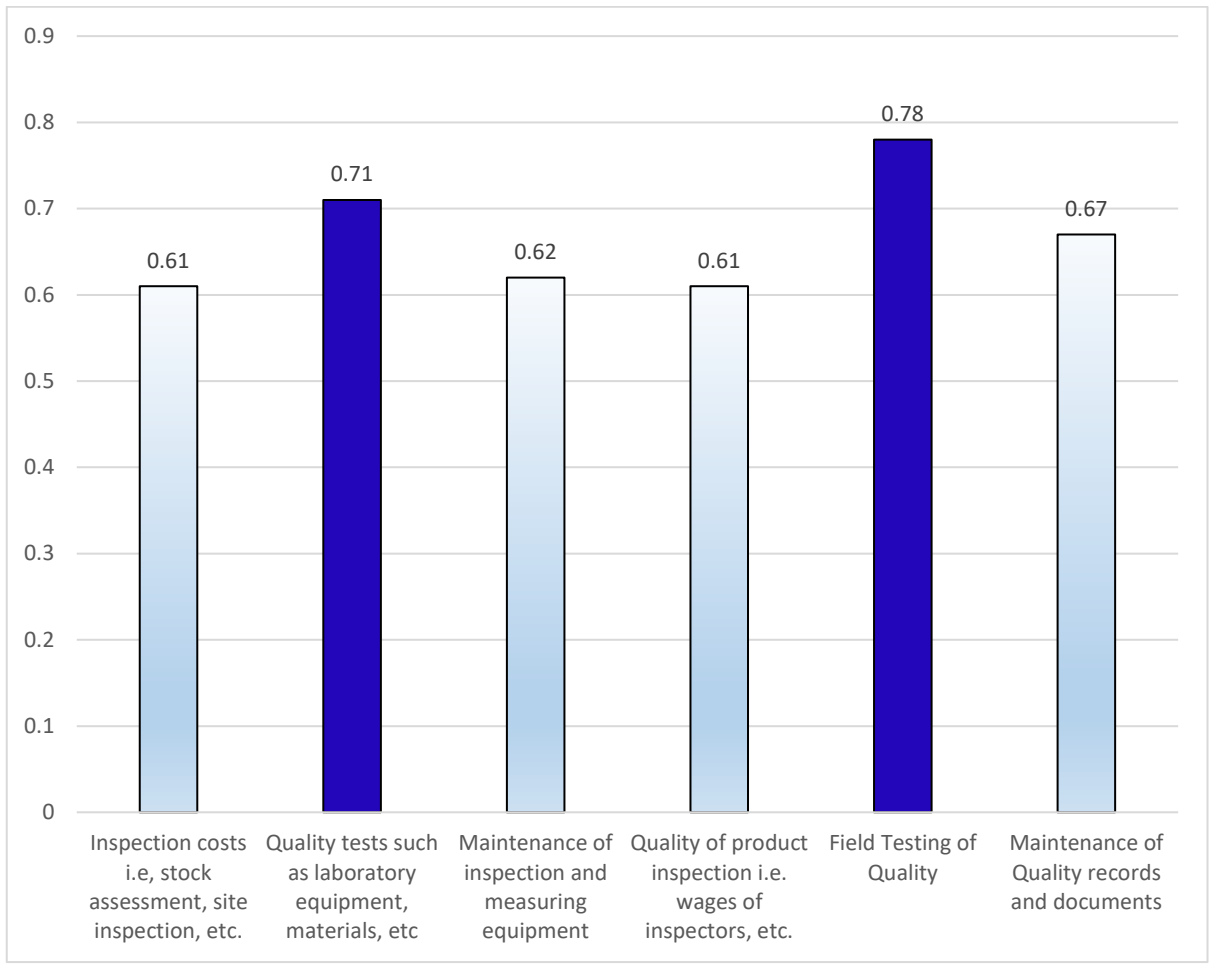


Figure 4

❖ **Major Factors According to rank:**

Table 5 Ranking of Factors

Factors	Rank
Design changes	<u>1</u>
Rework	<u>2</u>
Scope Creep i.e. changes in scope due to clients change of mind	<u>3</u>
Downtime (defect-related)	<u>4</u>
Field Testing of Quality	<u>5</u>
Repair of work	<u>6</u>
Quality Audits i.e. Internal Audit, Third Party Audit, etc.	<u>7</u>
Quality tests such as laboratory equipment, materials, etc.	<u>8</u>
Process Monitoring i.e. Quality checks, documentation, quality test scheduling, process reviews etc.	<u>9</u>
Supplier Quality Assurance i.e. Procurement, supplier evaluation, etc.	<u>10</u>

4.3 Pareto Analysis

Pareto analysis is an effective techniques for analysing the data and determining the most crucial 20% factors which account for 80% of the obstacles.

Pareto analysis for costs of quality states 80% of the quality cost is caused by 20% of the cost of quality factors.

To perform the Pareto analysis, the categories of costs of quality were sorted in descending order according to the number of elements in each category, their percentage and cumulative percentage were obtained. The data in Table 2 were used to achieve the Pareto analysis as in Fig. (2) For all cost of quality categories.

A total of 37 responses were gathered and the data collected is then analysed using the above Technique.

❖ **For Internal Failure Costs:**

Table 6 Pareto Analysis for Internal Failure Costs

Factors	Sum	Percentage	Cumulative Percentage
Design changes	148	17.9	17.9
Rework	148	17.9	35.8
Downtime (defect-related)	144	17.4	53.2
Repair of work	143	17.3	70.5
Re inspection of activity	123	14.9	85.4
Scrap of work	121	14.6	100

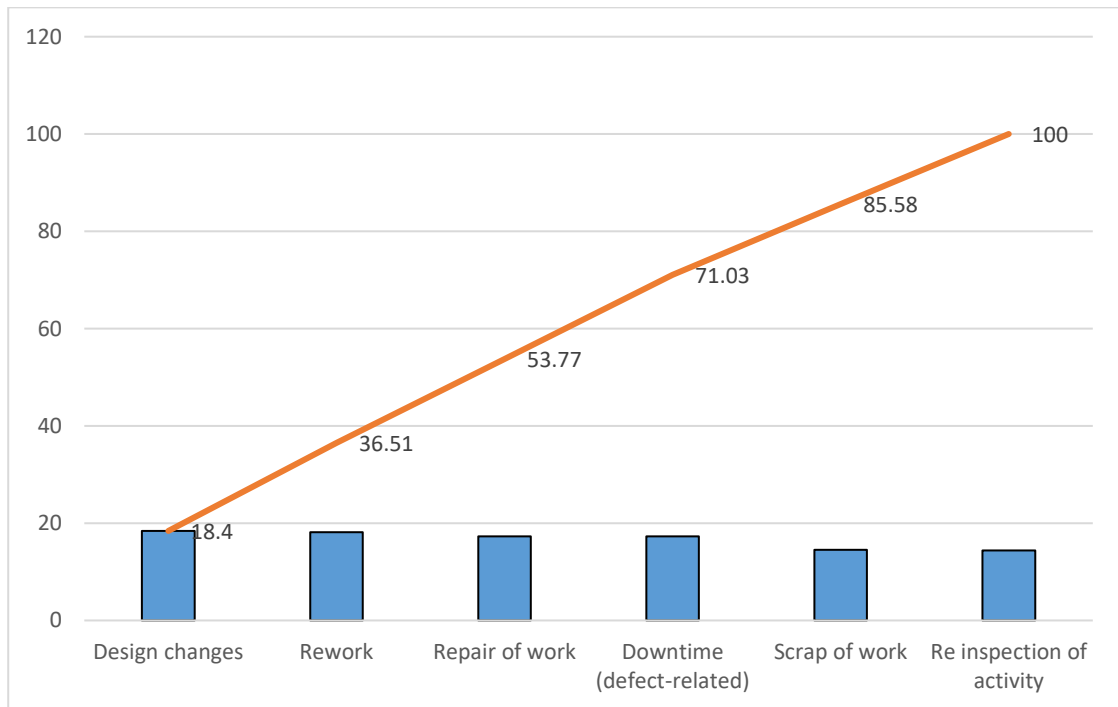


Figure 5

❖ **For External Failure Costs:**

Table 7 Pareto Analysis for External Failure Cost

Factors	Sum	Percentage	Cumulative Percentage
Scope Creep i.e. changes in scope due to clients change of mind	146	21.3	21.3
hidden costs i.e. repair cost after product delivery	117	17.1	38.4
Returns: investigation of rejected or recalled products, including transport costs	113	16.5	54.9
Warranty Costs i.e. cost of Re checking on Clients complaint	109	15.9	70.8
Cost of Claims i.e. liability to bear defects	107	15.6	86.4
Grievance Redressal	93	13.6	100

