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Analytical Hierarchy Process for measuring Construction Project Performance

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ABSTRACT
Construction is an important sector that contributes greatly in the economic growth of a nation. The sector is labour-intensive and, including indirect jobs it, - provides employment to more than 49.5 million people. Success of a construction project highly depends on its performance. So, the performance of this Industry is a big challenge today. This paper presents a conceptual research framework for a performance measurement of the construction project by using Analytical hierarchy process. The main objective is to identify the criteria which affect the most on the performance. This framework is generated with the help of two rounds of questionnaire survey. The respondents comprising of project managers, contractors and site engineers of construction firms. First round is for the selection of factors based on pilot survey and an interview with experts and second round is, to give weightage to the factors which are identified from the first round. Main factors identified for the construction project performance are cost, time, quality, productivity, employee & client satisfaction, health & safety and environment. It is anticipated from the result that this study will positively impact as a rewarding input for all the stakeholders to enhance the approach towards their construction project performance.

Keywords: Analytical hierarchy process, consistency ratio, construction industry, factors, performance measurement

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I. INTRODUCTION

Construction industry plays a major role in development and achievement the goals of society. Indian construction industry is one of the fastest growing construction industry internationally and the second largest employer in India. The construction industry is generally considered to have underperformed compared to other industry. Although Construction industry is very complex in nature because it contains large number of people as consultants, contractors, clients, direct and indirect stakeholders and many others who involved with the work. Construction project also involves numerous parties, various approaches, different phases and stages of work (Takim and Akintoye, 2002) at different level of project. So, construction projects in India suffer from many problems and complex issues in performance such as cost, time, safety and quality.

In construction industry performance measurement is used as a systematic way of judging project performance by evaluating the inputs, outputs and the final project outcomes. However, very few companies systematically measure their performance in a holistic way. Moreover, the existing systems tend to focus more on product and less on process and design. This can lead to the sub- optimal quality of the performance measurement system, the misinterpreting of relative performance, and to complacency and the denying of appropriate rewards to the deserving. The survey findings indicate that the most important factors affecting project performance are: delays because of materials shortage; unavailability of resources; low level of project leadership skills; escalation of material prices; unavailability of highly experienced and qualified personnel; and poor quality of available equipment and raw materials (A. Enhassi. 2009). Previous studies have revealed that performance measurements can be in terms of financial and non-financial measures, or the combination of both. When measurements are being implemented to-, contractors, consultants and the management team's performances are blamed as the major reasons for the failure of a particular project. In relation to this, working groups on key performance indicators (KPI) have identified ten parameters for benchmarking projects, in order to achieve a good performance in construction industry (R. Takim. 2002). Many construction industry sectors have been experiencing chronic problems such as poor safety, inferior working conditions and insufficient quality. These problems have been identified as factors that affect construction productivity and will affects companies performance (S. Alwi. 2003). The success of construction project depend on its performance, which is measured base on timely completion, within the budget, required quality standards and customers satisfaction (A. Omran.2012).

In the ever-evolving field of construction where project managers strive to deliver successful projects, there is often an absence of standard benchmarks for evaluating the projects performance and success. Therefore, there is need for identifying the key measures of performance that are used commonly in the field of construction and that constructions organizations need to develop systems and process to measure in order to satisfy a wide variety of clients (S. Bhatti. 2013).

According to Yang(2010), methods for performance measurement in construction industry are gap analysis, integrated performance index, statistical methods data envelopment analysis (DEA) method. Some of the popular techniques in construction industry are for performance measurements are the “spider” or “radar” diagrams and the “Z” chart. These tools are in graphical form and easily understood because they are capable of showing multiple dimensions simultaneously.

Rankin (2011) used radar diagrams to show the cost predictability, time predictability, cost and time per unit to measure the performance of Guyana”s construction industry.

Statistical methods, such as regression analysis, multiple regression and various descriptive statistics are used to analyse data in performance measurement. Yeung (2010) also suggested that by using multiple regression analysis we can not only measure but prediction of the project performance can also be done. Data envelope analysis adopts the linear programming technique to evaluate the efficiency of the analysed units. DEA is able to evaluate the performance quantitatively as well as qualitatively.

