Global Scientific JOURNALS

GSJ: Volume 8, Issue 7, July 2020, Online: ISSN 2320-9186

www.globalscientificjournal.com

ANALYSING THE QUALITY OF A ROAD THROUGHOUT THEIR LIFE CYCLE.

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ABSTRACT

To Measure the quality in an integrated form is necessary to evaluate the performance of any project. A number of papers have been published for evaluating qualities of construction projects. However, limited studies are reported on the measurement of quality in an integrated form. To address this research gap in the body of knowledge, this study is aimed at identifying and analysing the quality of a road throughout their life cycle. Different stages of quality such as concept, design, construction, conformance and quality of performance are considered in this study. On the basis of both, detailed literature review and expert opinions, a total of 54 factors were identified and then a questionnaire was developed to obtain the opinions of respondents to measure the effect of each factor identified. The questionnaire was circulated to owners, engineers, contactors, design consultants, construction managers and 27 responses were received. The effect of each factor was measured in terms of its importance index and then was ranked accordingly. The reliability analysis of data obtained is done using Statistical Package for the Social Science (SPSS). The result of this study demonstrates that owner's policy and effective quality management system found to be highly significant factor at conceptual stage. In the design quality, the nature and type of subgrade soil and design errors found to be extremely important factors. Similarly, quality of raw materials i.e. aggregate etc. and method of construction are of prime importance in quality of construction. Effectiveness of QA/QC program and subgrade failure, rutting, shoving are significant factors for quality of conformance and performance respectively. The findings of this study will help the project managers to focus on the critical

factors in order to achieve better quality in construction of road projects which will result in less maintenance cost.

Keywords : Critical factors, Lifecycle, Project management, Quality, SPSS.

1. INTRODUCTION

1.1. General

Every construction project is unique in nature and differs from another project in terms of period, scope, purposes, risks, difficulties and some other measurements. Because of these constraints, the construction industry is always facing chronic problems such as cost overrun, time overrun, low productivity poor quality of construction, high construction waste etc. Projects are reportedly failing across all the key performance measures including time, cost and quality. Understanding the important factors affecting all these key performance measures is still an area of research all over the globe. Among various issues, poor construction quality is a serious issue faced by the construction industry globally, although its magnitude varies considerably among the projects (Ali and Wen, 2011). Achievement of acceptable quality levels in the construction industry has long been a problem (Griffith and Sidwell, 1997). Quality is the most important factor in the success of construction projects. However, numerous reports have condemn the construction industry, especially in terms of quality (Ali, 2010), and the majority of construction managers focus on the time and cost instead of quality for construction projects, but the research scholars highlight more attention should be given towards quality (Mane and Patil, 2015).

The measurement of quality in an integrated form is necessary to evaluate the performance of any project. A construction project goes through various stages i.e. lifecycle of quality such as quality of concept, design, construction, conformance and performance. Improvement in the quality of construction projects is linked with quality management in the project life cycle (Mallawaarachchi and Senaratne, 2015). Similar to time and cost, quality is an important function in all infrastructure developments. In roadway construction industry, quality is a key factor in assessing how well a road pavement will enact under traffic loading and when exposed to environment. Furthermore, it gives a tool to the clients and construction professional's to ensure that the desired results are obtained to produce high quality and long life roads. In roadway construction projects, the ultimate goal of an owner is to construct a road that will have high serviceability and durability under the local climatic conditions and traffic to which the road pavement will be exposed during its service life. A

road pavement performance is a function of the road's quality which is influenced by various factors such as pavement's structural design, construction materials and the construction process by which these materials are built into pavement, quality control programs implemented etc. Depending upon the above mentioned factors, the pavement deteriorates with the passage of time and the rate of deterioration varies widely (Ebrahim Abu El-Maaty et al., 2016). However, good quality of construction will greatly reduce the rate of deterioration. Awareness of the critical factors amongst these will help the project managers to achieve better quality in road construction and performance. Road infrastructure involves a large construction cost for achieving high quality which could be reduced by this study.From the literature survey related to study, it was observed that, a number of papers have been published for evaluating qualities of construction projects. However, no studies have reported on the measurement of quality in an integrated form. Also very few study have been reported on quality of infrastructure projects. To address this research gap in the body of knowledge, this study is aimed at investigating, identifying and analyzing the factors influencing the quality throughout the lifecycle of a road project and thereby giving suggestions to improve the quality of road projects.