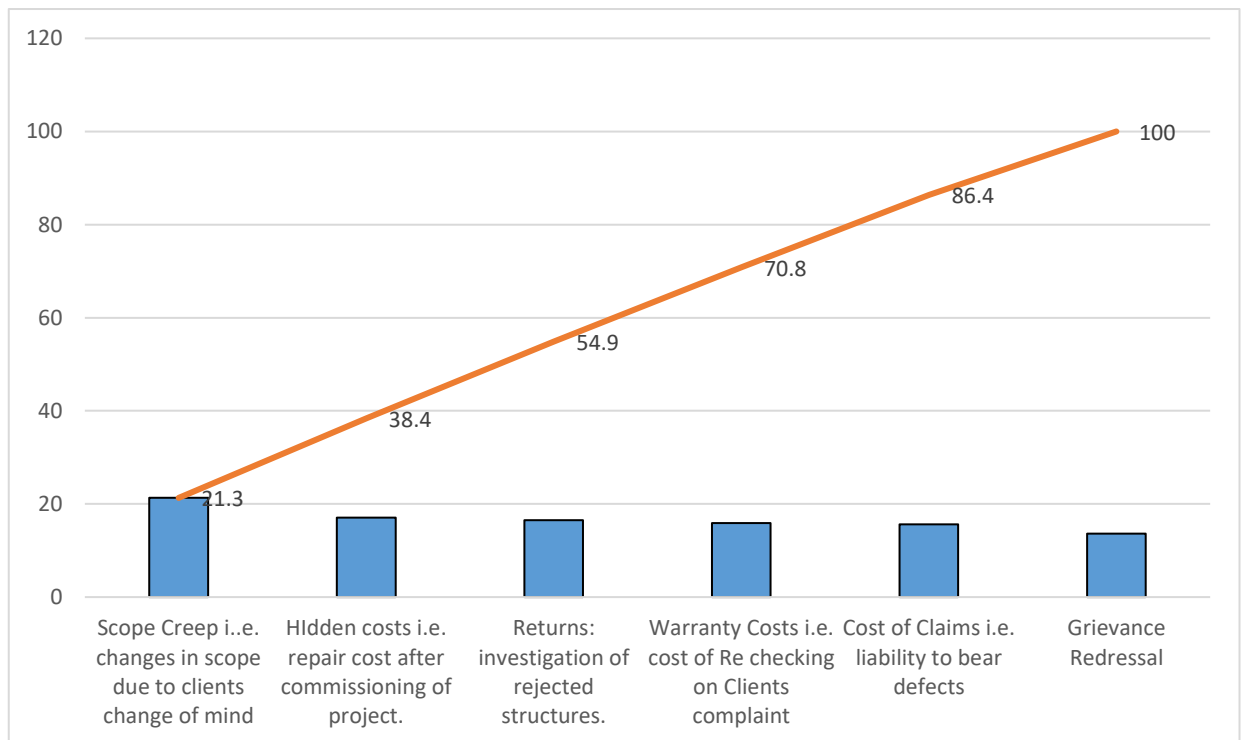


Figure 6

❖ **For Prevention Costs:**

Table 8 Pareto Analysis for Prevention costs

Factors	Sum	Percentage	Cumulative Percentage
Quality Audits i.e. Internal Audit, Third Party Audit, etc.	133	18.3	18.3
Process Monitoring i.e. Quality checks, documentation, quality test scheduling, process reviews etc.	129	17.8	36.1
Supplier Quality Assurance i.e. Procurement, supplier evaluation, etc.	126	17.5	53.6
Quality Training Programmes i.e. Quality improvement training, Quality assurance workshops, etc.	115	15.8	69.4
Quality Strategy i.e. quality plans, Quality records, etc.	113	15.6	85
Quality circles i.e. Employees who meet regularly to consider ways of resolving problems	108	15	100

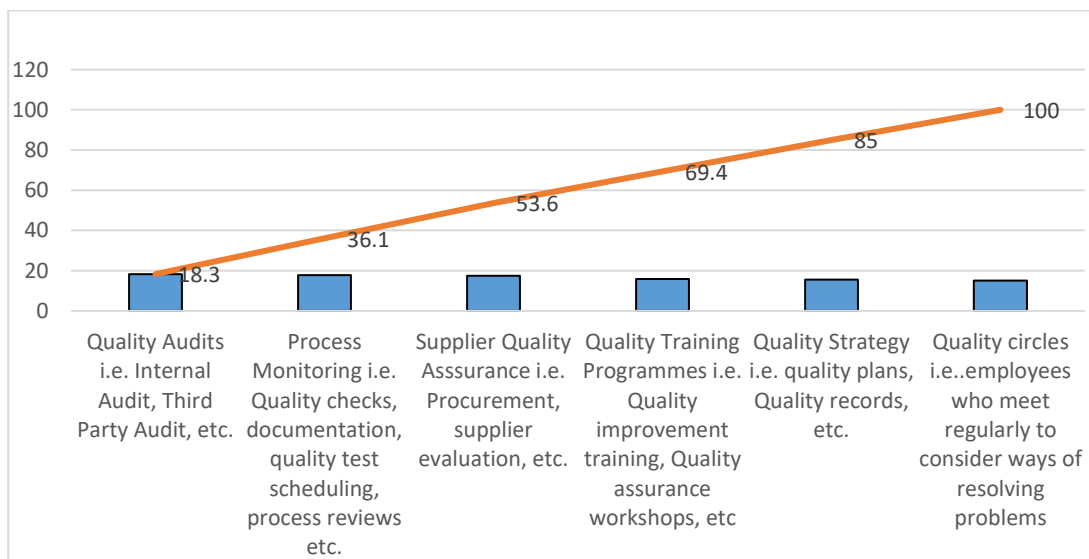


Figure 7

❖ **For Appraisal Costs:**

Table 9 Pareto Analysis for Appraisal Costs

Factors	Sum	Percentage	Cumulative Percentage
Field Testing of Quality	142	19.1	19.1
Quality tests such as laboratory equipment, materials, etc.	132	17.8	36.9
Maintenance of Quality records and documents	124	16.7	53.6
Inspection costs i.e. stock assessment, site inspection, etc.	115	15.5	69.1
Maintenance of inspection and measuring equipment	115	15.5	84.6
Quality of product inspection i.e. wages of inspectors, etc.	114	15.4	100