Many researchers have generated performance index for different sectors for design build projects Hamilton (1997) also developed a success index to benchmark the project success.

II. METHOD

2.1 Development of questionnaire

Questionnaire-1 consists of 12 main factors and 57 sub factors that affect the construction project performance which are selected from literature review. Main factors include cost, time, quality, productivity, employee & client satisfaction, health & safety and environmental factors. The survey conducted followed by a three point scale (1) high important (2) medium important (3) low important. From the analysis seven main and thirty seven sub criteria were shortlisted which are given in the following table.

Table1. Factors affecting construction project performance

Code	Factors/Sub factors
A	**Cost**
A1	Cash flow of project
A2	Project resource cost
A3	Waste materials cost
A4	Project overtime cost
A5	Rework cost
A6	Project design cost
A7	Regular project budget update cost
B	**Time**
B1	Site separation time
B2	Planned time for construction
B3	Time needed to rectify defects
B4	Average delay in claim approval & material storage
B5	Average delay in regular payments
C	**Quality**
C1	Conformance to specification
C2	Unavailability of competent staff
C3	Quality of equipment and raw materials
C4	Quality assessment system in organization
C5	Quality training/meeting
D	**Productivity**
D1	Project complexity
D2	Management-labour relationship
D3	Absenteeism rate through project
D4	Sequencing of work according to schedule
E	**Employee & client satisfaction**
E1	Employee attitudes
E2	Recruitment and competence development
E3	Employees motivation
E4	Belonging to work
E5	Communication between different parties
E6	Speed and reliability of service
E7	Number of rework incidents
F	**Health and safety**
F1	Health policy for worker
F2	Safety at project
F3	Rate of accident during work execution
F4	Availability of PPE

G	Environment
G1	Air quality & Noise level
G2	Sustainable practice at site
G3	Wastes around the site
G4	Use of hazardous material
G5	Utility of waste

2.2 Data analysis using AHP

From data collected and response analyzed of the first questionnaire a new design of Questionnaire-2 was developed with the shortlisted factors to assign weights to them which is based on Analytical Hierarchy Process (AHP).

There are many methods to assign weights to factors, however in this paper Hierarchy Process (AHP) is used to assign weights, which is widely used most effective method for weighing. The Analytical hierarchy process was developed by Saaty (1980) which is based on additive weighting process. Over the years, it has been widely reviewed and applied in the area of construction management, and its use is supported by several commercially available, user-friendly software packages (Hastak 1998)

Table1. Fundamental scale for comparison criteria

Intensity of importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favors one activity over another
6	Strong plus	
7	Very strong	An activity is favored very strongly over
	Demonstrated Importance	another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

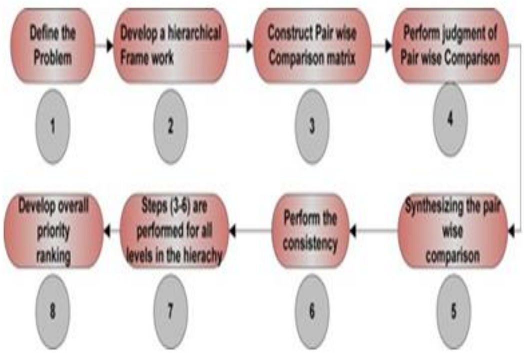


Fig. Analytical Hierarchy Process

(Source: H. Parekh et al. vol. 19, no.1, page no. 39, 2015)

AHP formalizes the conversion of the factors weighting problem into the more tractable elements of making a series of pair wise comparisons among competing factors. The AHP tool is composed of following steps:

1) Identification of goal.
2) A hierarchy of decision criteria is developed.
3) A pair-wise comparison matrix (size n*n) is constructed for the lower level. The pair-wise comparisons generate a matrix of relative rankings for each level of hierarchy. The number of matrix depends on the number of factors at each level.
4) Perform judgment of pair-wise comparison matrix. It begins with comparing the relative performance of two selected elements and the decision makers have to compare each element by using the relative scale pair-wise comparison.
5) Synthesizing the pair-wise comparison. Average of Normalized Column (ANC) is used to calculate the Eigen value of priorities. ANC is to divide the element of each column by the sum of the column and then add the element in each resulting row and divide this sum by the number of elements in the row (n).
6) Perform the consistency. The consistency is determined by Consistency ratio (CR). $CR = CI/RI$

Where, CI = Consistency Index
RI = Random Index
$CI = (\lambda max-n)/(n-1)$
$RCI = (\lambda' max-n)/(n-1)$

Where

λmax = maximum Eigen value of the judgment matrix;

n = dimension of the pair wise comparison of judgment matrix

$\lambda' max$ = average Eigen value of the judgment matrix derived from randomly generated reciprocal matrices using the scale.

