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# ENGINEERING ATTRIBUTES AFFECTING QUALITY OF ROAD CONSTRUCTION

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**Abstract—** An efficient and successful completion of road project depend upon many factors e.g. Planning, site condition, resource (material, manpower and fund) availability, natural catastrophe etc. However, the life cycle and maintenance issues of a particular road are greatly influenced by quality of resource material used, and workmanship. Therefore, measurement of quality in an integrated form is necessary to evaluate the performance of any project. This study attempts to identify and analyse some key factors influencing the quality of road pavement. The analysis reveals that the Government policies and their effective quality management system are mainly responsible system at conceptual stage. During construction stage the nature of terrain (including subgrade) and engineering properties of resource materials are dominant factors. A systematic construction method may be a prime importance factor but need to be articulated with planning and resource management system. 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 with time and resource savings.

**Keywords—** Critical factors; Lifecycle; Project Management; Quality

## I. INTRODUCTION

Road projects are distinctive in nature and differs from another project in terms of period, scope, purposes, risks, difficulties and some other measurements (Ali, 2010). Some common constrictions almost every road project undergoing may envelop problems on account of cost overrun, over time, low productivity, poor quality of construction, high construction waste etc. Projects performance measures are judged for time, cost and quality (Ali and Wen, 2011). Quality is the most important factor in the success of construction projects beside the fact that achievement of acceptable quality levels in the road construction industry has long been a problem (Griffith and Sidwell, 1997).

Now a days, the issues of quality control are an integrated part to evaluate the performance of road project during execution i.e. conceptualization, design, construction, conformance and maintenance. Improvement in the quality of construction is linked with quality management in the project life cycle (Mallawaarachchi and Senaratne, 2015). Road quality is assessed how well a road pavement will enact under traffic loading and when exposed to environment. Therefore, in roadway projects, the ultimate goal is to produce road surface possessing high serviceability and durability under the local conditions and traffic. overall road performance is mainly influenced by design, materials and the process (Ebrahim Abu El-Maaty et al., 2016). From the literature survey a number of papers have been found for evaluating qualities of construction projects but a little has been reported on the measurement of quality in an integrated form particularly about the quality parameters of road projects (Mane and Patil, 2015). This study is to address this research gap focusing the factors influencing the quality of a road project and thereby giving suggestions to improve the quality of road projects.

## II. LITERATURE REVIEW

During last four decades a number of research work carried out on identifying the controlling factors and evaluation of performance in road projects. Bubshait (2010) identified factors affecting quality were design, specifications, environment (traffic and temperature), material and construction process management. For performance evaluation he analysed design related factors (e.g. aggregate quality, structural design, material composition, characteristics and mix design); and process related factors (e.g. aggregate characteristics, uniformity of materials, process of mixing, placing and compaction). El-Hamrawy et al. (2017) focused on modelling for ascertaining quality level beside identifying and evaluating the factors influencing the quality performance of highway projects in Egypt. Ebrahim Abu El-Maaty et al. (2016) have used 39 road construction related factors to determine their impact on the pavement quality through the fuzzy triangle approach and were ranked according to their impact values.

The conceptual quality has always been studied by researchers in various forms. Warsame (2013) studied the most common



procurement methods used in transport projects and evaluate how these methods contribute to the quality and performance of the road context to client competence. He concluded that the selection of procurement method and client's competence affect quality of road projects. Favie (2010) studied the effects of audit based quality monitoring system and pointed out that the procurement process played a major role in deciding the well suited quality monitoring system. Neyestani (2017) identified that the impact of Quality Management System (QMS) on road projects (through time, cost, quality, scope, customer requirements, risk, and resource) can be most effective on Quality objectives, improvements, assurance and audit process. Lu and Tan (1995) focused on longevity of road projects and credited the success to conformance to the predetermined standards (Code / Manual / Handbook / Guidelines etc.) for all parameters related to the material, management, machinery, process etc. Mangila (2018) prepared a model to workout Pavement Condition Index based on data related to surface condition, riding comfort, driving speed etc.

