Success factors for safety performance in public construction projects

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The construction industry is inherently hazardous. Human life is precious and thus construction safety is of paramount importance. Thus, there is a need to make the construction site a safe place to work although the poor safety record remains a concern. The identification of success factors for safety performance is considered to be a starting point for achieving construction safety in public projects. Through literature review, 36 success attributes were identified, and based on a questionnaire survey the responses of professionals on these attributes were collected and analyzed. The factor analysis on the responses yielded four success factors: awareness of and compliance with rules and regulations; pre-project planning and clarity in scope; effective partnering among project participants; and external monitoring and control. Identification of success factors helps in paying attention to only few areas, which will minimize the number of injuries and fatalities. The four success factors when subjected to multivariate linear regression, resulted in "Pre-project planning and clarity in scope" as the most significant contributing factor to safety performance in public construction projects. All construction safety management programs require compliance on safety standards, procedures, policies, and training programs but focused attention on these success factors can significantly reduce the number of injuries and fatalities and increase the safety performance. The results would be helpful to public construction project professionals, in taking proactive measures for meeting the safety requirements during the successful completion of public projects.

1.0 INTRODUCTION

In India, the construction industry contributed about 8.1% to GDP in 2010–2011, up from about 5.1% in 1999–2002 [1]. The Project Management Institute-Federation of the Indian Chamber of Commerce and Industry (PMI-FICCI) also reported that the infrastructure sector is the largest contributor to India's GDP. As per the twelfth five-year plan, an investment of US $1 trillion in infrastructure projects is expected in India during the period 2012–2017 (an approach to the twelfth five-year plan, 2011). Construction industry is also one of the largest employment sectors in the economy. For example, in Australia employment grew by 57% in the 10 years to February 2011, making it the second largest growth industry over this period [2]. However, this sector is also associated with the poorest project delivery performance coupled with a low adoption of best management practices [3]. Construction is an integral part of infrastructure development, but construction is inherently hazardous. This is evident from the comparative statistics of fatal and non-fatal injuries that have taken place over the years, in different industries involving construction. The US construction industry accounts for 19% of all occupational fatalities and, despite a gradual decline, remains the highest source of fatal occupational accidents [4]. The reasons behind the statistics are many.

Construction is mostly a one-off activity and situations encountered in construction projects are also unique. Construction these days is practiced under the framework of a multi-layered subcontracting system, with workers with different skill sets and from different age groups. The work is also characterized by its casual nature, temporary relationships between employer and employee, uncertain working hours, lack of basic amenities, and inadequacy of welfare facilities. The construction workers, especially in India, are mostly unskilled and uneducated. According to the Construction Industry Development Council's (CIDC) country report 2005–06, in India, the unskilled work force comprises 73.1% of the total construction work force of 33 million people [5]. Furthermore, they have to work under difficult outdoor climatic conditions. The workers are employed mostly on a temporary basis, and often change their employers. Even on one site their services may be required for different construction activities, under different charge hands and foremen.

Human life is precious, and all stakeholders should endeavor to make the construction site a safe place to work. In addition to the human aspect, injuries sustained at construction sites have legal and economic aspects associated with them, thereby requiring all the more attention. The poor safety record of the construction industry continues to be an international cause for concern [6].

Different governments are at advanced stages of framing the rules to be applicable in their respective states. Wherever the rules exist, their enforcement needs a lot of improvement. Though the awareness about safety is increasing day by day, more is still required to reach global safety standards. One such step taken by the Ministry of Labor, Government of India, was the declaration of 2008 as the year of industrial health and safety.

Employee safety behavior also plays an important role in preventing accidents. Cooper observed that 86% of the variation in employees' safety behavior was associated with senior, middle and front-line manager's safety leadership behavior, and the corrective action rate [7]. Furthermore, he identified that the manager's safety leadership influences the success of behavioral processes. Safety in construction must be given priority during preconstruction, construction, and post-construction phase. The onus lies on the management and workers to be sincere about safety issues in construction. Experience has shown that a preventive safety culture is beneficial for workers, employers and governments alike.

Top performing companies express a high commitment towards safety [8]. However, the commitment of an individual manager to the organization's safety goals and the behavioral safety process is a significant factor in achieving this [9]. In many instances this does not occur, and safety is compromised. Perceptual data obtained from the UK construction industry suggested that managerial commitment to safety could exert an impact

Figure 1. Scaffolding at a construction site

of approximately 51% on a behavioral safety process [10]. The safety performance increases with more interactions between the management and subordinates [11]. In the construction industry, it is front-line management that has the maximum influence [7]. Senior managers influence the behavior of middle managers, who influence the behavior of front-line managers, who subsequently influence employee behavior.

In theory, most construction injuries can be either prevented or controlled. Unfortunately, achieving this goal has been very slow in practice [12]. This emphasizes clearly the importance of the management role in construction safety performance, whose objective is to reduce construction injuries and death (both of labor force and the public), by taking the lead in promoting construction site safety, and making the work environment safe. Zhou et al. have studied the emergency management system and identified the success factors for it, but emergency occurs when attention is not paid in routine circumstances [13]. There are a large number of commissions and various publications in different parts of the world that successfully identify the attributes responsible for safety performance in construction practices. However, little attention has been given to the analysis of these attributes, in the context of overall success, keeping safety performance as the key area. The identification of success factors based on these attributes will be of great help in preventing accident, as well as in achieving overall success. This paper addresses that gap, and identifies various success factors that would help management to achieve a better safety performance.