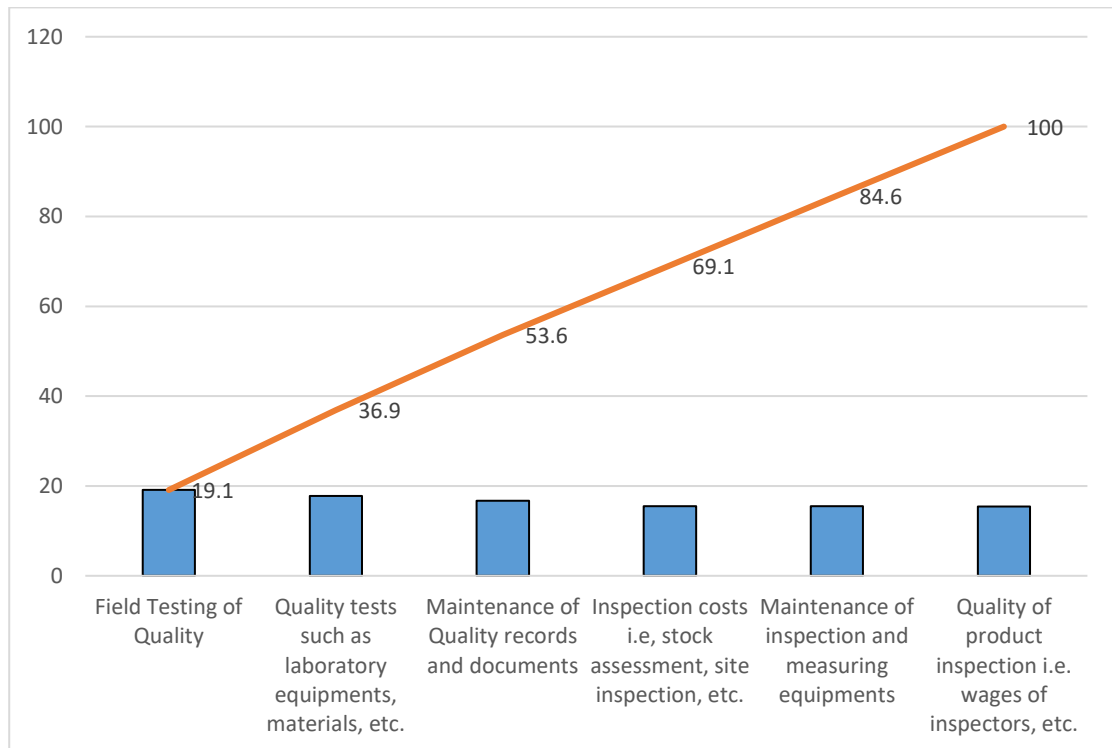


Figure 8

❖ **For Total Costs:**

Table 10 Pareto Analysis for Total Costs

Factors	Sum	Percentage	Cumulative Percentage
Internal Failure Costs	827	27.8	27.8
Appraisal Costs	742	24.9	52.7
Prevention Costs	724	24.3	77
External Failure Costs	685	23	100

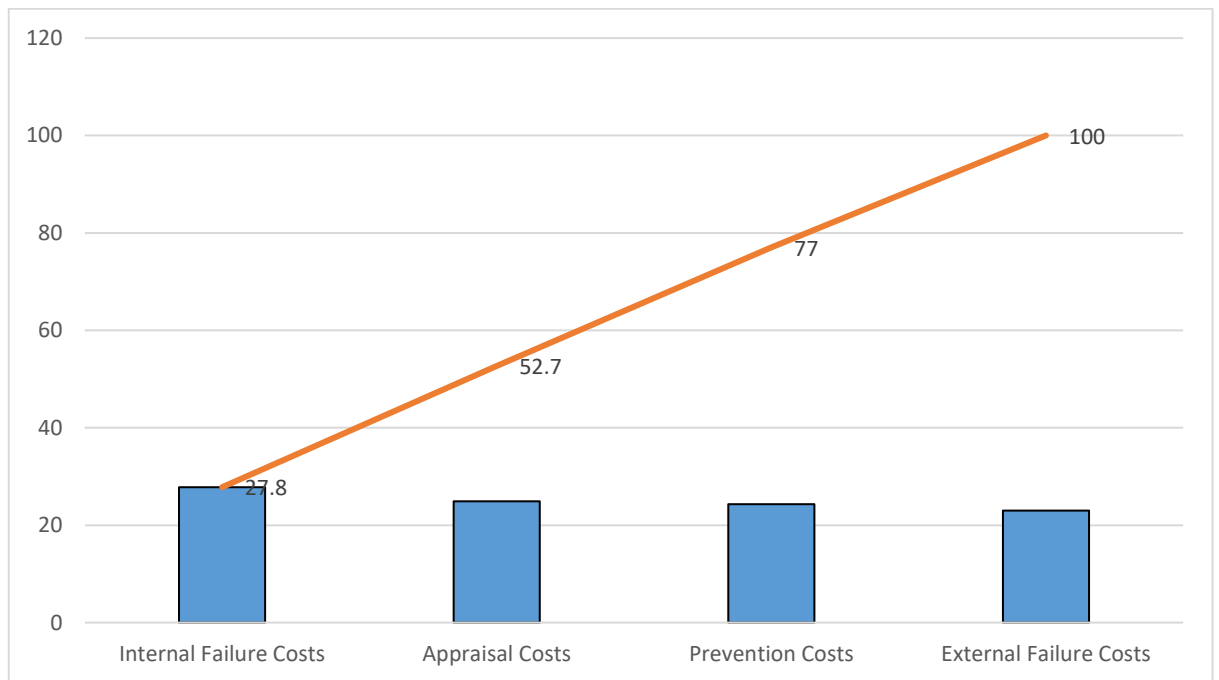


Figure 9

4.5 Data Analysis using SPSS;

SPSS is a well-known software for performing the data analysis. It also analyses the stability of Questionnaire Survey through Alpha Cronbach analysis.

Majority of the statistical analysis could be performed through this.

- To ensure the stability of the questionnaire, Alpha Cronbach was measured using SPSS V16. Following shows the stability coefficient of the research.
- A scale of 1 to 5 was chosen representing from *very low to very high*.
- This indicates that the stability coefficient of the questionnaire is good, where the stability coefficient should not be **less than 70%**.

Reliability Statistics

Cronbach's Alpha	N of Items
.713	24

Figure 10 Reliability of the Survey

4.5.1 Histogram:

Histogram of the top 10 factors identified in the previous analysis is shown below:

