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Critical Factors Affecting Quality Performance in Construction Projects

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ABSTRACT *The reasons for the underperformance of the quality of Indian construction projects were studied to suggest possible remedial measures. A preliminary survey identified 55 attributes responsible to impact quality performance of the projects. Statistical analysis of questionnaire responses on the attributes resulted into two distinct sets of success and failure attributes. Further analyses of individual sets of success attributes and failure attributes separately grouped them into fewer critical success and failure factors. The critical success factors obtained were: project manager's competence; top management's support; monitoring and feedback by project participants; interaction among project participants; and owners' competence. The factors that adversely affected the quality performances of projects were: conflict among project participants; hostile socio-economic environment; harsh climatic condition; PM's ignorance & lack of knowledge; faulty project conceptualization; and aggressive competition during tendering. Analyses also led to the conclusion that the extent of contribution of various success factors varies with the current performance ratings of the project. Project manager's competence and top management support are found to contribute significantly in enhancing the quality performance of a construction project. As in the manufacturing industry, the study establishes that management plays an important role in achieving quality even in construction projects.*

KEY WORDS: Quality performance, construction projects, project manager's competence, top management support, conflicts, questionnaire survey

Introduction

Collins (1996) describes quality as the world's oldest documented profession. Quality professionals use a number of definitions to define project quality. Quality in its simplest form can be defined as: 'meeting the customer's expectations,' or 'compliance with customer's specification.' No matter what definition we follow for quality, it becomes very complex when we try to put it into actual practice. For a user, quality is nothing but satisfaction with the appearance, performances, and reliability of the project for a given price range.

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In the realm of project management, the schedule, cost and quality achievement is also referred to as the iron triangle. Out of these three aspects, it is the achievement of schedule and cost compliances that the project management is attending to most of the time. This results in a half-hearted attempt to achieve quality at project sites. In order to achieve the schedule and cost objectives, project quality is sometimes also overlooked. Although many studies have recognized the importance of maintaining and doing quality projects these aspects are sacrificed in lieu of achieving short-term objectives, such as handing over of some critical structures, or only part of the structures falling in the critical path etc. Barnes (1987) emphasizes that the control of the performance of the installation, building or engineering structure should be managed in the same way as the management of time and cost. In a recent survey conducted among Indian construction professionals, it has also been found that, out of the five commonly used project performance criteria – compliances to *schedule*, *cost*, *quality*, *no-dispute* and *safety* – the *quality compliance* has come second next to schedule compliance (Jha, 2004).

Delivering projects of poor quality can have far reaching consequences. Collins (1996) quotes one that was recorded during the reign of a Babylonian king.

> If a builder constructed a house but did not make his work strong with the result that the house which he built collapsed and so caused the death of the owner of the house, the builder shall be put to death.

Existing laws might prevent such harsh penalties in the present scenario, but the consequences may rather be in terms of loss in productivity, additional expenditures by way of rework and repair, re-inspection and retest in the short term. In the long term, poor quality can hurt reputation, and if the company continues in the same way it might have to close its shop for want of new projects. If a number of construction companies of a country start neglecting the quality aspects in their projects, this also starts reflecting on the reputation of the country. Helping the construction companies to identify the critical attributes responsible for achieving the desired quality level (success factors) and also to find the attributes adversely affecting the project quality (failure factors) has been the motivating factor behind this study. It is realized that maximization of the success factors and minimization of failure factors will ensure the construction industry realizes its quality goals. Realizing these aspects, the present study was undertaken to suggest ways to improve quality as well as to take care of certain critical factors that may lead to loss of quality.

Objectives and Methodology

The objectives of the study set were as follows.

- To identify and evaluate various factors affecting the quality performance of construction projects.
- To suggest ways to improve the quality performance of construction projects.

For the study, a huge amount of documented data on completed projects was required. Owing to the non-availability of documented data on completed projects in India, a questionnaire survey approach was considered to find the impacts of various attributes on quality performance.