Hence, the identification of success factors for construction safety performance would be of great help in preventing accidents. The objectives of the study are as follows:

- to determine success factors for the safety performance of public construction projects
- to identify the relative importance of these success factors in safety performance.

Owing to the non-availability of documented and structured data on completed projects with professional organizations for the study, a questionnaire-based survey method was used for data collection. The responses received were analyzed statistically.

The literature review, research method, analysis of survey results, and application of research to construction projects are explained in the following sections.

2.0 LITERATURE REVIEW

The International Labor Organization (ILO) defines an occupational accident as an unexpected and unplanned occurrence, including acts of violence, arising out of, or in connection with, work, which results in one or more workers incurring a personal injury, disease or death [14]. According to a 2005 ILO report, workers suffer approximately 270 million occupational accidents each year. The US construction industry accounts for 19% of all occupational fatalities, and despite a gradual decline, remains the highest source of fatal occupational accidents [4]. The construction fatality rate in the United Kingdom has risen to 21.5% of total occupational fatalities [15]. Accidents in the construction industry cause a substantial loss to employers, workers and society. Although figures for fatalities are accurate, surveys commissioned by the Health and Safety Executive (HSE) indicate a reporting rate by employers, for other reportable injuries, as low as 40% [16]. Thus, the published statistics are merely the tip of the iceberg.

One of the oldest building regulations (Code of Hammurabi) known can be traced to approximately 2,000BC. Its first rule states: "If a builder builds a house for a man and does not make its construction firm, and the house which he has built collapses, and causes the death of the owner of the house, that builder shall be put to death" [17]. However, these strict rules only inhibited innovation. Modern designs are based on early phases of trial and error. Now we are able to build safer bridges and buildings with economical sections, with the help of modern codes.

In the early days, scope of "safety" was restricted to accident prevention, and to analyzing the cause of the accident. These included the removal of physical hazards and improving the industrial environment. Heinrich et al. [18] carried out a lot of scientific work in the area of industrial accident prevention during this era. Later, the scope of "safety" was enlarged to protect workers' health. Organizations such as the ILO and World Health Organization (WHO) promoted the occupational health of industrial workers globally. The word "industrial" was replaced by "occupational" to embrace all types of employment, instead of restricting it to factories and mines. The ILO identified the need for action, required to reduce the risk of accidents in the construction industry and, as far back as in June 1937, and adopted a Convention (No. 62) concerning minimum safety standards in the building industry. Thereafter, the ILO adopted a comprehensive Convention (No.167) and, in June 1988, its associated recommendation (No.175) on health and safety in the construction industry. According to these recommendations, national laws or regulations should require that employers and self-employed persons have a general duty to provide a safe and healthy workplace, and to comply with the prescribed health and safety measures. In addition, those concerned with the design and planning of a construction project should take into account the health and safety of the construction workers, in accordance with national laws, regulations and practice. Emphasis is also placed on preventive and protective measures, such as the safety of the workplace, scaffolds, lifting appliances and lifting gear, pile-driving, work over water, health hazards, dangerous atmospheres, fire precautions, radiation hazards, first aid and welfare, (Figure 1).

Workers' compensation laws were drafted for the first time in 1867, to provide some measure of protection to industrial workers in India. This small but significant step could be marked as the birth of modern safety movement. The safety movement in India started formally when the National Safety Council was set up in 1966. The council recognized that safety is the responsibility of management and in this endeavor, active support of workers was needed. In order to generate awareness, March 4th of each year is celebrated as National Safety Day. Lok Sabha (Lower House, Parliament of India) passed the construction workers' bill in August 1996, to regulate the working conditions of workers on all construction sites. The bill proposed the appointment of a Director General of inspection, with various subordinate inspectors to check adherence to the provisions of the bill, such as workers' wages, working hours, temporary accommodation, and other welfare measures. Subsequently, in 1998, the Central Rules on the building and other construction workers (regulation of employment and conditions of service), which is applicable to central establishments, also came into existence. Some important Indian Acts pertaining to labor are: (1) The Payment of Wages (Amendment) Act, 2005; (2)The Contract Labor (Regulation & Abolition) Act, 1970; (3) The Building & Other Construction Workers' (Regulation of Employment & Conditions of Service) Act, 1996; (4) The Child Labor (Prohibition & Regulation) Act, 1986; (5) The Workmen's Compensation (Amendment) Act, 2000; (6) The Employees' Provident Fund & Miscellaneous Provisions Act, 1952; and (7) The Unorganized Workers' Social Security Act, 2008. Compliance to these laws helps to avoid many labor-related problems to a great extent, during on-site construction.

