DEVELOPMENT OF BUILDING QUALITY MEASUREMENT TOOL: BUILDING CONSTRUCTION QUALITY INDEX (BCQI)

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India's economic development leads to an unprecedented increase in the pace of urbanization. In India, the rate of execution of construction projects has been increased to great extent from past few decades. This study develops and uses a tool, Building Construction Quality Index (BCQI). Developed index, BCQI can be used for checking degree of quality of building projects and benchmark for future improvement in quality. Developed index can also be used in comparing quality of building projects. This study adopts literature review, questionnaire surveys for data collection and application of developed model to measure construction quality of building projects. Analytical Hierarchical Process (AHP) has been adopted to determine weights of construction quality attributes. Since quality affects different aspects of project management, improvement in quality measurement in turn improves decision making of project management team. This study will contribute to improve construction quality measurement systems in developing countries like India.

Keywords: AHP, project management, quality system.

1.INTRODUCTION

As the urban population and incomes increase in India, demand for every key service such as water, transportation, sewage treatment, low income housing has increased in cities of every size and type. Increased competition among builders and construction contractors leads to reduction in cost of building projects. Architectural planning and provision of services also plays important role in achieving quality of building projects. Affordable/ Low cost houses have to be planned and organized considering healthy and clean environment with excellent sanitation and green area. These developments should be in close vicinity of workplace, shopping complexes and educational institutions Karim (2011). Thus architectural planning, public transport connectivity, drinking water supply, drainage systems, availability of services such as shopping markets, hospital and schools affects overall construction project quality and thus have been considered in this study. Cost and schedule parameters along with construction quality have been considered as project success parameters (Khosravi and Afshari, 2011).Yet very less weight has been given to construction quality in comparison with cost and schedule (Rwelamia and Hall 1995). Construction quality is equally important as cost and schedule parameters of project management Rad and Khosrowshahi (1998). It has been found that poor construction quality is responsible for cost and schedule overrun of the project (Love,2002, Round and ASCE, 1985). Other than schedule and budget overrun degradation of contractor, loss of trust and demoralization of employees are drawbacks of poor construction quality.

Indian construction industry has not yet witnessed uniform and objective quality measurement system and construction firms practice their own developed standards/ methods for quality measurement. These developed systems mostly include checklists and are subjective in nature and have proved difficult in rating construction quality objectively. Construction quality measurement has been proved cumbersome task because of subjective nature of quality definition Rad and Khosrowshahi (1998), Minchin et al. (2008).

This paper aims at development and application of simple, easy to implement building construction quality measurement model/ system based on model developed by Minchin et al. (2008) which can be uniformly accepted industry wide. By applying this developed model, one can measure quality of completed as well as ongoing building projects, which in turn can be used for comparing finished projects, tracking ongoing construction projects, and developing guidelines for construction companies for continuous improvements.

The research has included literature review, identification of attributes and sub-attribute, calculation of attribute weights using AHP, Development of quality measurement system BCQI.

II. CONSTRUCTION QUALITY DEFINITIONS

Paul Watson and Tim Howarth in their bookConstruction Quality Management have recognized the differences in quality definitions among various authors and claim that "quality means many different things to many different people".They reviewed following quality definitions, in the 1931, Shewhart defined quality as 'the thing which have positive attribute of conformance to specified standards'. Later in 1961 focus has been shifted from achievement of specifications to customer satisfaction and Feigenbaum defined quality as the customer determination which is based on customer's actual experience with the product or service, measured against customer's requirements. Crosby in 1979 reiterated importance of specifications and defined quality as conformance to requirements. Juran (1985) Quality is product performance which results in customer satisfaction and freedom from product deficiencies, which avoids customer dissatisfaction. In 1986 ISO 8402-1986 quality has been defined as 'Totality of features and characteristics of a product or service that bears on its ability to meet a stated or implied need'. Imai (1986) 'Quality is anything which can be improved.' Taguchi (1986) 'Quality is the loss of product causes to society after being shipped'. Feigenbaum (1986) 'Quality is the total composite product and service characteristics of marketing, engineering, manufacture and maintenance through which the product in use will meet the expectation of customer'. Deming(1986) 'Good quality means a predictable degree of uniformity and dependability at a low cost with a quality suited to the market.' Juran (1989) defined quality as 'Fitness for use'. Gitlow et al. (1989) 'Quality is the extent to which the customer or users believe the product or service surpasses their needs and expectations'.