7) Steps 3-6 are performed for all levels in the hierarchy.
8) Develop overall priority ranking using weight of criteria.

III. RESULT & DISCUSSION

After collecting data, analysis is done using AHP, a matrix for each respondent is prepared and CR value of each matrix was calculated. Perspective of each respondent different from each other and therefore result obtained from respondent vary from each other. As consistency of all matrix is not achieved so to overcome the effect, combined matrix method is used which suggested by Wakchaure and Jha (2012).This method says that the value of CR for the combined matrix should be less than 0.1, which achieved in all cases. It has mentioned in following tables.

Table No 3, shows eigen value of main factors and corresponding ranking of each after analysis and corresponding CR value of all 30 respondents is 0.0392, which satisfies the essential criteria of CR value, which must be < 0.1.

Table3. Normalised matrix for main factors

Main factors	Eignvalue	Rank	CR Value
Cost	0.2719	1	**0.0392**
Time	0.2692	2	
Quality	0.1291	3	
Productivity	0.0994	4	
Employee & Client satisfaction	0.0467	7	
Health & Safety	0.0987	5	
Environment	0.0849	6	

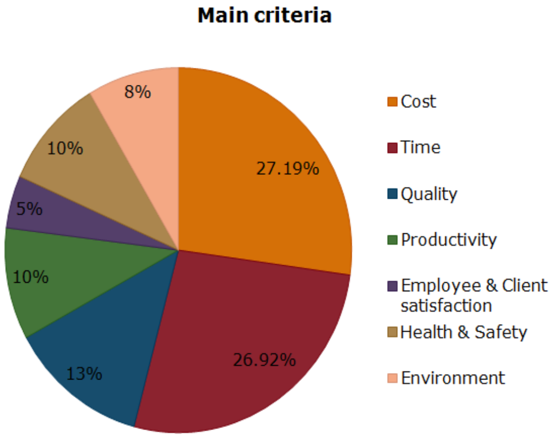
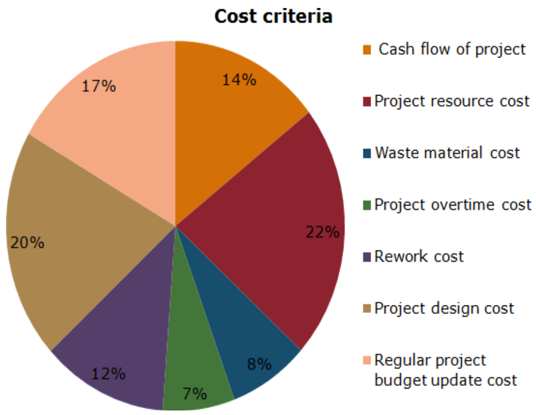


Chart1. Representation of main factors

Table no 4 shows eigenvalue of cost factors and corresponding ranking of each.

Table4. Normalised matrix for cost factors

Cost factors	Eigenvalue	Rank	CR value
Cash flow of project	0.1445	4	**0.0450**
Project resource cost	0.2227	1	
Waste material cost	0.0762	6	
Project overtime cost	0.0686	7	
Rework cost	0.1200	5	
Project design cost	0.2010	2	
Regular project budget update cost	0.1669	3	



Char 2. Representation of cost factors

Table no 5 shows eigenvalue of time factors and corresponding ranking of each.