III. METHODOLOGY

3.1 Identifying critical factors affecting quality

From the literature review survey it is observed that about 54 parameters are responsible for quality of road, these parameter are further classified in five (5) main groups namely quality of Concept, Design, Construction, Conformance and Performance. A comprehensive details of 54 parameters affecting road construction are enumerated in table 1.

3.2 Data Collection

In order to measure the impact of factors listed in table 1 on quality of roads and to decide the relative weightage of parameter data / information is collected from both the primary and secondary sources e.g. books, reference journals, Codes, Opinion of Consultant and Engineers.

3.3 Data Analysis

In order to decide the internal consistency of the scale and correlation among the different quality parameter reliability analysis is used. Then after the quality parameter can be ranked to show their relative dominance using Relative Importance Index (RRI). The information and responses received through data collection were analysed for the reliability and ranking.

A. Reliability analysis

A total of 247 information were collected and fed into software for the analysis. Since most of the responses were descriptive type their reliability (using cronbach alpha measure) and correlation were worked out. The value of reliability alpha coefficient is 0.937 and correlation coefficient is 0.946.

**Table 1: Classification of Factors Affecting Road Quality**

Stages	Factors affecting Quality
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<b>Concept</b>	Owner requirements and policies, Client's competence, Procurement method, Quality Management System (QMS), Audit / Quality Monitoring system, Applicable Codes & standards, Quality assurance / control requirements
<b>Design</b>	Pavement design, Nature and type of subgrade soil investigation, Design errors, Accuracy of Traffic study data, Temperature considerations, Specifications Clarity and accuracy, Owner's involvement, Material behaviour's considerations, Limiting specification. Over-specification, Mix Design Method
<b>Construction process</b>	Quality control procedures, Contractor QC willingness, availability & evaluation of material source, material properties, construction methods used, Aggregate quality, gradation and crushing process, asphalt content, mix design, Use of marginal material, Monitoring mixing operation, Condition of road bed soil, Mixture placement & compaction operations, Compacting pattern used.
<b>Conformance</b>	<b>I) Conformance to codes and standards:</b> Owner's willingness, Utilization of edition & article, Consistency of rules & standards, Quality documentation.
	<b>II) Conformance to owner's requirement:</b> clarity, accuracy and reasonableness, Changes to requirements.
	<b>III) Conformance to design process and procedures:</b> Completeness of design data, Effectiveness of QA/QC program, control over engineering changes
	<b>IV) Conformance to constructability:</b> Equipment & material supplies, construction methods and materials, 'Design for constructability' audit.
<b>Performance</b>	Comfortable driving speed, Riding comfort, Surface smoothness, Maintenance cost, Subgrade Failure, Free from rutting & shoving, No sign of potholes, Skidding or slipping of vehicle tires, Settlement over time.



**B. Relative Importance Index**

The Relative Importance Index (RII) is a regression based index which summarizes the magnitude of factors as a source of inequalities in opinions. RII is useful as it takes into consideration the size of the population and the relative differences in their opinion (Odeh et al., 2002). To determine the ranking of different factors the Relative Importance Index (RII) was computed as shown in Eq. 1. Degree of influence ranges from RII value of 0.0 (no influence) to 0.5 average (moderate) influence to 1.0 (extremely strong):

$$RII = \frac{\sum_{i=1}^A n_i \cdot I}{A \cdot N} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{A \cdot N} \dots\dots\dots (1)$$

Where N = Total Respondents, A = Highest response (i.e. 1-5), n = Respondents selecting options, I = Individual responses (i.e. 1, 2, 3, 4, 5)

**IV. RESULTS AND DISCUSSIONS**

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 road project management. The inferences drawn in this study are based upon the project completion reports of MPRDC, PWD and NH owned road development project in the state of Madhya Pradesh. The parameter focused are based upon the feedback from senior project management personals remain involved in project throughout the lifecycle (Mane and Patil, 2015). The Data collected from project professionals was processed to carry out the statistical analysis by using Relative Importance Index method and critical factor was calculated as per the procedure explained before.