In later years, focus has been shifted again to customer satisfaction, rework minimization, and repeat business. P. Hoonakker (2010) in his study has reviewed these changes in opinions in researchers about quality. (Chase(1998), Kanji & Wong(1998), McKim & Kiani(1995), Torbica & Stroh(1999)) define quality as 'meeting the expectation of customer', (Atkinson(1998), Love et al.(1999), McKim & Kiani(1995), Pheng & Wee(2001), Sypsomos(1997)) define quality as 'reduced rework or defects'. (Sommerville(1994), Sypsomos(1997)) define quality as 'Repeat businesses'. (Courtice &Herrero(1991), Gransberg et al.(1999), Jaafari(1996), Kiwus &Williams(2001), Loveet al.(1999), McKim & Kiani(1995), Ripley(1996), Sypsomos(1997), Wong & Fung(1999)) define quality as 'Completion on-time and within budget'.

III. QUALITY MEASUREMENT SYSTEMS

Literature review on quality measurement systems, following systems can be summarized. In order to improve construction process, successful systems in manufacturing industry like total quality management, lean production are being practiced in construction sector, while their successful implementation depends mostly on industry's culture of teamwork and cooperation between various players of project. (Hoonakker et al.2010). James D. Steven (1996) studied developed blueprint for quality measurement by Quality Performance Measurement Task Force (QPMTF) of Construction Industry Institute (CII) and its validation has been done through feedback from project management team and implementation on three projects. Developed blueprint has advantage of ease in implementation but its use has been restricted to EPC project only is the main drawback of developed system. Minchin et al. (2008) developed a construction quality index for highway projects by rating materials and workmanship. Development of Quality Based Performance Rating (QBPR) has been done to overcome shortcomings of subjectivity and inefficiency of State Highway Authority's (SHA) rating system. Quality index has been proved practical, easy to understand and applicable to both new and old projects. According to developed model, CQI of the pavement is summation of product of weight of layer and CQI of that particular layer. Teo and Ling (2006) created a model on Multi Attribute Value Technique (MAVT) to measure effectiveness of safety management system. Developed index is the summation of product of weight of particular attribute and rating of that attribute. Validation of developed model has been done using 3 site audits and feedback from the industry. Similar approach of Multi Attribute Value Technique has been used in development of Building Construction Quality Index (BCQI).

Rad and Khosrowshahi(1998) with the aim of development of methodology for objective measurement and quantification of quality, have developed quality measurement tree and reviewed quality from different perspectives such as client's perspective, contractor's perspective and customer's perspective and have identified attributes/factors affecting quality from above mentioned perspectives.

In this study extensive literature has been reviewed, attributes and sub-attributes affecting quality concerning building projects in Indian construction industry have been identified and circuited among experienced construction engineers for finding their preferences. Weights of these attributes on 0-1 scale have been calculated by using Analytical Hierarchy Process (AHP). Subjective nature of quality definition makes quality measurement very difficult and thus makes quality a non-measurable term, but it can be measured indirectly by measuring factors/attributes affecting quality (Rad and Khosrowshahi year). This study has tried to develop objective and thus measurable quality index, BCQI. According to Latham (1996) client being most important project player, clients' satisfaction has always been considered top priority and clients' satisfaction mainly concerned about construction quality. In this study, customer satisfaction has been recorded by rating quality attributes of different building componentson 1-5 Likert scale by customers/users through questionnaire survey. These ratings are then normalized on 0-1 scale. In studying ongoing construction projects, same questionnaire has been utilized as checklist or rated by site engineers. In situations where attribute/sis/are non-measurable, distribution of weight/s has been done to remaining attributes in relative proportions. Attributes' and sub-attributes' weights and their normalized ratings have been used as inputs in finding attribute, sub-attribute indices and ultimately BCQI indices of different building construction projects.