Literature Review

In order to address quality related issues, a number of studies have been conducted in different countries. Chua *et al.* (1999) have developed a hierarchical model for construction project success for different project objectives. For quality objectives they find that it is influenced by four main project aspects, namely, project characteristics, contractual arrangements, project participants, and interactive processes. Arditi & Gunaydin (1998) find that management commitment to continuous quality improvement, management leadership in promoting high process quality; quality training of all personnel; efficient teamwork to promote quality issues at the corporate level; and effective cooperation between parties taking part in the project are generic factors that affect process quality. Pheng (2004), through case studies, has shown that total quality management (TQM) – a successful management philosophy in the manufacturing and service industry – could be replicated in the construction industry with similar benefits. The benefits may be in terms of reduction in quality costs, and better employee job satisfaction. Bubshait & Al-Atiq (1999) observe that a contractor's quality assurance system, which ensures consistent quality, is essential in preventing problems and the reoccurrence of problems. His survey also points to the lack of documentation of a quality system for the majority of the contractors. Abdel-Razek (1998) has studied the quality improvement methodology and finds that 'improvement of employee satisfaction' is the most important area in contributing quality improvement in Egypt. Ledbetter (1994) has developed a quality performance management system (QPMS) that tracks labor costs in three main categories: normal work, quality management work (prevention and appraisal), and rework (deviation correction). He has assumed the cost of quality to be the sum total of quality management and rework. He finds QPMS to be useful in promoting awareness and improving the understanding of the quality process in addition to facilitating communication, reducing the overall cost of quality, and directing the management to the areas where quality improvements could be made. Love & Smith (2003) have proposed a generic framework for benchmarking rework at the interfaces of a project's life cycle. As can be seen from the above discussion, substantial research has been carried out that addresses the quality issues at international levels. Under Indian conditions, not many systematic studies have been undertaken for construction projects.

Identification of Success and Failure Attributes

An initial list of parameters/factors was prepared from the literature review. Leading journals and project management textbooks were referred to for this. These attributes included success and failure attributes. As the attributes selected were from the literature, which mostly catered to studies in the context of developed nations it was decided to take these attributes to selected Indian construction professionals as part of pilot survey in order to get the feedback on the attributes. The pilot survey helped in improving the list of attributes. Finally, a list of 55 project performance attributes was prepared. Although the list of 55 attributes could not be called exhaustive, owing to the vast magnitude and fragmented nature of the construction industry, the list covered a large portion of variety of construction projects.

In the first stage, the questionnaire was prepared with aim of assessing the impact of the above attributes on the four performance evaluation criteria: *schedule*; *cost*; *quality*; and *no-dispute*. However, only the 'quality' project success evaluation criterion is discussed in this paper. Responses on the extent of the effects of these attributes on quality were sought on a five-point ordinal scale: '1' referring to 'adversely affecting the quality', '2' to 'significantly affecting the quality' '3' to 'marginally affecting the quality', '4' to 'No effect', and '5' to 'helps in improving the quality'. The questionnaire is not appended here owing to space constraints.

A total of 450 questionnaires were distributed to top Indian construction industry professionals, in about the 50 large and medium size organizations. A total of 112 completed responses were received, giving a response rate of approximately 25%. The responses were analyzed using SPSS software. The mean responses on the attributes can be considered as the indicators of effectiveness of the attributes. In the present study it is assumed that if the mean score of responses for any attribute is significantly $\geq$4.5, that attribute contributes positively to the success of the project and it is named as a 'success attribute' and, conversely, if the mean score is significantly $\leq$3.5 then it causes a negative impact and is named as a 'failure attribute'. However, an attribute with a mean score falling between 3.5 and 4.5 can be considered as neutral as it would have neither positive nor negative impact. A total of 28 attributes emerged in first group ($\mu \geq 4.5$), five attributes in group 2 ($4.5 < \mu < 3.5$), and the remaining 22 attributes fell in group 3 ($\mu \leq 3.5$). Neutral attributes falling in the second group (with $4.5 < \mu < 3.5$) were discarded. They are subsequently ranked based on descending values of mean values in the case of success attributes and ascending order of mean values in the case of failure attributes. Owing to paucity of space, the entire rank order of success attributes or failure attributes is not given, but some of the high-ranking success and failure attributes are discussed below.

'Positive attitude of project manager and project participants' has emerged to be the most important success attribute for quality compliances at project sites. As could be guessed, some of the attributes with high importance are all related to the project manager. For example 'effective monitoring and feedback by Project Manager (PM)', 'Project manager's technical capability', 'leadership quality of PM', 'Effective monitoring and feedback by the project team members', 'authority to take day-to-day decisions by the PM's team at site' (rank 2, 3, 4, 5 and 6 respectively). The emergence of these attributes in the top rank indicates the importance of the 'project people' element in ensuring project quality. When there developed a misconception that, due to technological advancement and mechanization of most construction activities, the machinery rather than the people was the primary factor in achieving quality, Collins (1996) through his study also pointed out that it was a misconception that people play no great role in attaining quality. Even in this age of high technology and wonderful plant and machinery, the importance of people cannot be ruled out. We are yet to see the machines that completely eliminate the necessity of employing people at project sites. Drucker (1969), a Management Guru also advocates the importance of human element when he says:

> Modern production and especially modern mass production, is not based on raw materials or gadgets, but on principles of organization . . . not of machines, but of human beings . . .