Since, construction project activities are unique in nature, the quality is prior concern. To measure the factors influencing the quality of a road project, the responses from the field personnel's were considered. The scope of this study is limited to roadway projects where the critical factors affecting its quality throughout the lifecycle are determined and analyzed.

As construction projects are unique in nature, the findings of this study may not be directly applicable for the commercial, residential projects and some infrastructure projects such as railway, bridge, flyover, metro, etc. For the study, a huge amount of documented data on completed projects is required. Due to non-availability of documented data of completed projects for study in Mumbai, a questionnaire survey approach is considered to find out importance of factors affecting quality of roads.

2. LITERATURE REVIEW:

A lot of researches have been reported on identifying and evaluating factors affecting qualities of road construction projects. Bubshait (2010) identified and evaluated the factors affecting quality of pavement construction in Saudi Arabia. According to his study, by evaluating the critical factors, high quality in roads could be achieved. Based on a detailed

literature review and contractors survey, the contributing factors were identified. The main factors considered in this study were design, specifications, environment (traffic and temperature), construction process and managerial. The research included five design - related factors, namely, aggregate quality, structural design, asphalt mix design, mix composition, and asphalt characteristics; and five construction process - related factors, namely aggregate characteristics, uniformity of materials, placement and compaction process, mixing operation control, and acceptable procedure.

El-Hamrawy et al. (2017) focused on identifying and evaluating the factors influencing the quality performance of highway projects in Egypt. The study also included models to measure the quality level of highways. According to them, Quality measurement is the drive for quality improvement. In this study, a total of 39 factors were identified which may affect quality of highway projectson the basis of detailed literature review. These factors were grouped as design related factors such as; Pavement is not designed according to the regional conditions (e.g. soil typetemperature-traffic volume), accuracy of investigation performed on sub-soil type encountered, design errors arising from inadequate engineer assumptions and inaccurate data etc. and construction process such as; availability of experienced staff in the owner's and contractor's teams during the project execution, aggregate quality and its crushing process used in the construction process etc.

Ebrahim Abu El-Maaty et al. (2016) conducted a study on improvement of the management of highway projects in Egypt by identifying the most important factors influencing the quality performance of highways. In this study, the authors have introduced 39 factors and their impact on the quality has been determined through the application of fuzzy triangle approach and were ranked according to their impact values. The factors used in this study were classified as design related factors such as; Pavement design, accuracy of data related to traffic volume, composition, and expected growth, asphalt quality and type, construction materials suitable for climate (temperature), aggregates quality and gradation, required compaction level, Over specifying of materials and equipment etc. and construction process related factors such as; asphalt quality and type used in the construction process, variation in aggregates gradation in stockpiles and other similar operations, variation in asphalt content during mixture operation, amount of filler materials in the mixture, continuous changing in mix design etc. The conceptual quality has always been studied by researchers in various forms. Warsame (2013) studied the most common procurement methods used in infrastructure transport projects and evaluate how these methods contribute to the expected

quality performance of the final product in relation to client competence. In the questionnaire survey used in study, the respondents pointed out lack of client competence, which is vital in amassing the desired quality level through proper procurement, monitoring and evaluation procedures. The causes of project success and failure can be procurement method and how the owner selects that method. The quality performance and the effectiveness of any selected procurement method depends on the competence of client. Thus, the study concluded that the selection of procurement method and lack of client's competence affect quality of road transport infrastructure projects adverselyand could be concluded as factors affecting conceptual quality.

