CHAPTER - 2
LITERATURE REVIEW

2.1 FACTOR AFFECTING SAFETY IN CONSTRUCTION SITE

Mohammed (2002) mentions that construction industry has poor safety record compared to other industries. There are many perceptions indication accidents in construction projects, which can range from minor injuries to loss of life, as originated from workers unsafe act (Hinze 1997). In other words, unsafe acts are main causes of accidents. However, this perception is argued by Reason (1990) which states that attempts to reduce accidents by focusing only on unsafe act will not able to tackle the underlying causes.

2.1.1 Safety Culture

Mohammed (2003) defines safety culture “A sub-facet of organizational culture, which affects workers attitude and behavior in relation to an organization ongoing safety performance. O’Toole (2002) identifies safety culture as critical factor that sets the tone for the importance of safety within an organization.

Neal and Griffin (2002) presents a model identifying the linkages between safety climate, safety knowledge, safety motivation and safety behavior. Findings from a series of studies are reviewed that support the hypothesized linkages between safety climate and safety behavior. Longitudinal analyses have examined the role of additional factors, such as
general organizational climate, supportive leadership and conscientiousness as sources of stability, change in safety climate and safety behavior.

Tam et al (2001) stated that the construction industry of Hong Kong has a very poor site safety record. The overall accident rate has gone down a little during the last few years, but the number of fatalities has risen dramatically. In the past, the HongKong Government adopted a laissez-faire approach in managing construction safety, hoping that market forces would regulate the safety performance. However, the approach has proved to be ineffective. Since 1986, the Government has taken a proactive approach in combating construction site safety, and has introduced a series of safety programmes, which consist of encouraged and mandatory schemes aiming at nourishing a proper safety culture in the construction industry. Recently, the government decided to criminalize site accident cases by introducing a so-called 'Supervision Plan', aiming at changing the safety attitude and culture of construction practitioners. This paper applies an attitude-changing model, 'reinforcement theory', to predict the changing attitude of people in the construction industry. The results show that the attitude of construction practitioners in HongKong will change to be more positive when they receive more messages to confirm that people really are put into jail for the negligence under the Supervision Plan.

Fang et al (2006) conducted a comprehensive safety climate questionnaire on all sites of a leading construction company and its sub-contractors in Hong Kong. The results of this study were then compared to previous research studies. The findings revealed significant statistical relationships between safety climate and personal characteristics, including safety knowledge, direct employer and individual safety behavior. Ultimately, these findings could provide useful information for construction managers
and safety practitioners in the construction industry to improve their safety culture.

Fung et al (2005) in their study investigated the relationship between peoples’ behaviors, attitudes and perceptions towards safety culture and to compare safety culture divergences among three levels of construction personnel: top management, supervisory staff and frontline workers by conducting safety culture survey. The questionnaire, comprising general information and 36 safety attitude statements, were distributed to 423 construction personnel working in ten different construction sites in Hong Kong. The results from this study indicate that the 8 testable factors, including organizational commitment and communication, line management commitment, supervisor’s role, personal role, worker’s influence, risk taking behavior, obstacles to safe behavior and accident reports, have high inter-correlations and the three groups of respondents hold quite different views regarding safety culture. These findings can give invaluable indication to the construction personnel to have better understanding of safety culture in Hong Kong construction industry.

Zohar (1980) developed the first measure, after reviewing the literature, reporting characteristics which differentiated high and low accident-rate companies. After factor analysis, the author’s final model based on an Israeli sample included dimensions covering workers perceptions of the importance of safety training, management attitudes towards safety, effects of safe conduct on promotion, level of risk at workplace, effects of work place on safety, status of safety officer, effects of safe conduct on social status and status of safety committee.

An attempt to replicate this structure using confirmatory factor analysis did not support these dimensions in a sample of workers from the
USA (Brown and Holmes 1986). Further analysis of their data set revealed a three factor structure which was shown to have practical importance as it showed differences in safety perception between employees who had experienced an accident and those who had not. The three factors revealed by this analysis were employee perceptions of management concern about their well-being, management activity in responding to problems with their well-being and their own physical risk.