As expected, the most important attribute adversely affecting the project quality is the 'negative attitude of PM, and project participants'. Some of the other high-ranking failure attributes are: 'poor human resource management and labor strike', 'mismatch in capabilities of client and architect', 'tendency to pass on the blame to others', and 'conflicts among team members (ranks 2, 3, 4 and 5 respectively). All these attributes indicate that achievement of project quality is a team effort and if the team members are not working in unison it leads to adverse effects on the quality of a construction project. In fact, many of the tools (for example quality circles, brainstorming etc) to achieve quality revolve around team effort.

A close scrutiny of the 28 success and 22 failure attributes revealed that the attributes have some common properties, which were not very clearly distinguishable, but appear to be overlapping across several of them. It was felt that if the set of common properties represent the entire family of attributes to a reasonable level of significance and if they are fewer in number than the actual number of attributes, then the further study could concentrate on the fewer numbers of variables than the original attributes. Accordingly, factor analysis – which is a powerful method of statistical analysis that aims at providing a greater insight into the relationship among numerous correlated, but seemingly unrelated, variables in terms of a relatively few underlying factors – was adopted for this purpose (Overall & Klett, 1972). In the present study, Factor analysis was performed separately on 28 success attributes and 22 failure attributes. Initially, the extracted factors, which were all orthogonal to each other in nature, were not amenable to interpretation. Therefore, an oblique rotation of the reference axes, called varimax rotation, was performed and derived factors and their corresponding loadings were obtained. In the first case (for success attributes) these factors explain a total of 77% of the variance whereas for the second case (for failure attributes) these factors explain 70% of the variance. The reliability of factor model was also checked with the communalities of each variable. Communalities of all the variables are found to be much greater than the 0.3 that signifies that the factor model is reliable in the present study. Owing to a higher level of variance explained by the factors extracted and the reliability of the factor analysis exhibited by the communality, the factor results were relied upon and the extracted success and failure factors as given in the following paragraphs are considered for further study.

Success Factors

Extracted success factors along with the attributes prominently emerging in them (i.e. whose factor loadings were greater than or equal to 0.4), and the variance explained by each of factors are summarized in Table 1. Names assigned to these factors are discussed in the following paragraphs.

Project Manager's Competence

As can be seen from Table 1, 13 attributes appear under Success Factor_1 and it explains a variance of about 20% (19.52% to be precise). Most attributes appearing in this factor focus mainly on coordinating the ability and rapport of the PM, the trust imposed in the project team by the delegating authority to project team members, the technical capability, positive attitude and leadership. A project manager is the key person at the site who, within a set of guidelines kept in place by the top management, allocates resources and makes policy decisions at site level. Sometimes mere involvement of a project manager in site activities can lift the morale of team members and they start working with full zeal and enthusiasm to achieve the desired quality level. A competent manager *organizes resources*

Table 1. Factor structure of success attributes for quality performance criteria

Factor description	Loading	Variance
Success Factor_1		19.52%
Coordinating ability and rapport of PM with owner representatives	0.82	
Authority to take day to day decisions by the PM's team at site	0.77	
Commitment of all parties to the project	0.75	
Understanding of responsibilities by various project participants	0.71	
Project manager's authority to take financial decision, selecting key team members	0.71	
Coordinating ability and rapport of PM with other contractors at site	0.68	
Project manager's technical capability	0.66	
Scope and nature of work well defined in the tender	0.50	
Positive attitude of PM, and project participants	0.43	
Training the human resources in the skill demanded by the project	0.43	
Construction control meetings	0.50	
Ability to delegate authority to various members of his team by PM	0.44	
Leadership quality of PM	0.40	
Success Factor_2		15.94%
Top management's backing up the plans and identify critical activities	0.83	
Top management's enthusiastic support to the PM and project team	0.83	
Understanding operational difficulties by the owner engineer thereby taking appropriate decisions	0.83	
Availability of resources as planned throughout the project duration	0.61	
Positive attitude of PM, and project participants	0.60	
Effective monitoring and feedback by the project team members	0.50	
Training the human resources in the skill demanded by the project	0.49	
Developing and maintaining a short and informal line of communication among project team	0.45	
Timely decision by the owner or his engineer	0.47	
Success Factor_3		9.91%
Selection of PM with proven track record at an early stage by top management	0.87	
Delegating authority to project manager by top management	0.86	
Developing and maintaining a short and informal line of communication among project team	0.52	
Construction control meetings	0.51	
Success Factor_4		9.62%
Coordinating ability and rapport of PM with top management	0.84	