Favie (2010) conducted a study dealing with auditing the contractor provided with the design and construction part of the highway between Utrecht and Amsterdam in Netherlands. The effects of audit based quality monitoring system was analyzed in this study. The study pointed out that the procurement process played a major role in deciding the quality monitoring system to be used. The audits came with a result of conformance and nonconformance of certain processes like visual inspection etc. and suggests corrective action to be taken for nonconformance. The study concluded with a view that the audits i.e. quality monitoring systems played a significant role in quality conformance and performance of infrastructure projects by analyzing the supplier's compliance with assigned work.

Neyestani (2017) evaluated the impact of implementation of Quality Management System (QMS) on main factors of construction project in Metro Manila, Philippines. The study undertook a detailed literature review for understanding quality management system and identifying the main factors of construction projects concerning the effects of QMS on construction projects. The factors identified to evaluate the impact were time, cost, quality, scope, customer requirements, risk, and resource. The study showed that implementation of QMS can be most effective on Quality awareness improvements and understanding the quality objectives in the organization and also effective in quality assurance process and project audits.

Lu and Tan (1995) outlined that construction projects usually span several years and goes through many phases. The success of design and construction part of any project ultimately depends on its conformance to the predetermined standards. The study took into account concept, design and construction factors as input and then conformance factors as output. The various conformance factors considered in this study were (1) Conformance to codes

and standards from the input perspective: The impacting factors are: - owner's willingness to abide by the rules and standards etc. (2) Conformance to owner's requirements: The impacting factors are: - accuracy of owner's stipulated requirements, clarity and reasonableness of owner's requirements etc. (3) Conformance to design processes and procedures: The impacting factors are: - completeness of engineering design standards, manuals, guidelines, and handbooks, effectiveness of the quality control programme and the Q/A programme etc. (4) Conformance to Constructability: The impacting factors are: - timeliness and completeness of the equipment supplies and material supplies, audit of "design for constructability" etc.

Mangila (2018) prepared a user-friendly model which was presented for deciding the upgradation and prioritization of rural road networks in Maharashtra, Mumbai. The study took into account Pavement Condition Index to carry out the analysis of the data related to condition of rural roads. The factors considered in evaluating Pavement Condition Index were visual observation (description of surface condition), riding comfort offered by surface smoothness, comfortable driving speed provided by road pavement. The performance quality factors were took from this thesis.