It is a fact that nobody wants to be involved in an accident. In spite of this, accidents do happen (Figure 2). Haslam et al. observed that levels of involvement of key factors in accidents were: problems arising from workers or the work team (70% of accidents); workplace issues (49%); shortcomings with equipment (including personal protective equipment) (56%); problems with suitability

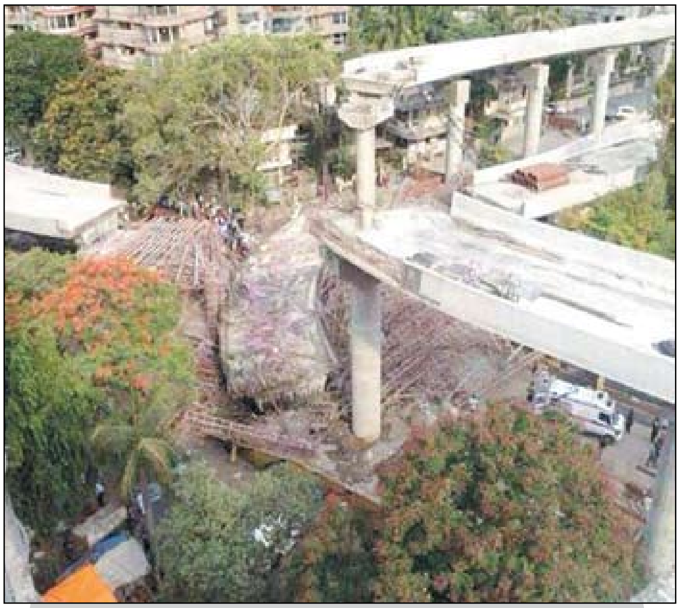

Figure 2. Tapi bridge collapse
Source: News paper Divya Bhaskar dated 10.06.2014

and condition of materials (27%); and deficiencies with risk management (84%) [6].

A number of theories have been developed over the years to understand and explain accident causation. Heinrich et al. propagated the domino theory to explain the causation of accidents [18]. According to Heinrich, when one of the dominoes falls, it triggers the collapse of next domino, and the next, and so on. The five dominoes used by Heinrich in his theory are: (1) social environment and ancestry; (2) fault of person; (3) unsafe act and/or unsafe condition; (4) accident; and (5) injury. Heinrich believed that people are the fundamental reason behind any accident. He was also of the opinion that management has the ability, and is thus responsible for the prevention of accidents. Vincoli gave an updated model in which he renamed the original five dominoes as: (1) management: loss of control; (2) origins: basic causes; (3) immediate causes: symptoms; (4) contact: incident; and (5) loss: people-property [19]. According to Vincoli, a lack of control by management initiates the process that eventually results in incidents [19]. Failure of management to fulfill its responsibility leads to basic causes from which incidents arise. The basic causes belong to personnel and job factors.

According to Petersen, a number of causes and sub-causes, combined together in random fashion, are responsible for an accident, and it is not possible to attribute the causation of accident to a single cause, as suggested simplistically by domino theory [20]. Under the goals-freedom-alertness theory, accidents are viewed as low quality work behavior, occurring in an unrewarding psychological climate, which does not contribute to a high level of alertness. The essence of the theory is that management should let a worker have a well-defined goal, and should give the worker the freedom to pursue that goal. Ferrel believed that accidents are caused as a result of human error, resulting from: (1) overload beyond the capacity of the human being; (2) incorrect response by the person owing to incompatibility, to which the human being is subjected; and (3) performing an improper activity either as a result of a lack of awareness, or deliberately taking a risk. He emphasized overload and incompatibility. Hinze developed the distractions theory to explain the accident-causation, wherein hazard was defined as: (1) physical condition with inherent quality which can cause harm; and (2) the preoccupation with work-related or unrelated issues, such as approaching deadline, anticipated parties, or death in the family etc. [21]. The lower the distractions from known hazards, the greater the probability of completing a task safely. Furthermore, the theory claims that, under similar hazardous and well-defined situations, the worker with more heavy mental baggage (mental distraction) has a higher chance of not completing the task in a safe manner.

In recent years, there has been a movement away from safety measures, based purely on retrospective data or "lagging indicators", such as fatalities, lost-time accident rates, and incidents, towards so-called "leading indicators", such as safety audits or measurements of the safety climate. The shift of focus has been driven by awareness that organizational, managerial and human factors, rather than purely technical failures, are prime causes of accidents in high reliability industries. The commitment of an individual manager to the organization's safety goals and the behavioral safety process is a significant factor in attaining safety [9]. Safety performance increases with increasing interactions between the management and subordinates [11]. In the construction industry, it is the front-line management that has the most influence on the workers, but this is influenced by senior managers to a great extent [7]. This definitely identifies the importance of the role of management in achieving safety.

3.0 RESEARCH METHOD

The research method involves a literature review to capture the existing body of knowledge about success attributes for safety performance. Then, a questionnaire-based survey was conducted to draw the views of experienced public sector professionals on these success attributes. Finally, univariate and multivariate data analysis, such as ANOVA, factor analysis and regression analysis, were applied. Through ANOVA, significant attributes for highly successful projects were identified. Then these attributes were grouped into small factors through factor analysis and, finally, regression analysis was done to identify the important factors. The steps involved are explained briefly below:

3.1 Preliminary interview

All reported success attributes of the public construction project were considered, in order to develop a list of items for empirical testing. The identified attributes were scrutinized and verified through a series of face-to-face interviews with a number of selected professionals, with sufficient experience in public construction projects, including senior management representatives in India. A total of 10 key target project participants were interviewed, to elicit their perceptions on the contribution of attributes to the success of public construction projects. The interviews were conducted in the respondents' head offices, and lasted for one to two hours, depending on the time allocated by the respondents, and the degree of detail in their answers. A pilot study questionnaire was drafted, to test the attributes and criteria adopted when assessing the success of a public construction project. The draft of the main empirical research questionnaire was reviewed by the participants during the face-to-face interviews. Since no major adverse comments were received from the respondents, the pilot study questionnaire, after slight modification, was taken as the final empirical questionnaire for the investigation. Finally, 36 success attributes were determined, and these constituted the basis for the empirical survey questionnaire.