IV. RESEARCH METHODOLOGY

This research has been conducted with objectives: development of quality attributes indexes and development of Building Construction Quality Index (BCQI) for measuring building project quality

Literature has been reviewed to select attributes and sub-attributes affecting quality. Material qualities, workmanship of different building members and services, architectural planning including sanitation, water supply, access to the housing projects, vicinity of facilities like hospitals, school been considered as attributes in this study. List of attributes have been sent to construction engineers having minimum five years of experience, researchers, designers and academician. Total 18 participants out of 62 have responded, showing response rate 29% and on identification of preferences of quality attributes, AHP has been applied and weights of attributes and sub-attributes have been calculated. List of attributes and their weights have been circulated to managerial level participants. On finalization of attribute weights, questionnaire survey has been conducted. Each attribute has been rated on 1-5 scale by project users for completed projects, site engineers or in some cases supervisors for ongoing construction projects. In few cases, designed questionnaire has also been used as a checklist by researcher to rate attributes and sub-attributes of construction projects. In few cases, where attributes are not measurable, their weights have been distributed in other respective attributes in proportion of their weights.

Attribute, sub-attribute indices and Building Construction Quality Index (BCQI) of residential building projects have been calculated using developed index in which inputs are weights of attributes, sub-attributes and their normalized ratings.