(*Table continued*)

Table 1. **(***Continued)***

Factor description	Loading	Variance
Coordinating ability and rapport of PM with his team members and sub-contractor	0.82	
Positive attitude of PM, and project participants	0.47	
Developing and maintaining a short and informal line of communication among project team	0.42	
Construction control meetings	0.41	
Success Factor_5		9.32%
Monitoring and feedback by client	0.81	
Monitoring and feedback by top management	0.79	
Timely decision by the owner or his engineer	0.61	
Ability to delegate authority to various members of his team by PM	0.54	
Success Factor_6		8.16%
Effective monitoring and feedback by PM	0.90	
Effective monitoring and feedback by the project team members	0.64	
Favorable climatic condition at the site	0.58	
Commitment of all parties to the project	0.43	
Success Factor_7		4.56%
Leadership quality of PM	0.57	
Coordinating ability and rapport of PM with other contractors at site	0.41	
Training the human resources in the skill demanded by the project	−0.41	
		Cumulative variance explained = 77.03%

through constant persuasion with his or her higher ups; takes active part in *construction control meetings* held at site level; acts as a catalyst in training the human resources in the skill demanded by the project; and he or she makes their people *committed* to the project through *effective leadership* and by acting in non-partisan ways. All these attributes can be thought of originating from a Project Manager's competence, hence the name.

Top Management Support

The attributes emerging under Success Factor_2 and Success Factor_3 account for a combined variance of about 25% (15.94% + 9.91%) and they explain the top management support and competence. Top management support is essential for achieving desired quality mainly on account of four issues. It is the top management's prerogative to set all the policy issues (including quality policy) and control resources. In addition, top management arrange training of human resources involved in the project and they have a big role to play in identifying the project manager. With the amount of variance explained (25%) by these two factors, top management support practically becomes the most important of all factors. It can be seen that top management controls all the key factors and hence their support is highly desired for the quality compliance.

Monitoring and Feedback by Project Participants

Two main attributes emerging in this factor explain the predominant aspects of monitoring and feedback. Since the other attributes appear as a combination, this factor is named after Monitoring and Feedback. Proper monitoring and timely feedback help in controlling the workmanship and they enhance the quality of a project. If each part of the activity of a project is monitored effectively and instances of poor workmanship and improper usage of resources – be it material, labor or plant and machinery – are reported promptly, it aids in achieving the desired quality level. Committed participants would stick to the quality plan and they would follow the accepted technical practices to carry out the different project activities.

Interaction among Project Participants

Attributes in Success Factor_4 and Success Factor_7 emphasize elements of interaction among project participants. Any project involves interaction among different project participants. The participants include the internal participants, such as the contractor's team members, as well as the external team members, such as different subcontractors and vendors. Most of the activities require proper understanding of the needs of the others. There are instances when the quality of the project suffers for want of proper interaction between the participants. This fact is more vivid if one executes projects that involve multiple categories of work; say, for example, civil works; electrical works; mechanical works; HVAC (heating, ventilation, and air-conditioning); and building automation etc. One can appreciate the havoc created to the quality of project activities on account of lack of interaction among project participants. The coordinating ability and positive attitude of project participants are great assets in such conditions. A short and informal line of communication as well as regular construction control meetings among project teams further support the achievement of the desired quality level.

Owners' Competence

The owners play an important role in achieving the desired quality level. Not only are they responsible for the preparation of a clear and unambiguous specification, but they must also monitor the actual work at the site. It is well recognized that having the clients' inspectors work with the contractor to establish good quality control procedures before the work is done, is much more effective than walking around after (Barnes, 1987). In addition, if any case of any discrepancies or deviation from the specification is observed it should be communicated immediately to the concerned person. If the owners desire a quality job, they should stick to the specification since any relaxation in quality performance, even for few times, can set a bad precedence. Thus competence of the owner plays a prominent role in defining the expected level of quality from the contractor organization; hence the factor truly justifies its importance.

Failure Factors

A summary of the failure factors, the attributes associated with each of the factors, their factor loadings and variance explained by each factor are presented in Table 2. The factors generated from the studies are described below.