3.2 Questionnaire development

The attributes identified were presented to the respondents. The respondents were requested to rate the success attributes for the project in which they were currently involved then (case project). The rating for each attributes was sought on a nine-point Likert scale in which "1" represented "strong disagreement" and "9" represented "strong agreement". If the respondent had no idea about a given attribute they were asked to state "don't know". An extract of the questionnaire is given in Annex 1.

3.3 Selection of respondent

A list of completed or ongoing public construction projects was developed, on the basis of information obtained from the website the of Ministry of Statistics and Programme Implementation (infrastructure and project monitoring division), Government of India (http://www.mospi.gov.in), which monitors all the public projects of more than 20 crore (US $ 50 million, at an exchange rate of Rs 40 for $1) in value. Projects costing between Rs 100 crore (1 crore=10 million) and Rs1,000 crore are called major projects, and projects costing between Rs20 crore and Rs 100 crore are called medium projects. All major and medium projects were considered. Representatives of all 813 major and medium projects were contacted. Several methods, such as email, postal services, and personal delivery, were employed to deliver the questionnaires, and to receive responses. In our study, the owner is the Government agency, local authority, a utility or any organization on whose behalf the engineer/project manager (PM) of public sector is executing the project. The uniformity of respondents' perception (public sector employees) was maintained by selecting only professionals involved in public construction projects.

One hundred and five responses from Project managers/ engineers were received. The average response rate was 12.92%, which can be regarded as reasonable considering the length of the questionnaire and the target respondents [22]. Respondents have a minimum of 7 years and a maximum 36 years' experience in the construction business, the average experience being 22 years.

3.4 Analysis method

The analysis included identifying the significant success attributes. Two statistical tools, viz. factor analysis and multiple regressions were used to analyze data from the survey questionnaire. Factor analysis was used to identify the underlying dimensions, and multiple regressions were used to find the importance of success factors.

Factor analysis is a statistical technique used to identify a relatively small number of factors that can be used to represent relationships among sets of many interrelated variables [23]. It is conducted using a two-stage process: factor extraction and factor rotation. The goal of factor extraction is to determine the factors using principal components analysis, whereas that of the second stage, factor rotation, is to make the factor more interpretable. Factor analysis addresses the problem of analyzing the structure of the correlations among a large number of variables, by defining a set of common underlying dimensions, known as factors [23]. Several tests are required to determine the appropriateness of factor analysis for factor extraction. These include the Bartlett test of sphericity, a statistical test for the presence of correlations among the variables, and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (MSA) etc. Details of the factor analysis process and the test procedures can be found in Hair et al. [23].

A regression model is a mathematical model that can relate a number of independent variables to a dependent variable. The models are developed using traditional regression techniques. In this research, the independent variables are the success factors obtained after factor analysis, as defined above. Safety performance is considered as the dependent variable.

3.5 Data analysis

Data analysis primarily consisted of univariate analysis, factor analysis, and multiple regression. Analysis of variance is a procedure used for comparing sample means, to see if there is sufficient evidence to infer that the means of the corresponding population distribution also differ. Based on the literature survey results, the following hypotheses were proposed:

H_0: *There is no significant difference in the perception of these attributes for a successful project.*

H_1: *There is a significant difference in the perception of these attributes for a successful project.*

The One-Way ANOVA model is employed for testing the hypotheses. The significance level is set to 0.05. The respondents were asked to rate the overall performance on a 9-point scale, wherein 1 represents “very low performance” and 9 represents “very high performance”. Projects rated more than 6 on the scale were considered as “high” performing ones. The projects which were “high” and “very high” in performance were rated as “successful projects”, whereas other projects with value/ rating less than 6 on the scale were rated “not successful”. Table 1 show that 20 attributes out of 36 are significant for successful projects. So only these 20 attributes were considered for factor analysis.

3.6 Application of factor analysis

Prior to factor analysis and multiple regression analysis, all attributes and personal perceptions of success were tested for potential outliers and normality. It was found, from the test results, that they all satisfied the basic assumptions of normality, and were confirmed to be acceptable and reliable. The reliability of the 9-point scale used in the survey was determined using Cronbach’s coefficient alpha, which measures the internal consistency. The test value was 0.950 (F statistic = 14.67; $p < 0.001$), which was greater than 0.5, indicating that the 9-point scale measurement was reliable at the 0.05 significance level.