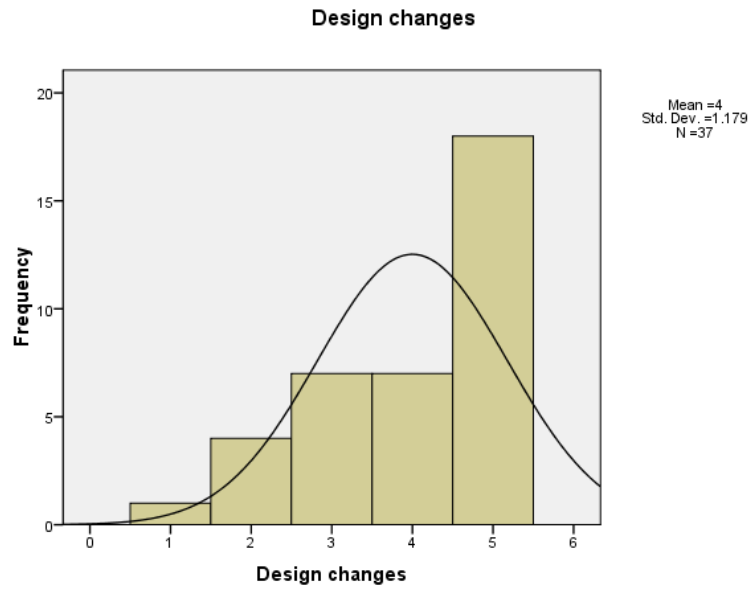


Figure 11

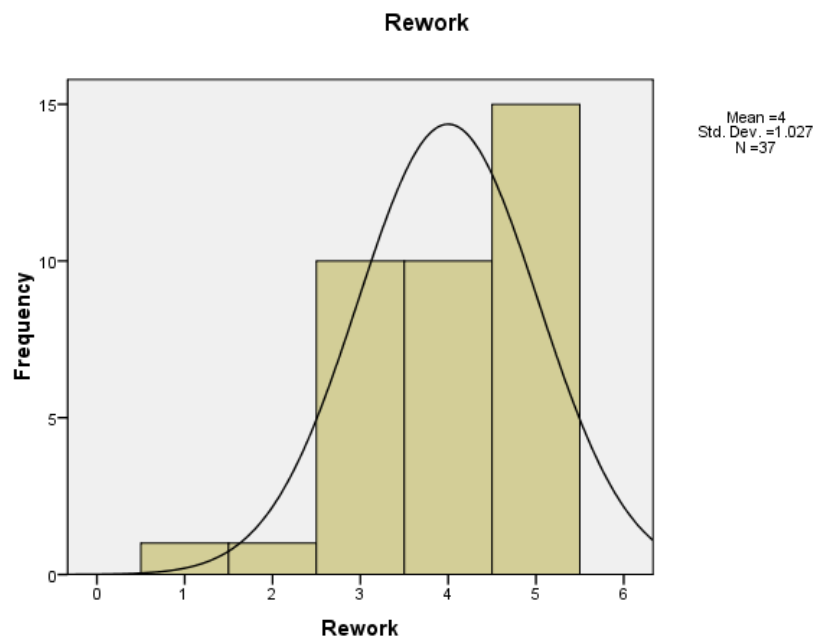


Figure 12

Scope Creep i.e. changes in scope due to clients change of mind

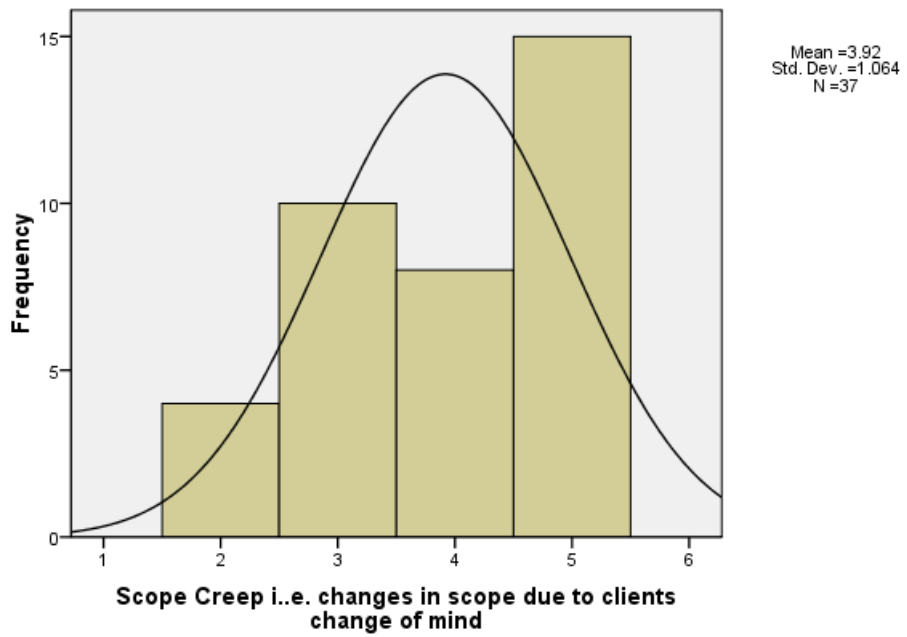


Figure 13

Downtime (defect-related)