Dedobbeleer and Beland (1991) tested this 3-factor model in construction workers and found that it was supported by their data, but that a two factor solution was superior. The two factors were interpreted to be management commitment to safety and workers’ involvement in safety.

2.1.2 Good Communication

Fang et al (2004) stated that the lines of communication between management and workforce are open; workers can bring reports of unsafe working practices and hazardous environments to management’s attention. Management in turn can also communicate their concerns and priorities of safety to gain employees’ compliance and awareness.

Vredenburgh (2002) examined that several management practices have been cited as important components of safety programs, how much does each incrementally contribute to injury reduction? This study examines the degree to which six management practices frequently included in safety programs (management commitment, rewards, communication and feedback, selection, training, and participation) contributed to a safe work environment for hospital employees. Participants were solicited via telephone to participate in a research study concerning hospital risk management. Sixty two hospitals provided data concerning management practices and employee injuries.
Overall, the management practices reliably predicted injury rates. A factor analysis performed on the management practices scale resulted in the development of six factor scales. A multiple regression performed on these factor scales found that proactive practices reliably predicted injury rates. Remedial measures acted as a suppressor variable. While most of the participating hospitals implemented reactive practices (fixing problems once they have occurred), what differentiated the hospitals with low injury rates was that they also employed proactive measures to prevent accidents. The most effective step that hospitals can take is in the front-end hiring and training of new personnel. They should also ensure that the risk management position has a management level classification. This study also demonstrated that training in itself is not adequate.

2.1.3 **Sufficient Resource Allocation**

Erikson (1997) said that goals of safety programs cannot be accomplished without adequate resources. An effective safety program results from the commitment of the top management to providing an appropriate level of resources. Management must consider and allocate sufficient resources to carry out day-to-day activities to accomplish both short-term and long-term goals. The resources required for effective safety program may include sufficient staff, time, money, information, methods used in safety works, facilities, tools, machines, etc.

Edward J. Jaselskis and Guillermo Arturo Recarte Suazo (1994) framed a questionnaire, which was used to collect safety related information from construction workers, field management and upper management in the Home Office on residential, commercial and heavy civil construction projects in San Pedro Sula, Honduras. Data were collected using face-to-face interviews from 108 construction workers, 10 field managers and eight senior
managers participated. Data were analyzed using correlation, regression and analysis of variance techniques. Results demonstrated a substantial lack of awareness or importance for safety at all levels of the construction organization. Workers rarely wore personal protective equipment, used poorly constructed scaffolds, improperly used tools and ladders and disregarded good housekeeping practices. Many of the field project managers stated that they did not provide workers with personal protective equipment or safety training and did not use a dedicated safety person on-site. Top level management does not appear convinced that it is in their best interests to improve safety performance either since only approximately 25% provided a company-wide safety training programme, maintained accident records and provided safety incentives.

### 2.1.4 Management Support

Stranks (2000) describes that management plays a very important role in an efficient and effective safety program. Management must fully and actively translate ideas into safety actions, including issuing a written comprehensive safety policy, allocating sufficient resources, promptly reacting to safety suggestions and complaints, attending regular safety meetings and training, regularly visiting the workplace, following the same safety rules as others, etc.

Herrero et al (2006) have developed a model of management which was necessary in the area of total safety. The proposed tree model explains what the determinant success factors of occupational safety and health management are: empowerment, management commitment, training and communication, and, finally, risk management. It is necessary to transmit this knowledge to other companies in the industrial sector to improve their safety results.
Osama Abudayeh et al (2006) stated that the costs resulting from injuries and equipment damage, combined with the associated financial loss resulting from schedule disruptions, insurance hikes, and workers compensation, impact the profitability of any construction operation. These costs may be minimized or avoided through focused safety efforts on construction job sites. The main purpose of this study is to determine the correlation between management commitment to safety and the frequency of construction-related injuries and illnesses. To achieve this purpose, a survey was developed and sent to a random sample of the top five hundred United States (US) construction companies. Survey results point to a clear statistical correlation between management commitment to safety and injury and illness rates.