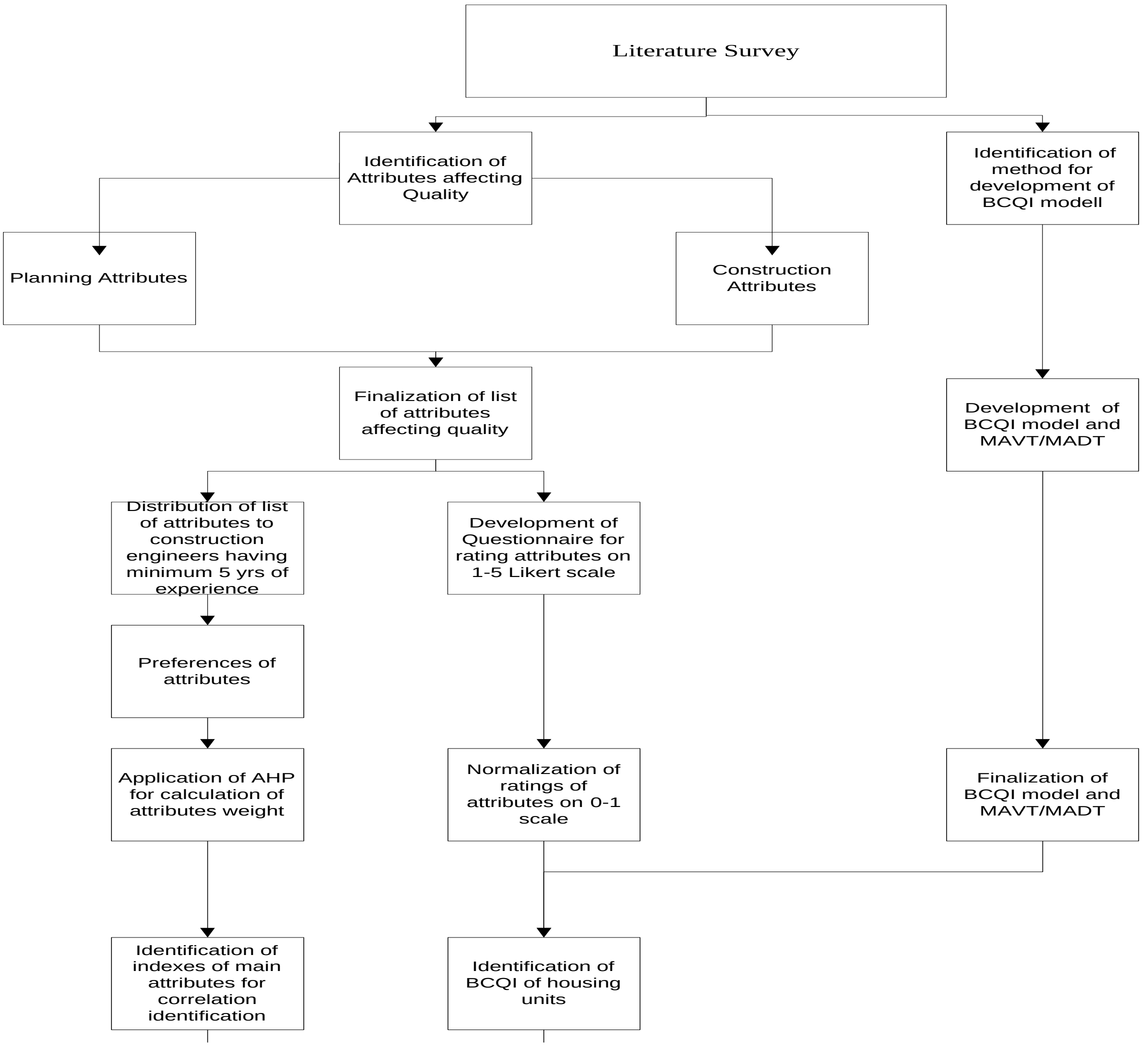

Figure 1- Research Methodology Flowchart

V. QUALITY MEASUREMENT ATTRIBUTES

Considering the importance of quality in construction industry many quality management systems, frameworks and methodologies have been developed by various authors. Rad and Khosrowshahi (1998) have developed quality measurement system in terms of quality attributes. They have categorized quality attributes in three aspects; quality in constructors view, quality in client's view and quality in third party's view. Authors have highlighted importance and difficulties associated in quality measurement. Jha and Iyer (2006) have identified critical factors affecting success and failure of the construction projects. Authors have initially shortlisted 55 attributes affecting quality of construction projects. Questionnaire survey followed by analyses of responses confirms project manager's competence, management support, feedback by participants, and interaction among participants as critical project success factors. Critical project failure attributes conflict among participants, hostile socio-economic environment, extreme climatic conditions, lack of knowledge and incompetence of project managers and competition during tendering. Karim(2011) identified factors responsible for quality living, sufficient size, sanitation, clean air and green area in vicinity for leisure and recreation, connectivity, education facilities and shopping outlets. Physical planning of city, family domain, physical environment and neighboring and community domain are responsible for quality of life.

In this research, attributes have been selected through extensive literature review and broadly classified in planning attributes and construction attributes. Planning attributes include building access, water supply, drainage system, road network, vicinity of essential services like schools and hospitals, external lights during night. Construction attributes have been selected considering components of building projects and thus include RCC elements, External walls, internal walls, doors and windows finishing, flooring, services and material storing and handling during construction. The constructions attributes are further subdivided in sub-attributes. Each attribute has been assigned weight on 0-

1 scale, calculated using AHP, with the help of preferences of attributes given by construction engineers; refer figure no. 2 for attributes, sub attributes and weights. Each quality attribute of the building project has been rated on 1-5 Likert's scale and on normalization of attributes to 0-1 scale ratings, MAVT/ MADT has been implemented to determine quality index of the building projects.

VI. CALCULATION OF WEIGHTS OF ATTRIBUTES USING ANALYTICAL HIERARCHY PROCESS (AHP)

Analytical Hierarchy Process has been introduced by Saaty in year 1980 as a multi attribute decision making management process which converts big problem into number of smaller problems making it simpler followed bycalculation of weights of factor/attributes is the primary objective of AHP.On arranging attributes on the basis of their dependencies,pair wise comparison matrix has been developed in which attributes have been arranged in decreasing order of their importance by assigning scores on 1-9 scale, 1 signifies equally important, 9- extremely important. Normalization of attributes has been done by dividing comparison matrix score by column total. Average of each row of normalized matrix gives priority or factor evaluation number of respective attribute. Validation of weights of attributes has been done by consistency ratio calculation. If consistency ratio is lesser than or equals to 0.10 then, assigned intensity numbers are consistent otherwise, reassign them.