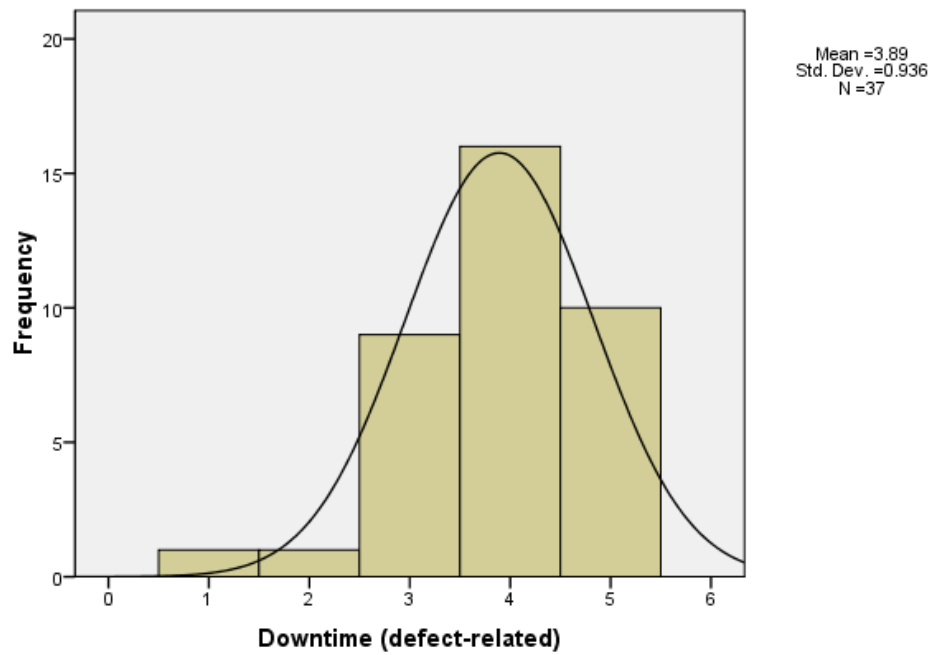


Figure 14

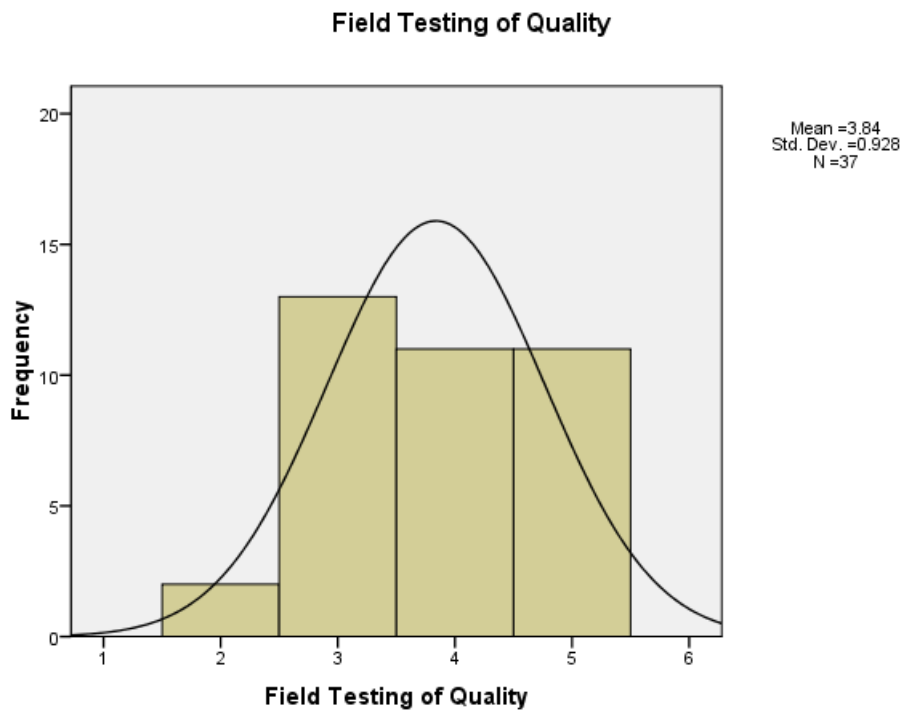


Figure 15

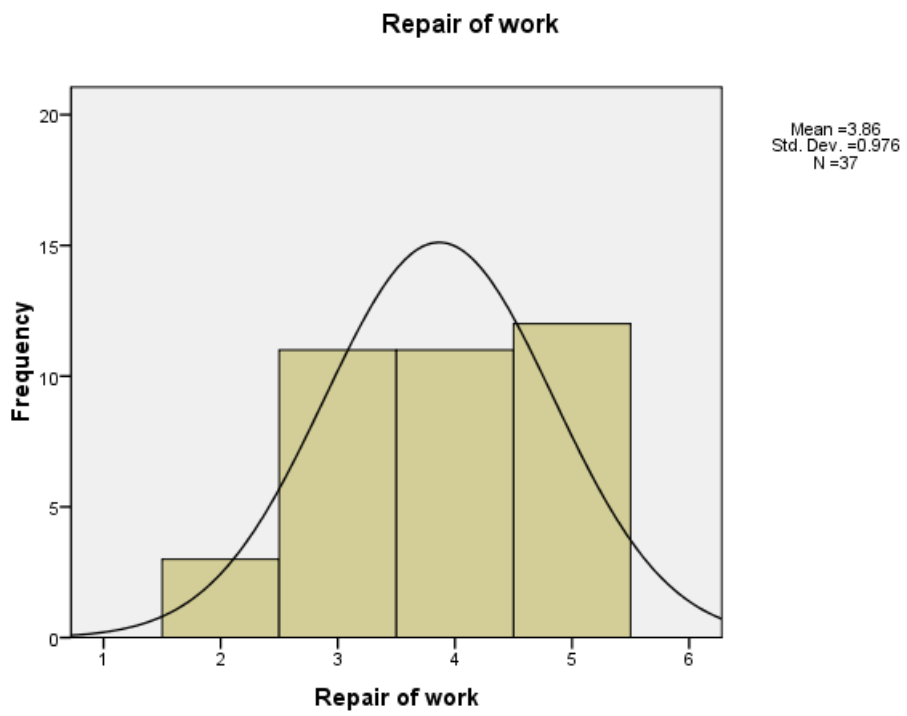


Figure 16

Quality Audits i.e. Internal Audit, Third Party Audit, etc.

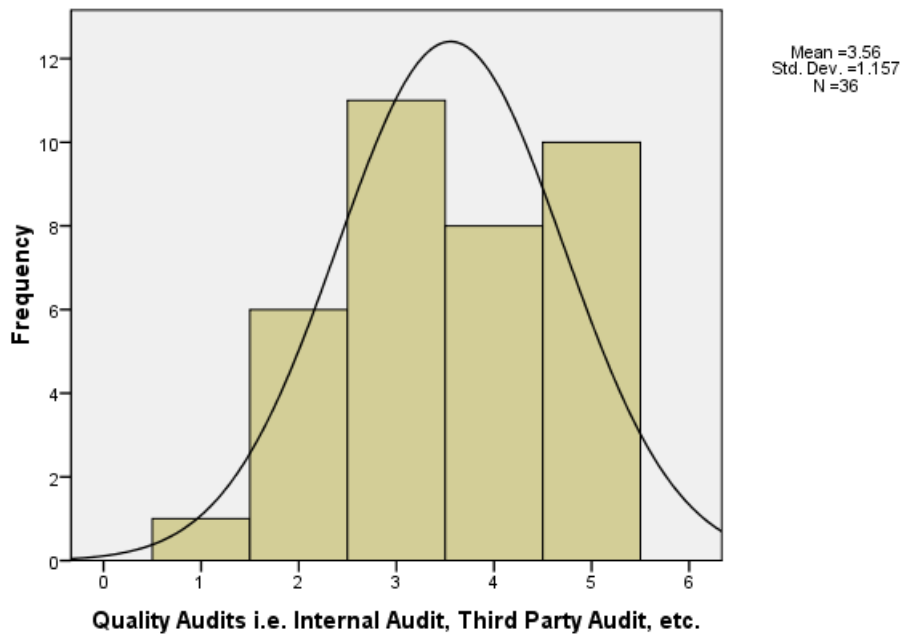


Figure 17

Quality tests such as laboratory equipments, materials, etc.

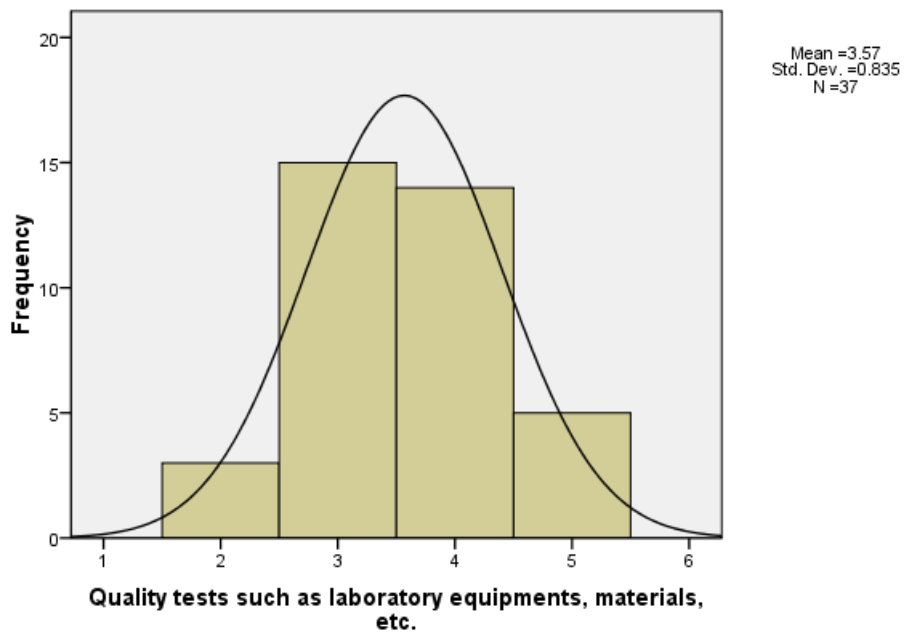


Figure 18

Process Monitoring i.e. Quality checks, documentation, quality test scheduling, process reviews etc.

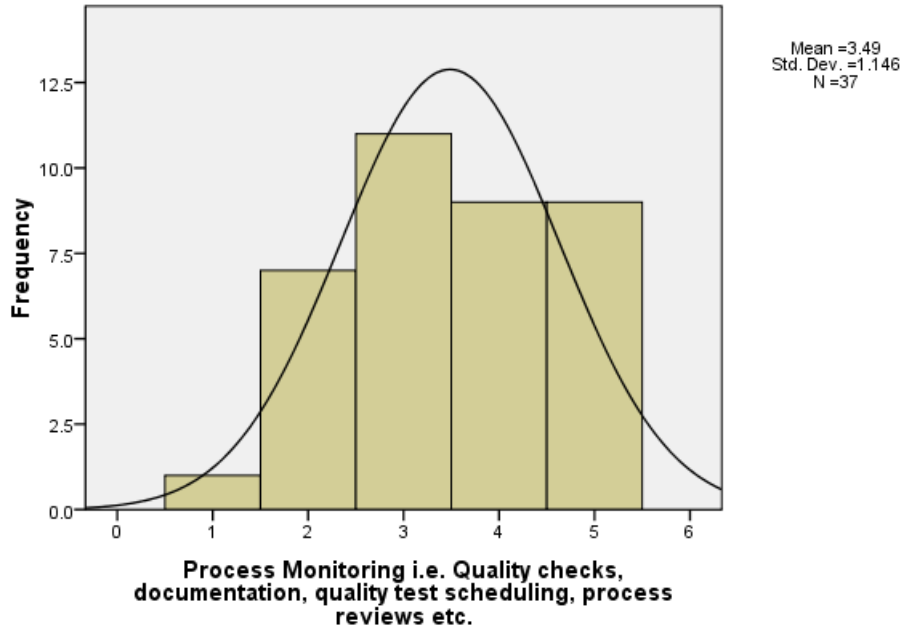


Figure 19

Supplier Quality Assurance i.e. Procurement, supplier evaluation, etc.