3. METHODOLOGY:

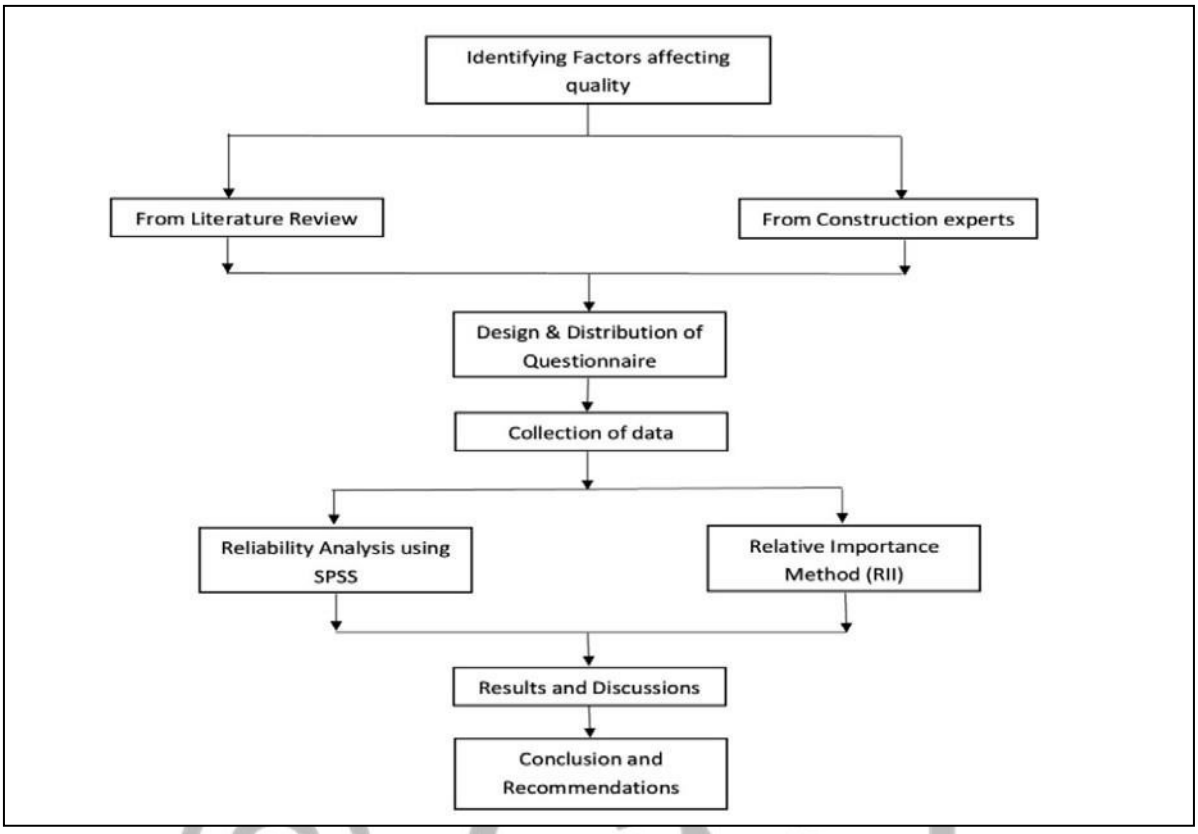

Figure 1: Research Methodology

3.1. To Identif critical factors that affecting quality:

From the literature review survey and opinions of construction experts, it was observed that several factors affect quality of infrastructure and construction projects and their nature varies from project to project. In the present study, it has been decided to select the factors affecting quality in road construction projects. The factors affecting quality were categorised into 5 main groups according to stages of quality such as quality of concept, design, construction, conformance and performance which were further sub-categorised into total 54 sub factors as shown in table 1.

Table 1: Factors influencing quality throughout the lifecycle of a road project.

Stages	Factors affecting Quality
A) Concept	1) Owner requirements and policies.

	2) Owner's or Client's competence.
	3) Procurement method.
	4) Effective Quality Management System (QMS).
	5) Audit System (Quality Monitoring system).
	6) Quality codes and standards.
	7) QA/QC department.
B) Design	1) Pavement design.
	2) Nature and type of subgrade soil investigation
	3) Design errors
	4) Accuracy of Traffic study data.
	5) Climate (Temperature) considerations.
	6) Specifications Clarity and accuracy.
	7) Owner's involvement.
	8) Material behaviour's considerations.
	9) Over-specification issue.

	10) Limitation imposed by specification.
	11) Mix Design Method used.
C) Construction process	1) Quality control procedures.
	2) Contractor's quality control.
	3) Owner's evaluation of contractor's material source.
	4) Availability of material.
	5) Uniformity of material at source.
	6) Method of construction used.
	7) Aggregate quality and crushing process.
	8) Variation on aggregate gradation.
	9) Variation on asphalt content.
	10) Continuous change in mix design.
	11) Use of marginal material.
	12) Monitoring mixing operation.
	13) Condition of road bed soil.
	14) Mixture placement &

	compaction operations.
	15) Compacting pattern used.
D) Conformance	***I) Conformance to codes and standards:***
	1) Owner's willingness
	2) Utilization of edition & article.
	3) Consistency of rules & standards.
	4) Quality documentation.
	II) Conformance to owner's requirement:
	1) Owners clarity, accuracy and reasonableness of stipulated requirements.
	2) Changes to requirements.
	III) Conformance to design process and procedures:
	1) Completeness of engineering design data.
	2) Effectiveness of QA/QC program.
	3) Engineering change control.
	IV) Conformance to constructability:
	1) Equipment & material supplies.