Table 2 Factor structure of failure attributes for quality performance criteria

Factor description	Loading	Variance explained
Failure Factor_1		16.32%
Negative attitude of PM, and project participants	0.75	
Poor human resource management and labor strike	0.74	
Mismatch in capabilities of client and architect	0.71	
Vested interest of client representative in not getting the project completed in time	0.66	
Holding key decisions in abeyance	0.63	
Conflicts among team members	0.51	
Reluctance in timely decision by top management	0.42	
Conflicts between PM and top management	0.41	
Failure Factor_2		12.57%
Hostile social environment	0.83	
Hostile political & economic environment	0.75	
Harsh climatic condition at the site	0.59	
Inadequate project formulation in the beginning	0.55	
Urgency emphasized by the owner while issuing tender	0.48	
Failure Factor_3		11.66%
Ignorance of appropriate planning tools and techniques by PM	0.78	
Reluctance in timely decision by PM	0.77	
Lack of understanding of operating procedure by the PM	0.75	
Reluctance in timely decision by top management	0.41	
Failure Factor_4		7.93%
Tendency to pass on the blame to others	0.78	
Project completion date specified but not yet planned by the owner	0.59	
Conflicts between PM and top management	0.44	
Failure Factor_5		7.83%
Uniqueness of the project activities requiring high technical know-how	0.87	
Size and value of the project being large	0.74	
Failure Factor_6		7.21%
Conflicts between PM and other outside agency such as owner, sub-contractor or other contractors	0.78	
Conflicts between PM and top management	0.41	
Conflicts among team members	0.41	
Size and value of the project being large	−0.45	
Failure Factor_7		6.80%
Aggressive competition at tender stage	0.82	
Urgency emphasized by the owner while issuing tender	0.48	
		Cumulative variance explained = 70.32%

Conflict among Project Participants

It can be observed from the attributes of Failure Factor_1, and Failure Factor_6 in Table 2, most attributes either represent differences in opinions or lack of coherence in some way or other. All blue- and white-collar workers must work in unison otherwise it leads to an improper quality level being achieved on site. In addition, in an organization where people at higher hierarchy levels tend to pass the blame to lower hierarchy people, the achievement of desired quality always remains in doubt. As discussed earlier, recognizing quality as a result of teamwork, the management should create a suitable environment to build a team by plugging all such causes that give rise to an adversarial relationship among team members.

Hostile Socio Economic and Climatic Condition

A hostile work environment affects the quality of a construction adversely, as suggested by this analysis. This has also been observed by other industries. A poor work environment not only decreases productivity but it also affects the project quality. In addition, harsh climatic conditions give rise to a fatigued workforce, leading to poor quality. As can be seen from Table 2, this factor accounts for 12.57% of the variance.

PM's Ignorance and Lack of Knowledge

If project participants lack job knowledge and they ignore the appropriate planning tools and established quality norms, it results in poor quality. This factor accounts for 11.66% of the variance. The top management should devise means to supplement the knowledge needs of project participants by providing training at regular intervals. A proper recruiting policy and arranging an in-house training program for the project team members can also tackle these aspects.

Faulty Project Conceptualization

Attributes under this factor represent faulty project conceptualization and conflict between PM and top management. However, the name of the factor has been kept as 'faulty project conceptualization' since conflict among participants has predominantly been present in Failure Factor_1 and Failure Factor_6. If the project completion date has been frozen without arranging inputs and proper planning, this can lead to hasty and unsystematic work towards the end of the project resulting in the project's quality taking a back seat. All this haste also leads to a relaxation in quality specification from the owners' side, as they tend to overlook the deviation by the contractor from the agreed technical specification. The contractor on his part tries to save time by adopting shortcuts and bad technical practices. All these lead to poor quality.

Project Specific Factors

As can be seen, the attributes emerging under this factor are project specific. The emergence of the attribute 'Uniqueness of the project activities requiring high technical know-how' in the failure attributes indicates that if a project involves certain unique activities that the project people have not performed on previous projects it contributes negatively to achieving the desired quality. Some learning time may also be required for the people involved with these activities. Apart from this attribute, if the size and contract value of the project is large, the limited number of project people may not be able to do justice in all areas and this may adversely affect the project quality.

Aggressive Competition during Tendering

Aggressive competition sometimes forces the bidders to quote low for the project. Once awarded the project they are not motivated enough to do a quality job. To make some profit out of the project they sometime try to use inferior materials and bad technical practices, leading to poor quality. The problem of a low bid is quiet common in cases of government-owned projects. While it is perfectly logical for the government, being the guardian of public funds, to accept low bids, selection of a low bidder more often than not causes problems to the project. In addition, the low bidder sometimes resorts to subcontracting the entire project to unqualified contractors, leading to poor quality.