Table5. Normalised matrix for time factors

Time factors	Eigen Value	Rank	CR value
Site separation time	0.2332	2	**0.0130**
Planned time for construction	0.2262	3	
Time needed to rectify the defect	0.3257	1	
Average delay in claim approval & material storage	0.0946	5	
Average delay in regular payments	0.1203	4	

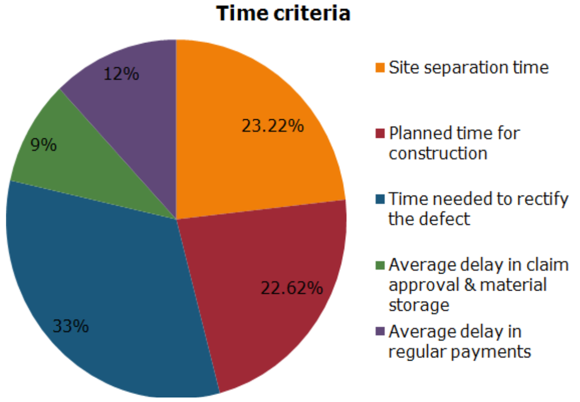


Chart3. Representation of time factors

Table no 6 shows eigenvalue of quality factors and corresponding ranking of each.

Table6. Normalised matrix for quality factors

Quality factors	Eigen value	Rank	CR value
Conformance to specification	0.2301	2	0.0234
Unavailability of competence staff	0.2792	1	
Quality of equipment and raw material	0.1787	3	
Quality assessment system in organization	0.1358	5	
Utility of waste quality training/meeting	0.1762	4	

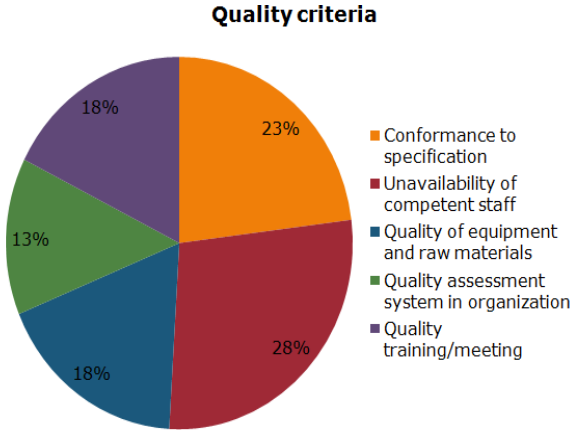


Chart4. Representation of quality factors

Table no 7 shows eigenvalue of productivity factors and corresponding ranking of each

Table7. Normalised matrix for productivity factors

Productivity factors	Eigen value	Rank	CR value
Project complexity	0.2648	2	0.075
Management labour relationship	0.2154	3	
Absenteeism rate through project	0.2038	4	
Sequencing of work according to schedule	0.3160	1	

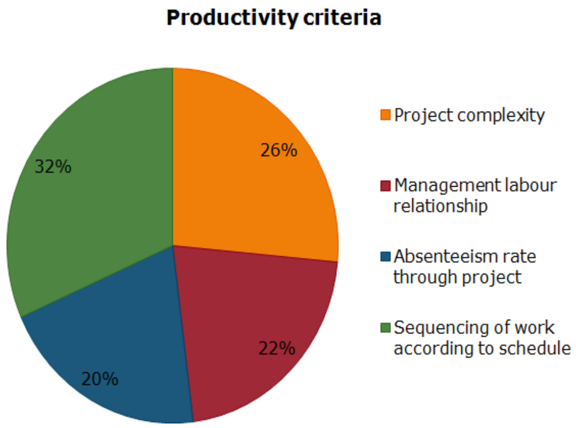


Chart5. Representation of productivity factors

Table no 8 shows eigenvalue of employee & client satisfaction factors and corresponding ranking of each.