Tam and Fung (1998) conducted a study of safety attitudes, practices and characteristics of construction firms in HongKong and their relationship to safety performance on construction sites. Forty five construction companies are compared and studied. Each adopted different safety management strategies. The 45 companies were composed of 11 small, 25 medium and 9 large-scale construction firms. Construction firms' safety performance is measured by site casualty rates. Based upon the information collected from the survey, the accident rates are first derived and compared with the industrial norms. Then the following safety measures, and strategies of contractors in HongKong and their associated safety performance, are compared: involvement of top management in safety management; safety orientation programmes for new workers; safety awards or incentive schemes; use of post-accident investigation systems; safety training schemes; safety committees; level of subcontracting. The first part of the research studies the relation between these measures and the safety performance using a number of tables. The results show that these practices have indeed improved site
safety. The second part uses a multiple regression analysis to study the combined effect of these schemes and practices on safety performance. The study concludes that the provision of safety training, the use of directly employed labor, the use of post-accident investigation as a feedback, and promoting safety practices by safety award campaigns and incentive schemes, are the most effective tools in mitigating site casualties.

Kari Häkkinen (1995) reported that growth of legal regulations in occupational safety during the 70's alienated, to some extent, to management from health and safety issues; safety was regarded as an activity of safety professionals and labor inspection. This lack of commitment to safety management led to reduced activity and awareness. However, both research and practice indicate that the role of top management is of crucial importance for achieving results in safety. Having realized the problem and the lack of appropriate training to meet the demands of top management, a program called “One hour for safety management” has been developed. The training is arranged in an “action” setting, during the formal meeting of the executive board of the company. The program consists of four main parts: (1) Principles of modern safety management, (2) The company's accident insurance system, the interdependency between compensation costs and premiums, (3) The safety situation of the company; accidents, premiums and losses, hazards, safety program, and (4) Setting the safety targets and action plans required. More recently, a short audit process has been developed to reveal the important sources of loss and the state of affairs in the company's loss control systems. The approach initiated or revived the top management interest in and awareness of safety in several companies. The success of the meeting seems to depend on several factors, e.g. consultation skills, safety expertise, style of presentation, corporate culture and co-operation in the preparation of the session. The factors that contribute to an effective training for top
management should further be analysed, and the impact of the management training on accident rates is a task for evaluation studies in future.

Raymond E. Levitt and Henry W. Parker (1976) studied the policies and practices used by top managers in construction firms and demonstrated that the top managers, by their own actions, can significantly reduce accident costs in their companies. Data were collected from a questionnaire survey on an in-depth study of one company, and face-to-face interviews with top managers and safety directors in 23 construction firms. Data from the interviews were analyzed, using each company’s workmen’s compensation insurance experience modification rate as a measure of safety. From the analysis, guidelines were developed which can be used by top managers who want to reduce accidents in their own companies. The data indicate that top managers should know about accident rates on individual projects, and use this knowledge to take decisions on salary and promotion of field managers. They should use their cost reporting system to encourage safety, and should insist on the orientation of newly hired workers, and detailed work-planning at the job level.

2.1.5 Positive Group Norms

Group norms are the accepted attitudes about various things amongst a group of people. In practice, members of a group conform to certain attitudes simply to avoid sanctions. If positive attitudes towards safety can be built and embedded within a group, safety can then be managed successfully. This is the basis of good safety culture (Petersen 1984).

2.1.6 Personal Attitude

Attitude is a tendency to respond positively and/or negatively to certain persons, objects or situations and is normally built up through
experience. Individuals, however, differ in their perception of risks and willingness to take risks. Successful safety programs can be achieved if the positive attitudes of employees toward safety are reinforced, (Levitt and Samelson 1993).