Table No. 1- List of attribute and sub-attributes, their preferences and weights

Attribute	Average Preference	Rank	Weight
Level I			
Architectural Planning		2	0.38
Construction		1	0.62
Level II (Architectural Planning Attributes)			
Access to building	2.13	1	0.44
Water Supply	3.13	3	0.13
Drainage system	3.40	4	0.09
Road Network in Project	2.53	2	0.26
School, Hospitals	4.67	5	0.05
External Lights (during Night)	5.13	6	0.03
Level II (Construction Attributes)			
RCC Components	1.60	1	0.38
External Walls	3.80	3	0.14
Internal Walls	5.40	6	0.05
Doors and Windows	4.47	4	0.09
Finishing	5.27	5	0.03
Flooring	5.53	8	0.04
Services	5.47	7	0.05
Material Storing, Handling	3.47	2	0.22
Level III (Attributes of RCC elements attributes)			
Footing, columns, beams, slabs			0.25
Level III (external and Internal walls attributes)			
Bricks	1.47	1	0.68
Joints in masonry	2.27	2	0.20
Workmanship	2.27	3	0.12
Level III (doors and windows attributes)			
Material Quality of panel	1.53	1	0.43

Material quality of frames	1.53	2	0.43
Fixtures and Accessories	2.63	3	0.09
Workmanship in fixing	3.00	4	0.05
Level III (finishing attributes)			
Plastering	1.10	1	0.66
Painting	1.63	2	0.34
Level III (flooring attributes)			
Quality of tiles	1.42	1	0.58
Maintenance of slopes	2.26	2	0.27
Workmanship in fixing	2.47	3	0.1
Finishing and cleaning	3.36	4	0.05
Level III (services attributes)			
Plumbing	1.30	2	0.5
Electrical fittings	1.15	1	0.5
Level IV (RCC Components)			
Quality of concrete	1.67	1	0.53
Reinforcements	1.93	2	0.30
Cover	2.53	3	0.12
Finishing	3.87	4	0.05

VII.BUILDING CONSTRUCTION QUALITY INDEX (BCQI)

Multi-attribute value technique/ Multi Attribute Decision Technique has been deployed for calculation of BCQIs of building projects, as implemented by Minchin et al. (2008) for development of CQI of highway projects, Teo and Ling(2006) to measure effectiveness of safety management system and Khosravi and Afshari (2011) have developed system to measure project success. It is Simple Additive Weighting (SAW) method or also called as weighted sum method (Fishburn, 1967). Simplest form of SAW can be given as

$P_i = \sum_{k=0}^{n} wk\ rk$

BCQI has been developed to quantify quality on 0-1 scale.

$BCQI = \sum_{k=1}^{p} wk \sum_{j=0}^{m} wj \sum_{i=0}^{n} wi \times ri$ (ri normalized to 0 – 1 scale)

BCQI model,

BCQI = 0.20 (PlanIndex) + 0.80 (ConsIndex)

PlanIndex = $0.44r_1 + 0.19r_2 + 0.13r_3 + 0.07r_4 + 0.06r_5 + 0.04r_6 + 0.03r_7 + 0.04r_8$

ConsIndex = $0.38r_7 + 0.14r_8 + 0.05r_9 + 0.09r_{10} + 0.03r_{11} + 0.04r_{12} + 0.05r_{13}$