	2) Utilization of construction methods and materials.

3.2. Design of Questionnaire and Data Collection:

In order to measure the impact of these factors affecting quality of roads, a questionnaire was designed to collect the responses from the construction professionals based on their experience. The questionnaire was divided into two sections: Section-1 recorded the general information about the respondent while Section-2 was assigned for54factors affecting quality as shown in table 1. The respondents were asked to complete the questionnaire form by assigning values to the factors ranging from 1 (very less importance) to 5 (very high importance) considering their relative importance. The factors were arranged into a questionnaire form. For each factor, reply was categorized on a five point Likert scale as follows:

Scale	Degree of Importance
1	Very less importance
2	Less importance
3	Medium Importance
4	High Importance
5	Very High Importance

Table 2: Five point Likert scale for importance index

3.3. Data Analysis The responses obtained from the owners, consultants (designers), engineers, construction managers and contractors were analysed using following the following two methods:

1. Reliability of data obtained to test the internal consistency of the scale and correlation used for measuring the factors using SPSS.

2. Ranking of the factors affecting Quality using Relative Importance Index (RRI).

4. CONCLUSIONS & SUGGESTIONS

Quality of a project goes through many stages such as quality of concept, design, construction, conformance and performance. The measurement of quality in an integrated form is necessary to evaluate the overall performance of a project. There are several factors affecting quality throughout the lifecycle of a road project. Monitoring and controlling quality is one of the most important parameter considered in Project management. This study focused on identifying and evaluating the various factors affecting quality throughout the lifecycle of a road project in Mumbai. The current study considered 54 factors affecting quality of roads throughout its lifecycle and circulated to various stakeholders in construction sector. The responses were analysed and significant level is determined. The following are the key findings observed from the present study.

1. Effective Quality Management System (QMS) and Owner's requirement and policies has been identified as extremely important factors affecting quality of roads at conceptual stage with RII of 0.93 and 0.821 respectively.

2. Similarly, nature and type of subgrade soil investigation with RII of 0.948 and Design errors with RII of 0.884 have been identified as the most significant design related factors affecting quality of roads.

3. Also, among construction process related factors, aggregate quality and its crushing process and method of construction used with RII of 0.896 and 0.887 respectively were recognized as most prominent by the construction professionals.

4. Among overall conformance related factors, it was observed that 'Design for constructability' audit has the highest RII of 0.934 followed by effectiveness of QA/QC with RII of 0.883 and were identified as most important factors.

5. From performance related factors, Subgrade/Pavement failure and free from rutting and shoving were found to be most critical factors affecting quality of roads with RII of 0.965 and 0.873 respectively.

The outcome of this research would help the project managers, owners, contactors, clients, etc. by giving guidance to focus more on the critical factors for achieving better quality of roads.

According to the above mentioned findings, the following points are suggested to achieve better quality of construction in road projects:-

1. The owner's site inspection team should be qualified enough to visually verify that good quality materials are incorporated into the pavement and that good construction practices are followed to achieve a good pavement quality. Training programs can be very effective in counteracting inspector's lack of experience.
2. The aggregate material represents up to 90 – 95% by weight. Improvement in the aggregate selection method and processing (crushing), especially in regions where marginal materials is available, can result in an improvement in the quality of road pavement at lower cost.
3. The adoption of properly developed quality codes and standards suitable for the particular type of road project should be done to have better conformance of quality.
4. Accurate data of nature and type of subgrade soil should be collected by performing comprehensive and detailed site investigations to avoid pavement failure at a later stage. The investigation should involve the type of soil that exists along the roadway, material strength, moisture content, durability, compatibility and drainage characteristics. Furthermore, the design errors identified should be rectified as soon as possible by the designers and contractors collaboratively.

A detailed audit should be done at the end of road project by the owner before it is handed over to him to make it sure that his requirement are satisfied and the project has been completed with predefined quality codes, standards and procedures.

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