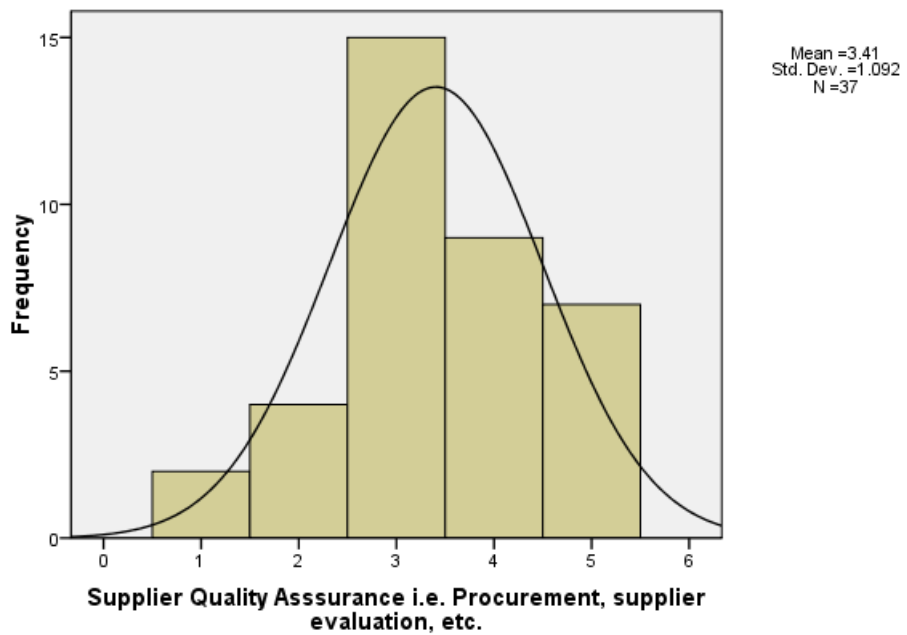


Figure 20

CHAPTER 5

RESULT AND DISCUSSION

There has been a general notion in construction Industry that financial stability and liquidity is the basis of quality so most people do not work for the quality at the expense of losing their money. Therefore this research aims at identifying the factors which impact the cost of Quality and how these factors could be catered in order to reduce the cost.

Based on the findings of the questionnaire Survey, several astonishing results have been witnessed. The findings throw light on the identification of major factors responsible for increase in cost of Quality in construction.

Majority of respondents responded to all the questions which lead to an accurate and effective data collection.

According to majority of respondents, their perception of cost of quality was just about procuring best materials and using best standard practises, however cost of quality is a wider and broader term with several interlinked factors. This implies that cost of quality is still a less known topic among the construction players.

Results of some introductory questions of survey also bring significant information about the notion of quality. It reflects that **83.33%** of people believed that there is a dire need of quality improvement in construction while **7%** of people believed that May be there is a need.

About **52.4%** people defined *quality as the best fit for purpose being served* while **31%** of the people defined it as *high conformance to standards ad specifications*. Only a few people of about **16.7%** defined it as having zero defects in the system.

The answer of yet another important question revealed that **more than 50%** of the respondents believed that the most crucial stage for Quality Management in terms of Cost of Quality is the *Execution Stage*. Around **23%** believed that *Monitoring and Controlling Stage* is the most crucial phase of construction.

After data analysis, following points got highlighted for:

The results of field study clearly depict that Internal Failure cost have the most impact on cost of quality. Within Internal Failure costs, design changes and rework are the topmost factors responsible for increasing the cost of Quality in construction.

Result of RII analysis shows that the third topmost factor affecting the cost of Quality is Scope creep which falls under the external failure cost.

Prevention cost and Appraisal cost also have significant impact on the overall cost of Quality.

The lowest impact on Cost of Quality is of External Failure costs. Based on the data collected and analysed.

Following Table shows the most Crucial Factor in each type of Cost:

Table 11 Final List of Crucial Factors

<u>Type Of cost</u>	<u>Most Crucial Factor</u>
Internal Failure Costs	Design changes
Appraisal Costs	Field Testing of Quality
Prevention Costs	Quality Audits i.e. Internal Audit, Third Party Audit, etc.
External Failure Costs	Scope Creep i.e. changes in scope due to clients change of mind

CHAPTER 6

CONCLUSION

Based on the data analysed, it is observed that the major factors affecting cost of Quality fall under the regime of Internal Failure Costs and the Prevention Costs.

A Ranking list of Factors has been obtained according to the analysis for the most crucial factors.

As per the observations, major factors impacting Cost of Quality need to be managed with utmost care and efficiency.

As far as the major crucial factors identified for each type of Quality cost. There is a huge scope of this study in the domain of Quality management with regard to cost of Quality.

Some Recommendations on how these factors could be minimized are as follows:

□ *Verifying Personnel Training and Certification*

Personnel must be certified as competent supported education, training, skills, and knowledge. Personnel qualification processes must be standardized and documented.

□ *Verifying Equipment Calibration*

Equipment resources must be maintained to assure their optimal performance to capabilities and functions, especially measurement equipment and to verify the brand. The upkeep and calibration processes for equipment and tools must be standardized and documented.

□ *Supplier Collaboration Portal*

A Supplier Portal is quite an innovative area to post files for the supplier. It's an area to collaborate online with suppliers by exchanging communications, extending solutions and dispatching tasks.

Secure cloud-based portals let suppliers view open Corrective Actions, helping resolve problems faster and thereby reducing cost of Quality.

❑ **Faster Event Resolution**

Addressing catastrophic events and before they become systemic issues is key to reducing costs. Looking at the biggest quality issues in survey, it's clear the costliest problems are those that weren't effectively managed from the beginning.

❑ **Streamlined Change Management**

In today's economy, the ability to evolve and grow is necessary to keep up with the competition prevailing in construction sector. Unfortunately, the sheer and high cost of any proposed change can make it difficult for companies to stay agile.

❑ **Continuous Risk Reduction**

Effective Risk Management is critical to reducing quality costs at all phases of construction. Audits generate lots of data, frequently leading to a long list of potential action items. This data could help in identifying high-risk items (and likely contributing the most to quality costs), helping a person to prioritize follow-up in a strategic way.

❑ **The intangible costs** of external quality failures (including customer dissatisfaction, loss of reputation and loss of future sales) might be difficult to calculate, but are not hard to portray as having a huge negative impact on the future prospect. The best way to reduce external failure cost is to not have them at all at first. The best way to dodge external quality failure costs is to focus on improving the other three costs of quality.

► Unless quality is internalized at the personal level in any construction organization. It will never become engrossed in the culture of an organization.

► Thus quality must begin at a personal level at best

And that means YOU!

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List of Publication

- It comprises of the research paper that is being published after the completion of the work.
- The following Research paper is published in the sixth issue of the eighth volume of ***International Research Journal of Engineering and Technology***(IRJET).
- IRJET is a peer reviewed and multidisciplinary journal in various discipline of Science, Engineering and Technology.