2.1.7 Safety Equipment Acquisition and Maintenance

Toole (2002) and Tam et al (2004) said that workplace must be carefully assessed to determine possible hazards in order for proper selection of safety equipment. An effective safety program results in fewer injuries due to proper safety equipment’ acquisition and maintenance. Managing a safety equipment program takes up not only a large percentage of time for purchasing the correct equipment, maintaining them in good condition, and inventory control, but it also requires a good cooperation amongst the safety manager/head, purchasing, production, warehouse supervisor and maintenance supervisor.

2.1.8 Appropriate Supervision

Weber (1992b), Levitt and Samelson (1993), Fang et al (2004) reported that sound safety program requires employers to provide sufficient supervision in protecting workers from workplace hazards. Successful supervision requires competent personal to assign work in line with the workers’ ability, appraise workers when they do jobs safely, communicate by listening and speaking, set a good example by following the same safety rules and correct arising safety problems.

2.1.9 Appropriate Safety Education and Training

Cooper and Cotton (2000) said that successful safety program can be achieved if all employees are given periodic educational and training programs in order to improve their knowledge and skills on safety at work.
Sawacha et al (1999) discussed various variables that influence safety on construction sites. The impacts of the historical, economical, psychological, technical, procedural, organizational and environmental issues are considered in terms of how these factors are linked with the level of site safety. The results suggest that variables related to organization policy are the most dominant group of factors influencing safety performance in the United Kingdom construction industry.

Hale (1984) said that training has become almost an axiomatic part of accident prevention strategies, but it is questionable whether the level of analysis and the development of training programmes is sufficiently high to produce the return expected. Without this investment safety training is in danger of getting a bad name.

Gun (1993) measured the impact of safety regulations on the occurrence of occupational injury, an investigation was made of 98 worksites where severe or moderately severe injuries had recently been reported, and, where possible, of matching worksites where a similar accident had not occurred, at least for a period of 2 years. 53 of the 98 injuries were considered to be attributable to a violation of a regulation. Interviews with management at the complying worksites suggested that compliance was more often related to a conscious effort to comply with regulations than a fortuitous outcome of what appeared to be sound engineering practice or “common sense”. Compliance was significantly associated with the training of management in safety, and with observance of apriori determined principles of good safety management. Of the 98 injuries investigated, 48 were considered to be amenable to regulatory control. Investigation of all non-accident worksites studied (n = 78), yielded practical information in 25 on means of reducing the
risk of the injury which had occurred at the corresponding accident site. It is concluded that regulations have a substantial relevance to occupational injury. In that (i) the injury rate would be at least halved if all regulations were complied with; (ii) there was nevertheless a substantial rate of compliance with regulations, without which the rate of severe injuries may be more than doubled; (iii) substantial benefit may be gained from increasing the ambit of regulations; and (iv) management training and good management practices are most likely to prevent those injuries which are associated with the violation of regulations.

The development of safety systems, safety practice and procedures; monitoring of safety compliance, establishment of safety committees at site level, communication of safety policies to site personnel, participation of safety officers, consultation between site staff and safety officers also affect the safety performance (Wong et al 1999). The most effective safety techniques for projects as proposed by the Construction Industry Institute, United States include pre-project/pre-task planning for safety, safety orientation and training, and written safety incentives (Hinze and Wilson 2000). In addition, to avoid accidents recurring on the same site, post-accident investigation systems need to be carried out to establish their causes (Tam and Fung 1998). Other recommendations for improving safety at project level include reducing the turnover of project management teams, devoting more time to site safety issues, increasing the number of formal safety meetings with supervisors and specialty contractors, increasing informal site safety inspections, increasing fines to workers with poor safety performances, etc. (Jaselskis et al 1996). However, in organizational level, Fang et al (2004) identified key factors that improve safety management. The authors also developed a method for measuring safety management performance on construction sites. The results indicated that safety management performance
was highly related to organizational factors, economic factors and factors related to the relationship between management and labor on site. Based on this benchmarking study, a practical safety assessment method was implemented on six construction projects. Improvements in organizational structure, organizational importance of safety, safety responsibility and accountability, communication, management behavior, employee involvement, and employee responses and behavior can help improve safety performance (Erickson 2000). This would involve the development of more detailed written safety programmes, greater expenditure on safety programmes, additional training to part time safety coordinators, and better indoctrination of new staff on company policies and guidelines (Jaselskis et al 1996). While safety awards or incentive schemes, safety training schemes, safety committees and level of subcontracting are also recommended for consideration (Tam and Fung 1998).