Extent of Contribution of Critical Factors

As discussed earlier, project performance has been measured on four performance evaluation parameters: *schedule*; *cost*; *quality*; and *no-dispute*. In addition, since factors extracted under different performance evaluation parameters are different, a union of all factors is considered for further study. A total of 20 factors (including 11 success factors and nine failure factors) are formed from the analyses on the four performance parameters and they are taken for further study through the second stage questionnaire survey. These factors, along with their identification numbers are given in Table 3.

In the second-stage questionnaire, these 20 factors are used as variables and responses are sought on the extent of contribution of these factors in the performance of the choice project. A response on the extent of the contribution of individual factors is sought on an 11-point scale (-5 to $+5$ through 0, with -5 indicating high contribution,

Table 3 Pooled list of factors identified under various performance evaluation parameters

Sl. No.	Factor names	Factor identification number
1	Project manager's competence	F1
2	Top management support	F2
3	Monitoring and feedback by project participants	F3
4	Favorable working condition	F4
5	Commitment of all project participants	F5
6	Owners competence	F6
7	Interaction among project participants-internal	F7
8	Interaction among project participants-external	F8
9	Good coordination among project participants	F9
10	Availability of trained resources	F10
11	Regular budget update	F11
12	Conflict among project participants	F12
13	Project manager's ignorance and lack of knowledge	F13
14	Hostile socio economic environment	F14
15	Owner's incompetence	F15
16	Indecisiveness of project participants	F16
17	Harsh climatic condition at site	F17
18	Aggressive competition during tendering	F18
19	Negative attitude of project participants	F19
20	Faulty project conceptualization	F20

0 being no effect and +5 indicating high positive contribution). Also, the performance rating of a choice project in a 10-point scale (1 to 10 with 1 being very poor performance to 10 being very good performance) is obtained. The responses of performance ratings of any project would however be different in different parameters, such as schedule, cost, quality, and no-dispute. Using the performance rating of the choice project as a response variable and the extent of the contribution of various factors as explanatory variables, multiple regression is applied as given in equation (1) below; the data points would however be the responses of these variables in the second stage questionnaire.

$$\text{Performance rating} = f(\text{F1, F2, F3}, \ldots, \text{F20}) \qquad (1)$$

Since the responses on response variables and explanatory variables were discrete variables, the multinomial logistic regression is considered more appropriate. When the multinomial logistic regression is carried out using all 20 variables (factors) none of the variables has emerged as significant, although the percentage prediction using this model is 100%. As suggested by statisticians, the inclusion of irrelevant variables can result in poor model fit, so the number of variables should be restricted (Whitehead 1998, SPSS Release 9 manual). This is like stepwise regression in linear multiple regression. Accordingly, a number of multinomial logistic regressions are performed using only those variables (factors) in the right-hand side of equation (1) that have emerged from the corresponding performance criteria and whose rating is used as a response variable in the left-hand side of the equation. In the present case, separate analyses using the success factors of quality parameter, F_1, F_2, F_3, F_6, F_7 and F_8; and failure factors F_{12}, F_{13}, F_{14}, F_{17}, F_{18}, and F_{20}, as explanatory variables and the effects on the level of quality achieved in the chosen project were carried out. The important results of multinomial logistic regression between success factors and quality performance rating are summarized in Table 4, and, before discussing the results, a section on the interpretation of Multinomial Logistic Regression is given for ease of understanding.

Interpretation of Multinomial Logistic Regression Models

The multinomial logistic regression is an extension of binomial logistic regression and the chances of occurrence of a particular value of a response variable are compared with the chances of occurrence of the reference value of the response variable – the performance level of the project. In the present study, since our interest is to look for the best outcome and identify those explanatory variables that would enhance the chances of bringing the performance level closer to the best outcome, as well identifying those that drag the performance level down, the reference value of the performance level is set as 10, i.e. the ‘very good performance’ rating.

The interpretation of the results of this regression is drawn from three main components: ‘odds ratio’, generally written as e^B; ‘log of odds ratio’, B; and the ‘current value’ of the explanatory variable which is compared with the reference value 10.