Assessment of Factors Affecting Cost of Quality in Construction Project

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Abstract – Quality management is one of the most important consideration in any infrastructure construction project. Cost of Quality is one of the most significant parameter for analyzing the quality performance of any construction Project. It becomes increasingly necessary to pay attention to measurement of cost of Quality and optimizing it. This research paper deals with identifying the major types of cost of quality and the prime factors which affect this. The data collected through survey analysis was analyzed through Pareto Analysis to obtain the desired results. The field survey showed that the Internal Failure cost have the utmost impact on the Cost of Quality. Prevention and Appraisal cost also provide huge Impact on Cost of Quality as compared to External Failure Costs. Based on these results, several points of Optimizing Cost of Quality have been suggested.

Key Words: Quality Management, Cost of Quality, Quality Performance, Pareto Analysis

1. INTRODUCTION

Due to the development of the economy in the developed countries, competition has led to the survival of the fittest. Due to increased competition in the market, there is an increasing obligation on the construction companies to improve their internal quality and strengthen management. It specifically means that companies need to improve quality control in order to satisfy the needs of quality assurance of customers. [1]

Quality is a quite wide word that has a lot of meanings and for different people often means different things. Quality control and safety represent increasingly important concerns for project managers. [2]

Defects or failures in constructed facilities can result in very large costs. Even with minor defects, re-construction may be required and facility operations impaired. Increased costs and delays are the results [3]. In the worst case, failures may cause personal injuries or fatalities. Accidents during the construction process can similarly result in personal injuries and large costs. Indirect costs of insurance, inspection and regulation are increasing rapidly due to these increased direct costs. Good project managers try to ensure that the job is done right the first time and that no major accidents occur on the project. [4]

1.1 Quality Costs

Quality costs may be regarded as a criterion of quality performance but only if valid comparisons can be made between different sets of cost data. Clearly the comparability of sets of data is dependent on the definitions of the categories and elements used in compiling them.

Quality is one of the most important and significant dimension of any construction project. From the inception to completion of any activity involved in construction, quality is one parameter which is kept on constant check at every stage [5]. There are different standards and procedures for checking the quality at each and every stage which involves different kinds and types of costing required. Quality costs generally refers to the cost involved or incorporated in maintaining and adhering to the necessary specific standards and desirable outcomes.

No matter which quality costing approach is employed, the most basic idea behind the Cost of Quality analysis is the linking of improvement activities with associated costs and customer expectations, thus allowing targeted action for reducing quality costs and increasing quality improvement benefits. Therefore, a sensible estimate of Cost of Quality, which is that the appropriate trade-off between the amount of conformance and non-conformance costs, should be considered an important element of any quality initiative and an important issue for any manager. Variety of organizations are now seeking both theoretical advice and practical evidence about quality related costs and therefore the implementation of quality costing systems. [6]

1.2 Major Categories of Quality Costs

a. Internal Failure Costs

Internal failure costs are incurred because products and services do not conform to specifications or Client needs.

b. External Failure Costs

External failure costs are incurred because products and services fail to conform to requirements or satisfy customer needs after being delivered to Client.

c. Prevention Cost

Prevention costs are incurred to prevent poor quality in the products or services being produced.

d. Appraisal Costs

Appraisal costs are incurred to determine whether outcomes are conforming to their requirements or Client needs.

2. LITERATURE REVIEW

During the beginning of 20th century, a new technique of quality control i.e. statistical process control was introduced by Stewart. After the mid of 20th century, several other notable persons such as B G Dale, Crosby and Juran gave some phenomenal concepts about quality assurance, quality control and Total Quality Management.

Since the onset of the 21st century much debate is about how to improve quality with minimal effect on other parameters such as time, cost, etc. Many researchers focused on this aspect of construction and tried to carve out new inferences and conclusions which would be beneficial for the academic sector as well as the industrial sector.

Dickson Sam J Danam says that in today's construction industry, quality and its concepts are vital. The authors are of the view that Total quality management principles and philosophy apply to construction industry. He emphasizes the total quality principles should be impregnated construction industry in an innovative manner. Several contradictions to this could be possible which need to be studied thoroughly. [7]

Several strategies are formed keeping in view the leadership aspect of Quality. Paul Schiltz focussed on the effect of leadership on quality in an organization. This research demonstrates that what type of leadership characteristics best support the quality management function. The author provides valuable insights into questions concerning which leadership characteristics best support the leadership prescribed by Deming, Juran and others concerned with quality [8]. Peter Hoonakker discussed the difficulties in construction industry for defining quality, determined benefits quality implementation, and at barriers to implementation of quality in construction. They collected data with the help of questionnaire. They showed development which may help to overcome failure. From the finding they stated that contractors do know the value of quality but there are obstacles for implementation. [9]

A.I. Romanova researches into creating a unified approach to the organization of the control system and the evaluation of the quality of construction at the facilities of the investment. The author specifies some particular problems related to quality and finds out the possible solutions related to quality in construction. The author tries to provide an approach which aims towards building a self-regulatory organization. [10]

Sahil sanjeev Salvi focussed on the point that the construction industry faces a huge economic loss due to loss of quality in construction projects. He emphasized on internal quality control and quality assurance as the key two factors which would greatly impact the quality on construction site. He argues about the point that there are several contradictions to quality which needs to be monitored. [11]

Vishal Patil focussed on cost of poor quality in construction. The author tries to review the use of quality

in construction industry. The author throws light on the issue that defective building construction not only contributes to added construction cost of the project but also the cost of maintenance, which can be substantial. According to research done by author, the cost of quality is equivalent to 1% of the total project cost. [12]

Maysoon Abdullah Mansor draws attention to the measurement and determination of cost of quality so as to identify qualitative problems and opportunity for improvement of work done. The author identifies the categories and item of cost of quality through theoretical literature then uses Pareto analysis to find the high impact categories and items on the cost of quality. The findings show that prevention and appraisal items have an important influence in minimizing the failure cost where the quality audit cost is of utmost importance. This research uses a very reliable technique such as Pareto analysis for coming to conclusions. [13]

3. METHODOLOGY

A thorough literature review was conducted in order to gain a profound and deep knowledge about the cost of Quality. A questionnaire survey was prepared by choosing the major factors which impact the cost of Quality in Construction. A scale of 1-5 was taken representing from very low to very high for each factor stated below. This Survey was floated among the major stakeholders of construction for data collection.

Factors Chosen for the Survey Analysis

- Quality Audits i.e. Internal Audit, Third Party Audit, etc.
- Process monitoring i.e. Quality checks, documentation, quality test scheduling, process reviews etc.
- Supplier Quality Assurance i.e. Procurement, supplier evaluation, etc.
- Quality Training Programmes i.e. Quality improvement training, Quality assurance workshops, etc.
- Quality Strategy i.e. quality plans, Quality records, etc.
- Quality circles i.e. employees who meet regularly to consider ways of resolving problems
- Field Testing of Quality
- Quality tests such as laboratory equipment, materials, etc.
- Maintenance of Quality records and documents
- Inspection costs i.e. stock assessment, site inspection, etc.
- Maintenance of inspection and measuring equipment.
- Quality of product inspection i.e. wages of inspectors, etc.

- Design changes
- Rework
- Downtime (defect-related)
- Repair of work
- Re inspection of activity
- Scrap of work
- Scope Creep i.e. changes in scope due to clients change of mind
- Hidden costs i.e. repair cost after product delivery
- Returns: investigation of rejected or recalled products, including transport costs
- Warranty Costs i.e. cost of Re checking on Clients complaint
- Cost of Claims i.e. liability to bear defects
- Grievance Redressal

To ensure the stability of the questionnaire, Alpha Cronbach was measured using SPSS V16. Following shows the stability coefficient of the research. This indicates that the stability coefficient of the questionnaire is good, where the stability coefficient should not be **less than 70%**.