Factor analysis was applied to reduce the 20 success attributes to a small number of “underlying” factors. As recommended in Hair et al. a factor loading of each factor should exceed 0.50, with a sample size around 100 [23]. Additionally, at least one half of the variance of each variable must be taken into consideration. Therefore, each variable’s communality, representing the amount of variance accounted for by the factor solution for the variable, should be equal to, or more than, 0.5 to have sufficient explanation [23].

The responses on the success attributes were subjected to principal component analysis. The value of the Bartlett test of sphericity is 1441.375, and the associated significance level is small ($p < 0.001$), which suggests that the population correlation matrix is not an identity matrix (Hair et al. 1998). The correlation matrix shows that all variables have significant correlation at the 0.05 significance level, which implies that the deletion of any other success attribute is not necessary. The value of the KMO MSA is 0.869, which is greater than 0.6, hence the responses were considered appropriate for factor analysis [23].

For the analysis, the varimax orthogonal rotation of principle component analysis was used to interpret the components. The factor labels, percentage of the variance explained by them (in parentheses), and the attributes emerging under them are shown in Table 2. The details of the factor loading and communalities are also given in Table 2. The values shown in Table 2 are compared

Table 1. Twenty significant attributes

Attributes	Role in safety	References	Sig
Regular monitoring and feedback by owner	Helps in noticing damage, deformations leading to failure etc	Staender et al.,1997	0.031
Scope of work clearly articulated	Helps in sound design and to a great extent limit the changes during construction	Ortega, 2000	0.040
Comprehensive pretender site investigation done	Help in proper planning and sound designing of the structure	Goodden, 1996	0.000
Timely valuable decision by project manager and staff	Management needs to provide necessary resources and support timely on safety issues	Duff et al., 1994	0.023
Resources available (fund, machinery, material etc.) as planned throughout the project.	Shortcoming with equipment, including personal protective equipment causes accident	Haslam et al., 2005	0.010
No major changes in the scope of work during construction	Changes during construction may alter the design and may lead to failure	Ortega, 2000	0.002
Thorough understanding of scope between PM and Contractor	There should be through understanding of scope especially material handling, design of scaffolding, tools safety	Koehn et al., 1995	0.000
Regular quality control and quality assurance activities	Quality management helps in preventing accident	ASCE,1990	0.031
Full cooperation of all project's participants	Safety can be enforced by close cooperation of the designers, contractor and PM.	Koehn et al., 1995	0.041
Adequate communication among all project participants	Lack of communication and attention results in accidents during construction phase	Rise, 1994	0.040
A high degree of trust shared by project participants	Trust between project participants helps in building confidence and cooperation	Koehn et al., 1995	0.000
Conflict resolved quickly by project participants	Safety being overlooked in the context of heavy workload and other priorities, taking shortcut to save effort and time. Conflict will aggravate the situation if not resolved quickly	Haslam et al., 2005	0.001
No social and political interference	Political and social interference increases the economic pressure on construction industry , resulting in failures from careless design and inadequate construction practices	Ortega, 2000	0.000
No bureaucratic interference	Safety to be disassociated from bureaucracy	Haslam et el.,2005	0.003
No labour problem during construction at site	Long working hours, or working several long days without day off lead to tiredness and fatigue. The consequences of tiredness and fatigue are reduced concentration, poor decision making and it might be expected , compromised safety		0.012
Top management's support	Top management exerts a greater influence on employee motivation to behave safely than supervisors do	Andriessen, 1978; Jaselskis et al., 1996	0.006
Regular monitoring and feedback taken by top management	It significantly drive up the performance of safety	Jaselskis et al., 1996	0.000
Complying with rules and regulations of anticorruption in decision making process	This helps in selection of proper and resourceful bidders, who will adopt sound practice and help in successful completion of work. Improper selection of bidder may see short terms gain, can compromise quality and safety	Thai 2008	0.031
Awareness of rules and regulations of audit	Awareness of rules pertaining to labour payments, minimum wages etc helps in safety performance.	Kassel 2008	0.041
Complying with rules and regulations of audit in decision making process.	Rules are to be followed and responsibility shared	Kassel 2008	0.002

Table 2. Factor structure for success attributes

Factors and attributes description along with Percentage of variance explained	Communalities	Factor Loading
Factor 1. Awareness of and compliance with rules and regulations (21.965%)		
You had complied with anti-corruption rules and regulations in the decision- making process	0.812	0.864
You had awareness of the audit/financial rules and regulations	0.889	0.856
You had complied with the audit/financial rules and regulations in the decision making process.	0.849	0.864
There was no labor problem during construction at site	0.663	0.667
Factor 2. Pre-project planning and clarity in scope (21.845%)		
There was thorough understanding of scope between project manager and Contractor	0.771	0.833
Comprehensive pretender site investigation was carried out	0.699	0.804
No major changes were made in the scope of work during construction	0.730	0.755
There was no social and political interference	0.823	0.697
There was no bureaucratic interference	0.827	0.627
Scope of work was clearly articulated	0.511	0.621
Factor 3. Effective partnering among project participants (21.408%)		
Project manager for the project and staff had taken timely valuable decisions	0.844	0.900
There was adequate communication among all project participants	0.786	0.771
There was full cooperation of all project participants	0.845	0.756
Your team got top management's support	0.624	0.701
Conflict was resolved quickly by project participants	0.625	0.601
A high degree of trust was shared by project participants	0.777	0.574
Regular monitoring was conducted and feedback taken by top management	0.594	0.560
The resources (fund, machinery, material etc.) as planned throughout the project were available.	0.513	0.486
Factor 4. External monitoring and control (7.963%)		
Regular monitoring was conducted and feedback taken by owner	0.763	0.798
Regular quality control and quality assurance activities were conducted	0.720	0.584

with the values recommended by Hair et al. and found to be appropriate [23]. Four factors were extracted that accounted for 73.180% of the variance. In general, loading and the interpretation of the factors extracted were reasonably consistent. The factors are discussed in the following sections.