Odds ratio. This is the ratio of the likelihood of occurrence of an event to the likelihood of non-occurrence of that event, and it is denoted by e^B. Alternatively, it is also defined as the ratio of the chances of an event happening to the chances of all other events rather than this event happening. If the chances of occurrence of an event M (the current value of the

Table 4 Summary of important results of multinomial logistic regression between success factors and Quality performance rating

QPR* (1)	Variable (2)	Log of odds ratio, B (3)	Std. error, SE (4)	Wald Stat = $(B/SE)^2$ (5)	Sig. level, α (6)	Odds ratio, e^B (7)	p (8)	q (9)	Δp (10)	Δq (11)
5.00	Intercept	7.077	4.428	2.555	0.110					
	F_1	−1.780	1.005	3.138	0.076	0.169	0.14	0.86	−0.12	0.12
6.00	Intercept	4.931	3.974	1.540	0.215					
	F_1	−2.406	0.935	6.617	0.010	0.090	0.08	0.92	−0.07	0.07
	F_6	3.383	1.774	3.638	0.056	29.459	0.97	0.03	0.03	−0.03
7.00	Intercept	3.794	2.483	2.335	0.126					
	F_2	−1.000	0.543	3.386	0.066	.368	0.27	0.73	−0.15	0.15
	F_7	1.534	0.682	5.055	0.025	4.635	0.82	0.18	0.13	−0.13
8.00	Intercept	3.503	1.845	3.604	0.058					
	F_1	−0.926	0.419	4.879	0.027	0.396	0.28	0.72	−0.15	0.15
	F_8	−0.613	0.318	3.719	0.054	0.542	0.35	0.65	−0.12	0.12
9.00	Intercept	0.865	1.908	0.205	0.650					
	F_1	−0.852	0.405	4.439	0.035	0.426	0.30	0.70	−0.15	0.15
Model Chi square (degree of freedom)				= 65.605(36) significance level 0.002						
Nagelkerke R^2 value				= 0.556						

*Quality performance rating

response variable) is p, the chances of occurrence of the performance rating not being M or other than M will be $q = (1 - p)$. Since it is a binomial case and all comparisons are made with a reference value (the event N), the chances of the event not being M will be the chances of the event being N: $e^B = p/q = p/(1-p)$. Alternatively, the values of p and q can be determined from e^B and can be written as $p = e^B/(1+ e^B)$ and $q = 1/(1+ e^B)$.

The M and N in the present study pertain to the values of the response variable, i.e. M represents the occurrence of the project performance of some desired level called as ‘current value’ having values 2, 3 and so on up to 9; and N will be the ‘reference level’, which is taken as 10.

Log of odds ratio. This is denoted by B and, as the name suggests, it is the log of e^B, the odds ratio. This component is regarded more for its sign, which determines the impact of the explanatory variable on the outcome of the response variable. For the event M (the assumed value of the response variable), if the analysis shows a positive sign to B, it implies that any increase in the value of explanatory variable will increase the likelihood of the event being M. Conversely, the negative value of B indicates that an increase in the value of explanatory variable will decrease the likelihood of event being M, i.e. the occurrence of the response variable being at the current level. Since the performance level is compared with 10, a decrease in the likelihood value of the performance rating at the current level will indicate the increase in the likelihood value of the reference performance rating and vice versa.

The magnitude of the impact of the explanatory variable on the current value of the response variable is determined by the magnitude of the odds ratio, e^B. More precisely, a one unit increase in the value of the explanatory variable causes the odds ratio to change by $(1 - e^B)$ times, i.e. the new or changed value of the odds ratio would now be $e^B\{1-(1-e^B)\} = e^{2B}$. Accordingly, the new value of likelihood of event M, p' (say) and that of event N, q' (say) after change due to one unit of explanatory variable will be $e^{2B}/(1+e^{2B})$ and $1/(1+e^{2B})$ respectively. If Δp and Δq are the changes in the values of the likelihood of events M and N, they can be written as:

$$\Delta p = p_{\text{new}} - p_{\text{old}} = p' - p = \frac{e^{2B}}{1+e^{2B}} - \frac{e^B}{1+e^B} \tag{2}$$

$$\Delta q = q_{\text{new}} - q_{\text{old}} = q' - q = \frac{1}{1+e^{2B}} - \frac{1}{1+e^B} \tag{3}$$

As discussed above in this section, the M and N in the present study represent the occurrence of a desired level of project performance, and N is the reference level of 10. Δp indicates the change in likelihood of project performance being at the current level and Δq indicates the change in likelihood of project performance of not being at the current level, i.e. being at the reference level of 10. The values of Δp and Δq are thus complementary to each other. It could be further interpreted that the negative value of Δp which indicates decreasing chances of the project performance being at the current level, is also associated with the positive value of Δq indicating increasing chances of an alternative event, i.e. performance level being at 10. These lead us to conclude that a negative value of Δp indicates improvement in the performance level towards 10 from the current level. On the other hand, a positive value of Δp indicates increasing chances of performance of the project being at the same level and decreasing chances of performance being at the alternate level of 10. These lead us to conclude that with a positive value of Δp there will be diminishing chances of further improvement. These logics are used for interpretations of results of statistical analyses of responses as discussed below.