Reliability Statistics

Cronbach's Alpha	N of Items
.713	24

Figure -1: Reliability of Survey

Pareto Analysis was performed on the data gathered for getting the most crucial points for cost of Quality.

4. RESULT AND DISCUSSIONS

After performing the Pareto analysis following results were gathered:

For Internal Failure Costs

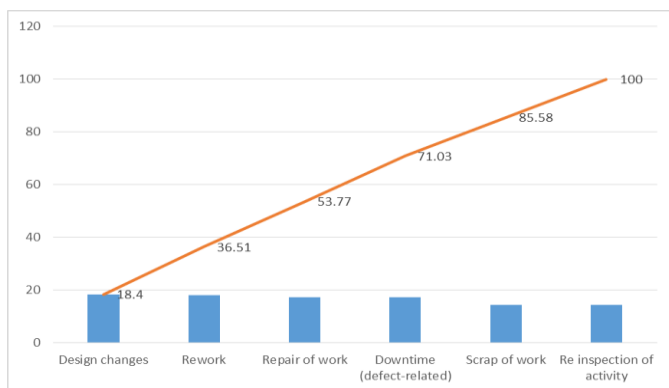


Figure -1: Result of Pareto Analysis for Internal Failure Cost

For External Failure Costs

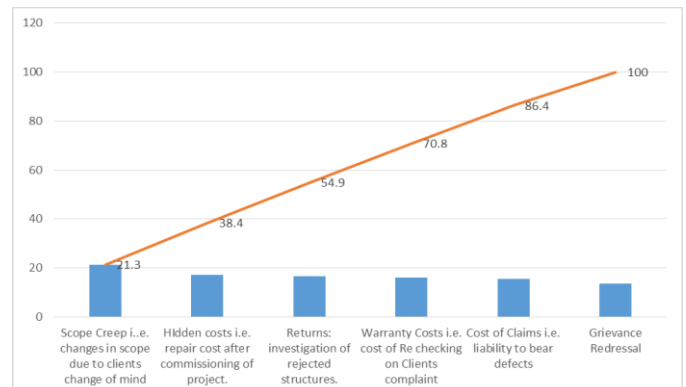


Figure -2: Result of Pareto Analysis for External Failure Cost

For Prevention Costs

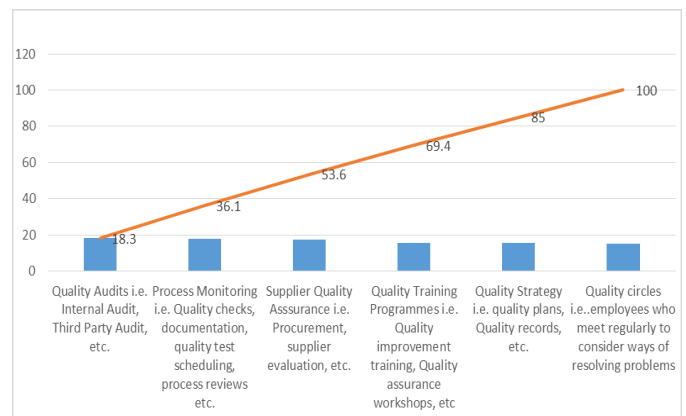


Figure -3: Result of Pareto Analysis for Prevention Cost

For Appraisal Costs

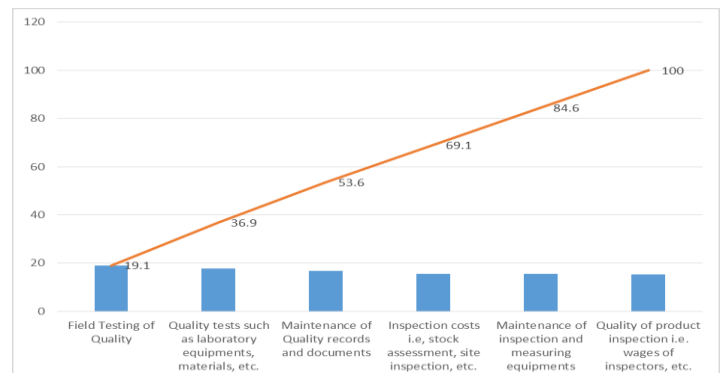


Figure -4: Result of Pareto Analysis for Appraisal Cost

For Total Costs

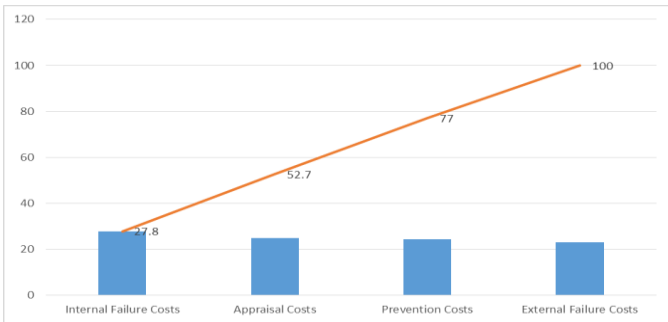


Figure -5: Result of Pareto Analysis for Total Costs

According to majority of respondents, their perception of cost of quality was just about procuring best materials and using best standard practises, however cost of quality is a wider and broader term with several interlinked factors. This implies that cost of quality is still a less known topic among the construction players.

Results of some introductory questions of survey also bring significant information about the notion of quality. It reflects that **83.33%** of people believed that there is a dire need of quality improvement in construction while **7%** of people believed that maybe there is a need.

About **52.4%** people defined *quality as the best fit for purpose being served* while **31%** of the people defined it as *high conformance to standards ad specifications*. Only a few people of about **16.7%** defined it as having zero defects in the system.

The results of field study clearly depict that Internal Failure cost have the most impact on cost of quality. Within Internal Failure costs, design changes and rework are the topmost factors responsible for increasing the cost of Quality in construction.

Table -1: List of Most Crucial Factors

Type Of cost	Most Crucial Factor
Internal Failure Costs	Design changes
Appraisal Costs	Field Testing of Quality
Prevention Costs	Quality Audits i.e. Internal Audit, Third Party Audit, etc.
External Failure Costs	Scope Creep i.e. changes in scope due to clients change of mind

5. CONCLUSION

Based on above results it could be concluded that there is need to assess the crucial points impacting cost of quality in construction.

Based on above analysis and results, some points which could be recommended for improving cost of quality are as follows:

Personnel must be certified as competent supported education, training, skills, and knowledge. Personnel qualification processes must be standardized and documented. A Supplier Portal is quite an area to post files for the supplier. It's an area to collaborate online with suppliers by exchanging communications and dispatching tasks. Secure cloud-based portals let suppliers view open Actions or correction, helping resolve problems faster. Addressing adverse events before they become systemic issues is a key to reducing quality costs. Looking at the factors highlighted from the survey, it's clear the costliest problems are those that weren't effectively managed from the beginning.

In today's economy, the ability to grow and excel is necessary to keep up with the competition. Unfortunately, the sheer cost of any proposed and revised change can make it difficult for companies to stay agile. Effective Risk Management is significantly critical to reducing quality costs. Quality Audits generate a lot of structured and unstructured data, frequently leading to a long list of potential action items. This data could help in identifying items which are at high risk (and likely contributing the most to quality costs), helping you prioritize follow-up in a strategic way.

The intangible costs of external quality failures (including customer dissatisfaction, loss of respect and loss of future sales) might be difficult to calculate, but are not hard to picture as having a huge negative impact on the future prospect. The best way to minimize external failure cost is to not have them at all. The best way to ignore external quality failure costs is to focus on improving the other three parameters of costs of quality.

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