Factor 1. Awareness of and compliance with rules and regulations

Four attributes have emerged under this factor accounting for a variance of 21.97%. Compliance with rules and regulations helps in the successful completion of the project [24]. A sound public procurement system needs to have good procurement laws and regulation [25]. It may be observed that most of the regulations for labor are part of the contract document and must be complied with. Problems arise with violations, such as not adhering to Minimum Wages Act, not providing adequate shelter, or other facilities, as stipulated by labor laws. It justifies the grouping of this attribute in this factor.

Factor 2. Pre-project planning and clarity in scope

Six attributes have emerged under this factor accounting for a variance of 21.85%. The importance of these attributes—clear articulation of the scope of work, comprehensive site investigation, absence of major changes during construction, thorough understanding of scope by the project manager and contractor, lack of social, political and bureaucratic interference—is well established. It may be observed that the attributes under this factor pertain to the pre-project planning stage, and their appraisal is only possible when a comprehensive pretender site investigation is carried out. This results in the clear articulation of work, and helps in developing a thorough understanding of the scope by the PM and contractor. This also prevents any major changes during construction. Bureaucratic, social and political interference could be avoided by involving all the stakeholders from the beginning, and ensuring good planning. Otherwise, such interference will only result in delays. In many instances, such interference is meant to change the scope of the project, a phenomenon which happens owing to a lack of sound pre-project planning and, to a certain extent, this can be avoided by sound pre-project planning.

Factor 3. Effective partnering among project participants

This factor has eight attributes accounting for 21.41% variance and pertaining to partnering. Here "partnering" denotes partnering among project participants. It is more effective than teamwork, as it involves effective working relationships between project participants. The fundamental principles of partnering include commitment, trust, respect, communication and proper consideration of interest. There are many studies which have established partnering as a success factor for construction projects [26, 27,28].

Factor 4. External monitoring and control

Two attributes have emerged under the factor accounting for 7.96% variance. The owner, for the purpose of this study, is considered as an outsider. As mentioned earlier, "owner" in this study, is the government agency, local authority, a utility or any organization, on behalf of which the engineer/project manager in the public sector is executing the project. Similarly, quality control and assurance are also done by an external agency, which explains the name of this factor. Dunnam [29] reported that:

> one way of successfully dealing with the many constraints that can arise during the life of the project is to keep the owner so close to the project status and involved in the decision-making process that he understands the impact of each deviation and, with full understanding, accepts the necessary adjustments.

An owner, noticing some damage or deformation, may help in preventing failure before it is too late [30]. Quality management in the construction industry helps in overall safety performance [31].

3.7 Application of multivariate analysis

This technique is chosen as the principal tool to identify the important factors for the safety performance of public construction projects. Multivariate regression analysis has been used to explore the relative importance of the factors, extracted from factor analysis, on the safety performance.

Initially, since there were large number of attributes and a limited sample size, there was a need to reduce the number of attributes before embarking on regression analysis. So, factor analysis was used to group the attributes.

Regression analysis is an iterative process. The responses of participants in public projects were used as input, and results are shown in Table 3. The analysis was done by stepwise procedures. The regression analysis techniques include maximizing the coefficient of determination (R^2) value, minimizing model variances, and only including variables in the model that have been proven to be statistically significant through *t*-tests, *F*-tests, and stepwise selection procedures. The coefficient of determination (R^2), is a measure of the goodness of fit. However, when more independent variables are introduced into the model, R^2 increases automatically. A better estimate of the goodness of fit is *adjusted* R^2. Unlike R^2, it does not increase inevitably as the number of included explanatory/independent variable increases. In Table 3, B represents Regression coefficient, σ, Standard error

Table 3. Stepwise multiple regression results for safety performance

Independent Variables	B	σ	b	t-value	p-value
Dependent variable: Safety performance; $R^2 = 0.26$, adjusted , $R^2 = 0.24$					
Constant	7.53	0.13	NA	56.73	0.00
Factor 2: Pre-project planning and clarity in scope	0.51	0.13	0.36	3.83	0.00
Factor 3: Effective partnering among project participants	0.49	0.13	0.35	3.69	0.00

of variable regression coefficient, and b, Standardized regression coefficient. The regression analysis has been used here to explore the relative significance of success factors for safety performance. The "pre-project planning and clarity in scope"(Factor 2) and "effective partnering among project participants"(Factor 3) were found to be significant at $p<0.05$, for safety performance of public construction projects.