2.1.10 Safety Perspective in Indian Industries

Raja Prasad and Reghunath (2011) said that proactive safety measures have to be framed to eliminate unsafe actions/conditions which contribute towards accidents and injuries by conducting safety sampling survey and overall safety performance was evaluated by inter-observer reliability of internal and external safety auditors.
### 2.1.11 Summary of Factors Affecting Safety in Construction Site

The summary of factors affecting safety in construction site is presented in Table 2.1.

<table>
<thead>
<tr>
<th>Researcher and Year</th>
<th>Factor</th>
<th>Key Statements</th>
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<tbody>
<tr>
<td>Mohammed (2002)</td>
<td>Safety statistics</td>
<td>Construction industry has poor safety record compared to other industries.</td>
</tr>
<tr>
<td>Tam et al (2001)</td>
<td>Safety attitude</td>
<td>It applies an attitude-changing model, 'reinforcement theory', to predict the changing attitude of people in the construction industry. The attitude of construction practitioners in Hong Kong will change to be more positive when they receive more messages to confirm that people really are put into jail for negligence under the Supervision Plan.</td>
</tr>
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<td>Fang et al (2006)</td>
<td>Safety culture</td>
<td>Significant statistical relationships between safety climate and personal characteristics, including safety knowledge, direct employer and individual safety behavior.</td>
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<td>Fung et al (2005)</td>
<td>Safety culture</td>
<td>The relationship between peoples’ behaviors, attitudes and perceptions towards safety culture and to compare safety culture divergences among three levels of construction personnel: top management, supervisory staff and frontline worker by conducting safety culture survey.</td>
</tr>
<tr>
<td>Zohar (1980)</td>
<td>Safety culture</td>
<td>Workers perceptions of the importance of safety training, management attitudes towards safety, effects of safe conduct on promotion, level of risk at workplace, effects of work pace on safety, status of safety officer, effects of safe conduct on social status and status of safety committee.</td>
</tr>
<tr>
<td>Study</td>
<td>Factor</td>
<td>Description</td>
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<tr>
<td>Dedobbeleer and Beland (1991)</td>
<td>Safety culture</td>
<td>The two factors were found to be superior (i.e., management commitment to safety and workers’ involvement in safety).</td>
</tr>
<tr>
<td>Fang et al (2004)</td>
<td>Good communication</td>
<td>There should be free communication between worker and management.</td>
</tr>
<tr>
<td>Vredenburgh (2002)</td>
<td>Communication and feedback</td>
<td>Six management practices frequently included in safety programs (management commitment, rewards, communication and feedback, selection, training, and participation) contributed to a safe work environment had been examined.</td>
</tr>
<tr>
<td>Erikson (1997)</td>
<td>Sufficient resource allocation</td>
<td>Management must consider and allocate sufficient resources to carry out day-to-day activities to accomplish both short-term and long-term goals.</td>
</tr>
<tr>
<td>Edward J. Jaselskis and Guillermo Arturo Recarte Suazo (1994)</td>
<td>Sufficient resource allocation</td>
<td>Project managers stated that they did not provide workers with personal protective equipment or safety training and did not use a dedicated safety person on-site.</td>
</tr>
<tr>
<td>Stranks (2000)</td>
<td>Management support</td>
<td>Management plays a very important role in an efficient and effective safety program.</td>
</tr>
<tr>
<td>Tam et al (1998)</td>
<td>Management support</td>
<td>The provision of safety training, the use of directly employed labor, the use of post-accident investigation as a feedback, and promoting safety practices by safety award campaigns and incentive schemes, are the most effective tool in mitigating site casualties.</td>
</tr>
<tr>
<td>Kari Hääkinen (1995)</td>
<td>Management commitment</td>
<td>Both research and practice indicate that the role of top management is of crucial importance for achieving results in safety. The lack of appropriate training to meet the demands of top management, a program called “One hour for safety management” has been developed.</td>
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<tr>
<td>Study</td>
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<td>Description</td>
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<td>-------------------------------------------</td>
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<tr>
<td>Raymond E. Levitt, and Henry W. Parker (1976)</td>
<td>Management support</td>
<td>Data from the interview were analyzed, using the guidelines were developed which can be used by top manager to reduce accidents in their own companies.</td>
</tr>
<tr>
<td>Petersen (1984)</td>