RccIndex (r_7) = $0.25r_{15} + 0.25r_{16} + 0.25r_{17} + 0.25r_{18}$

EwalIndex (r_8) = $0.68r_{19} + 0.20r_{20} + 0.12r_{21}$

IwalIndex (r_9) = $0.68r_{22} + 0.20r_{23} + 0.12r_{24}$

DawIndex (r_{10}) = $0.43r_{25} + 0.43r_{26} + 0.09r_{27} + 0.05r_{28}$

FinIndex (r_{11}) = $0.66r_{29} + 0.34r_{30}$

FloIndex (r_{12}) = $0.58r_{31} + 0.27r_{32} + 0.1r_{33} + 0.05r_{34}$

SerIndex (r_{13}) = $0.5r_{35} + 0.5r_{36}$

MatIndex (r_{14}) = $0.52r_{38} + 0.30r_{39} + 0.12r_{40} + 0.05r_{41}$

On identification of weights of factors affecting construction quality, model has been developed. The developed model directly quantifies the quality of building project. Weights have been already identified and used in the developed model. We just have to rate the identified attributes on 1-5 scale (and conver it into 0-1 scale) and put the values in developed model. The model will directly give the number, it represent the degree of quality of building project. Greater the number more is the quality of building and vice-versa.

BCQI = 0.20 Architectural Planning + 0.80 Construction Quality

$= 0.20\ (0.44\ r_1 + 0.19r_2 + 0.13r_3 + 0.07r_4 + 0.06r_5 + 0.04r_6 + 0.03r_7 + 0.04r_8)$

$+ 0.80\ ((0.38\ r_7\ (0.25r_{15} + 0.25r_{16} + 0.25r_{17} + 0.25r_{18})) + (0.14\ r_8\ (0.68r_{19} + 0.20r_{20} + 0.12r_{21}) + (0.05\ r_9\ (0.68r_{22} + 0.20r_{23} + 0.12r_{24}) + (0.09\ r_{10}\ (0.43r_{25} + 0.43r_{26} + 0.09r_{27} + 0.05r_{28}) + (\ 0.03\ r_{11}\ (0.66\ r_{29} + 0.34\ r_{30}) + (0.04\ r_{12}\ (0.58r_{31} + 0.27r_{32} + 0.1r_{33} + 0.05r_{34}) + (0.05\ r_{13}\ (0.50\ r_{35} + 0.50\ r_{36}\ )$

VIII.CONCLUSIONS

The developed model has been applied to different building projects and quality of building projects has been identified. It has been observed that developed model can easily be applied to any building projects.

Software and android applications can also be developed in MS excel, Matlab and other languages for commercialization of developed tool.

The paper presented a building construction quality index. Application of developed quality index can be done in checking for quality different buildings. The building construction quality index has been developed for building project in India, which can be generalized to any construction project.

REFERENCES

Florence Yean Yng Ling, (2005),"Models for predicting quality of building projects", Engineering Construction and Architectural Management, Vol. 12 Iss: 1 pp. 6 - 20
Guidelines for affordable housing, Government of India
http://mhupa.gov.in/w_new/AffordableHousing.pdf

Hafazah Abdul Karim "Low Cost Housing Environment:Compromising Quality of Life?" Procedia - Social and Behavioral Sciences 35 (2012) 44 – 53

K. N. JHA & K. C. IYER "Critical Factors Affecting QualityPerformance in Construction Projects"1478-3363 Print=1478-3371 Online=06=091155–16 # 2006 Taylor & FrancisDOI: 10.1080=14783360600750444

Paul Watson and Tim Howarth Construction Quality Management Spon Press

Peter Hoonakker "Barriers and benefits of quality management in the constructionindustry: An empirical study" Total Quality Management, vol. 21, No. 9, September 2010, 953-969

R. Edward Minchin, Michael I. Hammons and Junyong Ahn (2009) "A construction quality index for highway construction"Construction Management and Economics, 26:12, 1313-1324

Rad H N and Khosrowshahi F (1998) "Quality measurement in construction projects"Hughes, W(Ed.), *14th Annual ARCOM Conference*, 9-11 September 1998, University of Reading Association ofResearchers in Construction Management, Vol. 2, 389-97

Shahrzad Khosravi and Hamidreza Afshari "A Success Measurement Model for Construction Projects" *2011 International Conference on Financial Management and EconomicsIPEDR vol.11 (2011) © (2011) IACSIT Press, Singapore*

Thomas L. Saaty "Decision making with the analytic hierarchy process" *Int. J. ServicesSciences*, Vol. 1, No. 1, pp.83–98