4.0 DISCUSSION

Regression results were consistent with the findings of various previous studies. The most important factor contributing to safety in public projects was found to be the "pre-project planning and clarity in scope". Billy et al. recommended integrating safety with pre-project planning [32]. Hinze and Wilson pointed out that the most effective techniques of preventing a hazard are preplanning for safety, safety orientation, safety training and a written safety policy [33]. The ILO recommendation No.175 also puts the emphasis on management for the health and safety of the construction workers, and is concerned with the design and planning of a construction project.

For achieving safety, both the contractor and project manager must have a thorough understanding of the scope, which is only possible when the scope itself is clearly articulated, and there is no interference. Bobick et al. state that, "it is preferable to provide a fixed barrier to prevent a worker from falling rather than using personal protective equipment (PPE)", and also support the argument that "clarity in scope helps in planning for safety" [34].

Major changes during construction should also be avoided as they disturb the planning and become a potential cause of accident. Comprehensive site investigation helps in sound planning, resulting in minimum changes during construction, which helps in avoiding bureaucratic, social and political interference. The engineer and the architect should be allowed to adopt a professional design, rather than selecting/changing design arbitrarily as a result of bureaucratic interference. A peer review of the project design should also be considered. The effect of design changes (heavier loads, different loading pattern, modifications to connections details etc.) on design assumption should be analyzed carefully. Design changes should be documented systematically and studied before arriving at a conclusion.

The second important factor contributing to safety was found to be "effective partnering among project participants". The classical definition put forward by Bennett and Jayes [35] defined partnering as:

> a set of strategic actions that deliver vast improvements in construction performance. It is driven by a clear understanding of mutual objectives and co-operative decision-making by a number of firms who are all focused on using feedback to continuously improve their joint performance.

Partnering requires that all parties are committed to improving communication within the project team, and support from all levels of management [36]. Effective communication among all project participants is to understand the safety policy. Even the main contractor must have good coordination and communication with the subcontractor. Billy et al. also reported that an effective two-way flow of information is essential for safety [32].

In fact, conflicting parties should look for a mutually satisfactory solution, and this can be achieved by joint problem-solving, in order to seek alternatives for problematic issues. Top management can also help in resolving the conflict. In the long run conflict reduces the attention of participants on work, and results in construction failure.

Valuable timely decisions by staff and project managers can help in taking timely measures to prevent accidents. If any deformation during construction or operations is noticed, and timely decisions are given, remedial measures can be taken before it is too late.

According to Koehn et al. safety cannot be enforced by legislation alone, but needs the responsibility and cooperation of all project participants [37]. Even subcontractors must also have their own safety programs. The close cooperation of designers, engineers and contractors of a failed structure will help determine the cause of failure early, accurately, and economically. Collaborative designs by architects, engineers and contractors help to avoid accidents [38]. Construction projects are complex because of the division of tasks and responsibilities among architects, engineers and contractors. Construction projects requiring the presence of more than forty different specialists at the construction site are not unusual [30]. Lack of trust between different parties may lead to failure. Efforts to build trust are therefore important, to avoid failure. A commitment by workers would help to reduce the occurrence of accidents at a construction site.

In order to foster a safety culture at a construction site, top management support and commitment to safety programs is a must. Jaselskis et al. reported that commitment and support by top management would drive up the safety performance significantly [39]. The problem arises when the safety or labor officer does not have power to enforce the regulation strictly. It is vital for the top management to support the safety and labor officer at all times.

Top management's support of safety issues can not only be by means of better enforcement and stiffer punishment, but also through frequent training for workers and management. According to Hopton, training aimed at workers and operators would not only reduce accidents, but might also reduce costs and save lives [40]. Toole observed that if workers do not have proper safety training, they may not be able to recognize potential hazards at a site [41]. Top management's role becomes critical if accidents happen. It should also be ensured that the guilty are punished. This would prevent workers from repeating their offence. Serious enforcement and inspection need to be in place. In the absence of enforcement, the offences would be committed on a regular basis, and would be hard to prevent. It is well-known that the majority of the construction workers come from agricultural backgrounds. These workers have probably never been exposed to the construction of large projects. A study by Toe and Phang concluded that the attitude of the workers plays a very important part in adopting safe work practices at the workplace, and training can be one tool by which their attitude can be changed [42, 43].

5.0 CONCLUSIONS

A number of studies have been carried out in different parts of the world, to identify the attributes influencing general safety performance in construction practices. However, little attention has been given to analyzing these attributes, in the context of safety performance as a key area. The present study addresses the gap, and identifies various success factors which would help management to improve safety performance. Management can play an important role in improving safety performances besides completing the project on time, at cost, in accordance with specifications, and to stakeholders' satisfaction. Thus, the identification of success factors to improve safety performances of public projects would be of great help.

Based primarily on the literature review, 36 success attributes were identified. The attributes were presented in the form of statements, and the respondents were asked to provide their level of endorsements on a 9-point scale. The respondents were also asked to judge the safety performance of the project in which they were involved, using a 9-point scale. The one-way analysis of variance resulted in the identification of 20 significant attributes out of 36 attributes, which had statistically significant influence on the outcome of the project, in terms of overall success.