Table8. Normalised matrix for employee & client satisfaction factors

Employee & client satisfaction factors	Eigen Value	Rank	CR value
Employee attitudes	0.1484	3	0.0220
Recruitment & competence development	0.1103	5	
Employee motivation	0.0892	7	
Belonging to work	0.0969	6	
Communication between different parties	0.2185	1	
Speed and reliability of service	0.1445	4	

Number of rework incidents	0.1992	2	

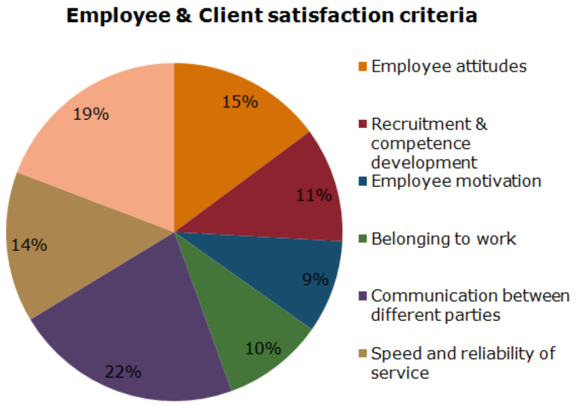


Chart5. Representation of employee & client satisfaction factors

Table no 9 shows eigenvalue of health & safety factors and corresponding ranking of each

Table9. Normalised matrix for health & safety factors

Health & safety factors	Eigen value	Rank	CR value
Health policy for worker	0.1399	4	**0.0291**
Safety at project	0.4101	1	
Rate of accident during work execution	0.1800	3	
Availability of PPE	0.2699	2	

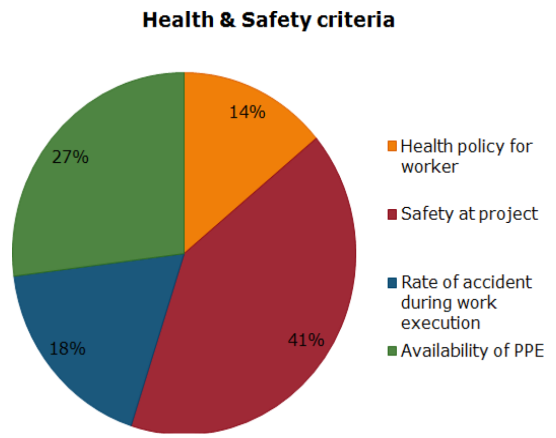


Chart7. Representation of health & safety factors

Table no 10 shows eigenvalue of environment factors and corresponding ranking of each.

Table9. Normalised matrix for environment factors

Environment factors	Eigen value	Rank	CR value
Air quality & noise level	0.1978	3	**0.0142**
Sustainable practice at site	0.1718	4	
Wastes around the site	0.2363	2	
Use of hazardous material	0.1175	5	
Utility of waste	0.2766	1	

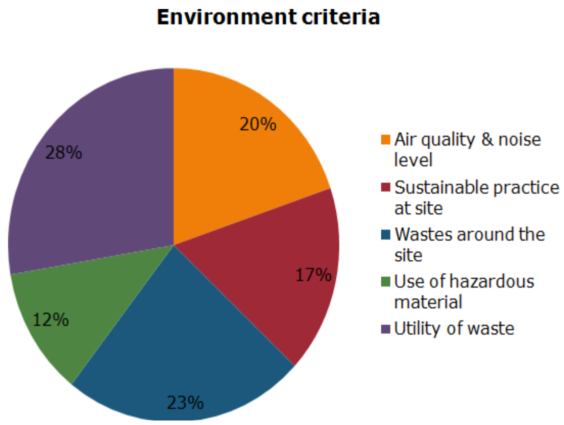


Chart8. Representation of environment factors

IV. CONCLUSION

In this study, an attempt has made to create a hierarchy of factors, which are important for enhancing construction project performance. In first stage from literature study, a total of 12 main factors and 55 sub factors have identified and they were sent to experienced stakeholders of building construction industry for their views followed by a pilot study. After this exercise only 7 main factors and 37 sub factors narrated for final study.

The analysis of main criteria demonstrated that cost comes at first place followed by other criteria in the order which effects on success of any construction project performance. Time is considered the 2^{nd} important factor, not only important for the project completion but also carefully managed during rescheduling of task and rectification of defects. Quality is considered the 3^{rd} important factor. Productivity means outcome per hour which must be increased as per schedule which comes at 4^{th} position. The analysis of health & safety demonstrated that safety at project comes at first place. The analysis of employee & client satisfaction demonstrated that communication between different parties is the most important factor. The analysis of environment factors demonstrated that utility of waste is the most important factor for success of any construction project.

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