<td>Positive performance indicator</td>
<td>If positive attitude toward safety can build with embedded group, safety can be then managed successfully.</td>
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<tr>
<td>Levitt and Samelson (1993)</td>
<td>Personal attitude</td>
<td>If positive attitude is developed, then we can implement safety successfully.</td>
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<tr>
<td>Cooper and Cotton (2000)</td>
<td>Training</td>
<td>All the employees should be given education and training about the safety.</td>
</tr>
<tr>
<td>Sawacha et al (1999)</td>
<td>Organizational factors</td>
<td>The top five important issues found to be associated with site safety were: (1) management talk on safety; (2) provision of safety booklets; (3) provision of safety equipment; (4) providing safety environment and (5) appointing a trained safety representative on site.</td>
</tr>
<tr>
<td>Hale (1984)</td>
<td>Training</td>
<td>Training becomes the one of the accident prevention strategies.</td>
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<tr>
<td>Gun (1993)</td>
<td>Compliance to regulation, training and good management practices</td>
<td>Regulations have a substantial relevance to occupational injury in that (i) the injury rate would be at least halved if all regulations were complied with; Compliance was significantly associated with training of management in safety, and with observance of a priori determined principles of good safety management.</td>
</tr>
<tr>
<td>Hinze and Wilson (2000)</td>
<td>Training</td>
<td>The most effective methods to improve the safety performance are safety training / safety plan.</td>
</tr>
<tr>
<td>Tam et al (1998)</td>
<td>Accident prevention</td>
<td>Post accident investigation should be carried out to find out causes and to prevent recurrence of the accidents.</td>
</tr>
<tr>
<td>Raja Prasad and Reghunath (2011)</td>
<td>Safety training</td>
<td>To improve safety behavior of workers, a major programme must be introduced. This could be consisted of safety training programmes, lecture series, and so forth.</td>
</tr>
</tbody>
</table>
In general Table 2.1 shows the summary of factors affecting safety in construction site. The construction industry had poor safety record than any other industries (Mohammed 2002). Safety on construction sites is linked with historical, economical, psychological, technical, procedural, organisational and work environment issues (Sawacha et al 1999). The most effective safety techniques for projects as proposed by the Construction Industry Institute, United States include pre-project/pre-task planning for safety, safety orientation and training, and written safety incentives (Hinze and Wilson 2000). In addition, to avoid accidents recurring on the same site, post-accident investigation systems need to be carried out to establish their causes (Tam and Fung 1998). Other recommendations for improving safety at project level include reducing the turnover of project management teams, devoting more time to site safety issues, increasing the number of formal safety meetings with supervisors and specialty contractors, increasing informal site safety inspections, increasing fines to workers with poor safety performances, etc. (Jaselskis et al 1996). There should be good communication between the management and workers to improve the safety at project sites (Fang et al 2004). Fang et al (2004) identified key factors that improve safety management. The results indicated that safety management performance was highly related to organizational factors, economic factors and factors related to the relationship between management and labor on site. Fang et al (2006) conducted a comprehensive safety climate questionnaire on all sites of a leading construction company and its subcontractors in HongKong. The results of this study were then compared to previous research studies. The findings revealed significant statistical relationships between safety climate and personal characteristics, including safety knowledge, direct employer and individual safety behavior.
2.1.12 RESEARCH PROBLEM

In developing countries like India as such, a rapid flux of economy and growth has been attributed to the sudden growth of the construction industry. The worker demand statistics has been drawn for unskilled workers from the rural to migrate to the urban construction site. Injuries at construction sites can be trivial or disastrous leading to loss of life. Reason behind such loss can be related to the lack of safety perception amongst workers and their ignorance as well as errors on the practices followed. The methodology to be adopted would instead lie in identifying the underlying factors that threaten workers safety. Safety and the adoption of the safety culture is also a part of the management’s responsibility and it is thus essential that management also plays a role in analyzing the components of safety in construction industry.