The application of factor analysis on these 20 attributes extracted four factors, namely: awareness of and compliance with rules and regulations; pre-project planning and clarity in scope; effective partnering among project participants; and external monitoring and control. These factors formed a sound basis for the performance evaluation of public construction projects on safety performance. The application of multivariate linear regression on the four success factors showed that two factors, namely, "pre-project planning and clarity in scope" and "effective partnering among project participants", were the most important factors for safety performance in public construction projects. "Pre-project planning and clarity in scope" needs special attention as it has a major influence.

The research has initiated a comprehensive investigation of safety attributes in the Indian construction industry. Success factors for safety performance benefit the contracting parties, including the client, consultants, project managers, main contractors, subcontractors, and on-site employees, but the main advantage is for project managers. Its essence is worthy of industry-wide attention, and project participants can derive many benefits from its implementation. Though construction safety management programs are mostly compliance programs which include safety standards, procedures, policies, and training programs but identification of success factors helps in focused attention on limited areas for deriving maximum benefit and reducing the number of injuries and fatalities. There is a need to pay attention to laid down regulation, carrying out detailed pre-project planning, and clearly defining the scope of work so that project participants have better understanding.

A series of in-depth case studies on various public projects should be launched in the future, to verify the applicability and reliability of the success factors identified in this study. Effective management strategies can also be suggested based on the identified success factors for enhanced safety performance.

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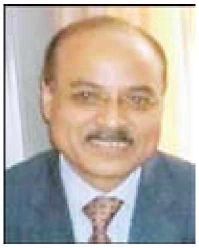

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Annexure 1 : Listed below are some of the attributes responsible for success of a project on safety. Please rate these attributes for the project under study by marking tick √ on the most suitable option given alongside the attributes. In the end there is also safety performance wherein please mark tick √ on the most suitable option for the project under study. If you have no idea about the question please mention "Don't know" against the question. (Following legend may be used)

1	2	3	4	5	6	7	8	9
Strongly disagree	Disagree		Neither agree nor disagree			Agree		Strongly agree

Sl. No.	Project success attributes	Level of endorsement								
1	Owner's need thoroughly understood and defined	1	2	3	4	5	6	7	8	9
2	Regular monitoring and feedback by owner	1	2	3	4	5	6	7	8	9
3	Scope of work clearly articulated	1	2	3	4	5	6	7	8	9
4	Adequate staff available for planning	1	2	3	4	5	6	7	8	9
5	Land available and there was no land dispute	1	2	3	4	5	6	7	8	9
6	Comprehensive pretender site investigation done	1	2	3	4	5	6	7	8	9
7	PM for the project selected early with proven track record	1	2	3	4	5	6	7	8	9
8	PM for the project selected with similar project experience	1	2	3	4	5	6	7	8	9
9	PM for the project had coordinating ability and rapport with owner, contractor, top management and his team	1	2	3	4	5	6	7	8	9
10	Thorough prequalification done for potential bidders	1	2	3	4	5	6	7	8	9
11	Adequate staff available for Execution	1	2	3	4	5	6	7	8	9
12	Timely valuable decisions received from top management	1	2	3	4	5	6	7	8	9
13	Timely valuable decision by project manager and staff	1	2	3	4	5	6	7	8	9
14	Resources available(fund, machinery, material etc.) as planned throughout project	1	2	3	4	5	6	7	8	9
15	No major changes in the scope of work during construction	1	2	3	4	5	6	7	8	9
16	Competent contractor's design consultants	1	2	3	4	5	6	7	8	9
17	Contractual motivation/ incentives clause exists for early completion of work	1	2	3	4	5	6	7	8	9
18	Thorough understanding of scope between PM and contractor	1	2	3	4	5	6	7	8	9
19	Timely finalization of detailed engineering plans and all drawings	1	2	3	4	5	6	7	8	9
20	Regular design and construction control meetings	1	2	3	4	5	6	7	8	9
21	Regular schedule and budget updates taken.	1	2	3	4	5	6	7	8	9
22.	Regular quality control and quality assurance activities	1	2	3	4	5	6	7	8	9
23	Full cooperation of all project's participants	1	2	3	4	5	6	7	8	9
24	Adequate communication among all project participants	1	2	3	4	5	6	7	8	9
25	A high degree of trust shared by project participants	1	2	3	4	5	6	7	8	9
26	Conflict resolved quickly by project participants	1	2	3	4	5	6	7	8	9
27	No social and political interference	1	2	3	4	5	6	7	8	9
28	No bureaucratic interference	1	2	3	4	5	6	7	8	9
29	No labour problem during construction at site	1	2	3	4	5	6	7	8	9
30	Contractor utilized up-to-date technology	1	2	3	4	5	6	7	8	9
31	Top management's support	1	2	3	4	5	6	7	8	9
32	Regular monitoring and feedback taken by top management	1	2	3	4	5	6	7	8	9
33	Awareness of all rules & regulations of anticorruption	1	2	3	4	5	6	7	8	9
34	Complying with rules & regulations of anticorruption in decision making process	1	2	3	4	5	6	7	8	9
35	Awareness of rules & regulations of audit	1	2	3	4	5	6	7	8	9
36	Complying with rules and regulations of audit in decision making process	1	2	3	4	5	6	7	8	9

How was the performance of this project on safety account on a scale of 1 to 9 (please tick √ on one only)	1	2	3	4	5	6	7	8	9
	Very low (Major accidents)	Low		Fair			High		Very high (No accidents)