As shown in table 4, among all concept related factors, Effective Quality Management System (QMS) and Owner's requirement and policies were found to be most significant factors (extremely strong influence) affecting quality of roads with RII of 0.93 and 0.821 respectively. The adoption of effective quality management system (QMS) by the parties to construction helps to achieve better quality levels in construction of roads. The owner's requirement and quality policies set by them have greater influence on attainment of desired quality level at a later stage. Procurement methods, owner requirement and policies are predefined and hence impact least to the project despite the fact that quality of construction is wholly depend upon the limiting aspects of these factors.

Among the indices of design parameters as quantified in Table 4, evidently nature and type of subgrade soil investigation with RII of 0.874, Pavement design method with RII 0.824 and Design errors with RII of 0.884 have been identified as most important and strong design related factors affecting quality of roads. The quality of constructed pavement is not wholly dependent on the construction process and its control. While these are essential, quality begins with proper and accurate design information, procedure and specification preparation. Design errors arising from the inadequate assumptions of engineers and from inaccurate data related to traffic, climate, soil type and material characteristics are frequently more serious and costly to correct, than quality problems caused by a contractor's operation during the construction phase. To achieve an adequate pavement structural design and a quality riding surface, special consideration must be given to factors affecting subgrade soil such as material strength, moisture content, drainage characteristics, etc. and detailed investigation should be performed.

While discussing over construction process related parameters, material source quality and engineering properties of material play vital role in quality contribution with RII of 0.92. Aggregate properties, and construction method stand next for the quality acquiring process since these are responsible to provide most of the load bearing characteristics of the pavement (the aggregate make up 75-85% by volume of the pavement layers). The method of construction used for road projects defines the whole construction process and is very important to achieve a quality construction.

As obvious from table 7 that conformance to code and standard contributes the highest RII of 0.89 followed by conformance to design process with RII of 0.88 as an extremely strong influence on quality of roads. The success of pre-design, design and construction part of a project wholly depends on its conformance to the predetermined objectives and standards.

As shown in table 8, Subgrade/Pavement failure and free from rutting and shoving were found to be most critical performance related factors affecting quality of roads with RII of 0.95 and 0.93 respectively with extremely strong influence on quality. A road pavement that is not designed and constructed according to the criteria may end up in inadequate pavement structure with subgrade failure and have defects such as rutting and shoving.

Table 4: Relative Rank of Factor Affecting Quality of Road Project

Factor (Concept)	Text Book	Reference Book	Codes	Engineer	Manager	Overall	Rank
	Relative Importance Index (RII)						
<b>Conceptual Factor</b>							