A number of causes influencing safety performance in the construction industry have been identified and that include workers attitude (Hinze 1981). The most effective safety techniques for projects as proposed by the Construction Industry Institute, United States include pre-project/pre-task planning for safety, safety orientation and training, and written safety incentives (Hinze and Wilson 2000). In addition, to avoid accidents recurring on the same site, post-accident investigation systems need to be carried out to establish their causes (Tam and Fung 1998). Fang et al (2004) identified key factors that improve safety management. The results indicated that safety management performance was highly related to organizational factors, economic factors and factors related to the relationship between management and labour on site.

In recent years, to overcome such safety problems, safety program implementation has been given significant consideration as one of the
effective methods. In order to effectively gain from safety programs, factors that affect its implementation need to be studied. 16 critical success factors (CSFs) (i.e., clear and realistic goals, good communication, delegation of authority and responsibility, sufficient resource allocation, management support, program evaluation, continuing participation of employees, personal motivation, personal competency, teamwork, positive group norms, personal attitude, effective enforcement scheme, safety equipment acquisition and maintenance, appropriate supervision, appropriate safety education and training) of safety program from safety literature and previous research and these were thereafter, validated by construction safety professionals. The survey intended to assess and prioritize the degree of influence of those success factors, have on the safety programs as perceived by the respondents. The result shows that the most influential factor is management support (Thanet Aksorn and Hadikusumo 2008).

In the past, researchers broadly considered two factors (i.e., project level and organization level factors). The review of literature reveals that there is not enough research evidence from India in the area of factors affecting safety in construction site. There is a wide scope to find out factors affecting safety in construction site in India, the diversity of language, literacy level and culture of Indian labour add further scope of studies. So this had motivated the researcher to find out the factors affecting in implementing safety in construction site and status of safety implementation in India.

This present research also considered both factors (i.e., organization factor and project level factors) from review of literatures. Questionnaire had been developed for the present research based on the past researchers literatures. The present research considered following factors for the preparation of questionnaire 1) Managerial perception of safety
2) Personal care and location 3) Self-assessment 4) Perceptions about the equipments used in the construction industry 5) Management commitment 6) Safety communication and feedback 7) Safety rules and procedures 8) Safety promotion policies.

2.1.13 Research Methodology

The following Chapter discusses in briefly about research paradigm, research design, types of data, sampling design, data analysis, collection and interpretation techniques adapted in this research in addition to explain ethical considerations and limitations involved in this research.

2.1.14 Research Paradigm

A research paradigm is defined as a framework of methods, values and beliefs within which the researchers work and the research work takes place (Krauss 2005). Research paradigms fall into two categories by name (1) Positivism and (2) Hermeneutics (Creswell 2003).

Positivism also known as quantitative research is objective in nature. It is conducted with the help of numerical data, facts and figures. Conversely, hermeneutics also known as qualitative research is subjective in nature. It is conducted with the help of text analysis and interpretation.

2.1.14.1 Research paradigm adapted

A mixed approach is adapted in this research. This study integrates hermeneutics and positivism. Hermeneutics is an approach in the study since the researcher has collected descriptive data for studying the problem proposed in the research. This research adapts positivism since it tests a
research hypothesis by analyzing numerical data collected from primary respondents.