Analysis of Responses to Success Factors

It is found from the analysis (Table 4) that none of the variables appear significant when the project quality is at the lower level, i.e. below level 5. Five factors F_1, F_2, F_6, F_7 and F_8 are found to be significant at different performance ratings. Even among these factors, F_1 (project manager's competence) has been found to emerge in four performance levels, 5, 6, 8 and 9. Its Δp and Δq values (Col 10 and Col 11) indicate that a one unit rise in the value of F_1, the likelihood of bettering the performance, will be 12%, 7%, 15%, and 15% respectively when the present performance level is 5, 6, 8, and 9 respectively. Even if the percentage increase in the likelihood of bettering is taken as indicative, it still leads us to conclude that the factor F_1 is the most important of all factors to achieve improved performance. The high level of importance given to a project manager's competence for achieving quality, as obtained in this study, also tends to emphasize the philosophy of quality gurus Juran and Cosby, that the key to quality lies with middle management rather than with the workforce itself.

It can be also observed from Table 4 that by increasing top management support (F_2), the likelihood of bettering the performance will be 15% from its current level of 7. In addition, when the project quality is at level 8, a unit increase in the interaction between project participants (F_8) would result in a 12% increase in the probability of producing the 'very good' (Level 10) quality. The meanings could not be assigned to the positive B value of variables F_6 and F_7 in levels 6 and 7 as they indicate that an increase in an owner's competence and the internal interaction between project participants are more likely to keep the project quality at the same level. This can also be linked to the philosophies of quality gurus that top management support and communication are essential ingredients of quality.

Analysis of Responses to Failure Factors

The application of multinomial regression for failure factors corresponding to quality performance, namely F_{12}, F_{13}, F_{14}, F_{17}, F_{18}, and F_{20} does not result in a significant model. The Chi-square value of 38.782 with 36 degrees of freedom is significant at 0.345, which means that the null hypothesis that the effects of the explanatory variable are zero can be accepted. Hence, the model formed in this case is not fit to be interpreted and hence is discarded.

Summary and Conclusion

Compliance with quality specifications is an important performance measure of any construction project. The repercussions and consequences of poor quality can be a loss in productivity; additional expenditure by way of rework and repair; loss of reputation, leading to loss in market share; and eventually being put out of business. The importance of performing work to the expected quality level has been recognized since ancient times. It has become even more relevant in the context of a barrier-free world. With the opening up of the economy to the outside world, Indian companies are going experiencing stiff competition, not only from domestic players alone but also from multinational companies. To help companies cope with the quality demands imposed by customers, through attending to the attributes affecting the quality of construction projects, has been the motivation behind this study. Through interviews of construction professionals and by searching the relevant literature, 55 project attributes were compiled. Out of these 55 attributes, 28 – referred to as success attributes in the study – were found to help achieve the desired quality, whereas the presence of 22 – referred to as failure attributes – were found to affect adversely to the achievement of the desired quality performance. The conclusions derived from the study are given below.

- *Project manager's competence*; *top management support and their competence*; *interaction between project participants*; *owners' competence*; and *monitoring and feedback by project participants* are the factors having positive contributions to achieving the desired quality level, while factors such as *conflict among project participants*; *hostile socio-economic and climatic condition*; *ignorance and lack of knowledge*; *some project specific factors*; and *aggressive competition at the tender stage* are found to adversely affect the quality performances of projects.
- The extent of the contribution of various success factors varies with the performance ratings of the project. A project manager's competence is observed to be the most significant factor at almost all levels of the quality performance rating. The other two factors that have a significant contribution in improving the project quality are found

to be 'top management support' and 'interaction between project participants'. The study re-establishes some of the earlier findings in the developing countries' context, that essential factors to achieve good quality are the 'human element rather than machinery' and 'good communication among people'. In addition, it also establishes that, similar to the production industry, in the construction industry the role of management is more important than the workforce itself in achieving quality. The results of the study prove to be closer to Juran's philosophy that middle management (project manager and his team in this case) play a more important role in most stages of the project, although the top management's role becomes more significant in further enhancing the level of quality when the existing level is already high.

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