Owner requirements & policies	0.6	0.38	0.27	0.68	0.89	0.564	6
Client's competence,	0.47	0.6	0.38	0.7	0.85	0.6	5
Procurement method	0.4	0.3	0.4	0.9	0.72	0.544	7
Quality Management System	0.7	0.76	0.74	0.89	0.91	0.8	3
Audit / Quality Monitoring System	0.8	0.6	0.66	0.4	0.56	0.604	4
Applicable Codes & standards,	0.9	0.93	0.95	0.8	0.54	0.824	2
Quality assurance / control	0.92	0.97	0.94	0.7	0.84	0.874	1
<b>Design related factors</b>							
Pavement design,	0.9	0.93	0.95	0.8	0.54	0.824	2
Nature and type of subgrade soil	0.92	0.97	0.94	0.7	0.84	0.874	1
Design errors	0.7	0.76	0.74	0.89	0.91	0.8	3
Accuracy of Traffic study data,	0.47	0.6	0.38	0.7	0.85	0.6	9
Temperature considerations,	0.8	0.6	0.66	0.4	0.56	0.604	8
Specifications Clarity & accuracy,	0.6	0.38	0.27	0.68	0.89	0.564	10
Owner's involvement,	0.4	0.3	0.4	0.9	0.72	0.544	11
Material behaviour's	0.8	0.85	0.87	0.68	0.63	0.766	4
Limiting specification.	0.6	0.72	0.76	0.61	0.58	0.654	6
Over-specification,	0.67	0.64	0.64	0.57	0.52	0.608	7
Mix Design Method	0.76	0.77	0.80	0.62	0.67	0.724	5
<b>Construction process related factors</b>							
Quality control procedures,	0.9	0.85	0.87	0.89	0.84	0.87	4
Contractor Quality Control	0.69	0.73	0.78	0.68	0.67	0.71	10
Avail. & eval. of material source	0.72	0.75	0.78	0.74	0.71	0.74	8
Material source and properties,	0.91	0.94	0.95	0.92	0.88	0.92	1
Construction methods used,	0.86	0.9	0.88	0.89	0.87	0.88	3
Aggregate quality, grading etc.	0.89	0.92	0.93	0.9	0.91	0.91	2
Variation on asphalt (mix design)	0.84	0.79	0.83	0.87	0.82	0.83	5
Use of marginal material,	0.67	0.73	0.75	0.71	0.64	0.7	11
Monitoring mixing operation,	0.76	0.79	0.84	0.77	0.79	0.79	6
Condition of road bed soil,	0.71	0.63	0.78	0.65	0.63	0.68	12
Mixture placement & compaction	0.77	0.74	0.78	0.75	0.81	0.77	7
Compacting pattern used.	0.63	0.65	0.68	0.64	0.6	0.64	13
Continuous change in mix design	0.72	0.75	0.8	0.71	0.67	0.73	9
<b>Conformance related factors</b>							
Conformance to codes & standard	0.89	0.92	0.88	0.85	0.91	0.89	1
Conform. to owner requirement	0.79	0.83	0.73	0.86	0.79	0.8	4
Conform. to design process	0.93	0.91	0.81	0.87	0.88	0.88	2
Conformance to constructability	0.86	0.81	0.81	0.78	0.84	0.82	3



Table 5: Relative Important Indices of Performance related factors

S N	Factor (Concept)	Text Book	Reference Book	Codes	Engineer	Manager	Overall	Rank
		Relative Importance Index (RII)						
1	Subgrade Failure	0.97	0.95	0.93	0.96	0.94	0.95	1
2	Free from rutting & shoving	0.94	0.96	0.89	0.92	0.93	0.93	2
3	No sign of potholes	0.91	0.89	0.88	0.92	0.86	0.89	3
4	Maintenance cost	0.9	0.85	0.88	0.8	0.83	0.85	4
5	Comfortable driving speed	0.85	0.88	0.79	0.76	0.77	0.81	5
6	Skidding / slip of vehicle tires	0.81	0.84	0.72	0.78	0.75	0.78	6
7	Riding comfort,	0.77	0.73	0.71	0.69	0.74	0.73	7
8	Settlement over time.	0.71	0.69	0.69	0.7	0.66	0.69	8
9	Surface smoothness	0.66	0.69	0.61	0.72	0.61	0.65	9

**V. CONCLUSIONS**

Quality of a project goes through many stages such as concept, design, construction, conformance and performance. The measurement of quality in an integrated form is necessary to evaluate the overall performance of a project. 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, Owner’s requirement and policies has been identified as extremely important factors affecting road quality at conceptual stage.
2. Similarly, nature and type of subgrade soil investigation with and Design errors 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 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 followed by effectiveness of QA/QC 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.

**VI. RECOMMENDATIONS**

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. 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 the quality materials and that good construction practices are followed. 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 can result in quality road construction 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. Assessment of nature, type and engineering properties of subgrade based upon site investigations is important to avoid pavement failure.
5. A detailed audit should be done at the end of road to ensure that the project has been completed with predefined quality codes, standards and procedures.

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