2.1.15 Research Approach

Research approach as the name suggests defines the methodology by which a research is conducted (Gliner and Morgan 2000). The two famous research approaches in practice are qualitative and quantitative research approaches (Thomas 2003). Qualitative research also known as inductive research is subjective in nature (Muijs 2010). In this research approach the research field is approached with the help of observations, interviews, text analysis and analysis of various artifacts. Besides, a lot of existing literature is reviewed in order to make an interpretation. On the other hand, to test a proposed research hypothesis with the help of statistical experiments and tools, quantitative analysis is used. Quantitative analysis makes use of numerical information. The following Figure 2.1 denotes how quantitative and qualitative research approaches work:

![Figure 2.1 Quantitative and qualitative research approaches](image)
From the Figure 2.1 it is clearly understood that quantitative research tests a proposed hypothesis and qualitative research generates a new hypothesis. This present research work makes use of both the approaches. The present research work interviews a total of ten managers working in 10 different construction companies in India for qualitative analysis. On the other hand, this research distributes questionnaires to 1500 workers working in the 10 construction companies in India.

2.1.16 Research Design

A research design is like a road map to a research. It is a strategy or plan that is followed by a researcher in performing a research. As the Figure 2.2 shows research designs are of two types by name conclusive and exploratory research design.

Figure 2.2 Types of research designs
2.1.16.1 Exploratory research design

Exploratory research design is used to identify the reasons behind the occurrence of a particular problem. Exploratory research design helps in defining a problem in a precise manner, gathering data or information that is relevant to the research problem and identifying alternative actions that helps in dealing with the research problem. Exploratory research is in general meaningful when the researcher does not have proper understanding on how to proceed with a research work.

2.1.16.2 Conclusive research design

Conclusive research is well structured and formal when compared with exploratory research. Conclusive research is based on samples that are large and is used to assist in identifying and selecting the best action in a particular situation. Conclusive research as the figure shows is of two types by name descriptive and causal research respectively. Casual research design is used to investigate the cause and effect relationship between variables. Causal research identifies the extent to which variables are interrelated with each other. On the other hand descriptive research is used to describe a specific phenomenon. It is an effective way in obtaining information and in formulating hypotheses. Descriptive research, describes the behaviours and attitudes identified during a research investigation (VanderStoep and Johnston 2009). Its major goals is to recognize new facts about events, people, activities or situations or frequencies with which specific events exist. Descriptive research is structured and pre-planned, since the information required is clearly defined.
2.1.16.3 Research design used in this study

This study makes use of descriptive research design. According to Thyer (2009) the descriptive research attempts to characterize the problem, situation, service, and phenomenon or programme systematically and offers information about the living conditions of a community or characterizes attitudes towards the problem. Researchers seek to do the descriptive research by better measuring and understanding how the variables are distributed naturally. The outcome is to offer data about the sample that characterizes the basic relationships to develop their understanding of queries which was being asked. Descriptive research often targets a phenomenon and/or a population and aims to answer the queries. Descriptive research may be used when the object of the research is very complex. Descriptive research is used in finding the relationship that exists between variables. It is for this reason, descriptive research is known as correlation research. Grinnel and Unrau (2008), points out that descriptive design makes use of the elements of both quantitative and qualitative research strategies in the same study. The current research study is descriptive in nature because this research has both quantitative and qualitative analysis.

Justification for choosing descriptive research design

The main difference between descriptive and exploratory research is that unlike, exploratory research, descriptive research formulates a hypothesis in advance. The current study of research is descriptive in nature because it analyzes briefly about the safety factors affecting the construction sites. Descriptive statistics provides a statistical summary of the data which has been collected. De Vos (1998) states that “the purpose of descriptive statistics is to reduce data to an intelligible and interpretable form so that the relations of research problems can be studied, tested and conclusions drawn”.
The descriptive statistics considered appropriate for this research included frequencies, percentages and cumulative percentage. Data analysts must begin with a visual inspection of data to ensure that assumptions are not flawed (Cooper and Schindler 2003). The present study will provide a visual representation of data in tabular format.

Besides descriptive research suits best for both quantitative and qualitative forms of analyses (Grinnel and Unrau 2008). This study makes use of descriptive research since there is a research hypothesis formulated in advance (Cormack 2000). Similarly, this study conducts a qualitative analysis that is subjective in nature. Hence in this study descriptive research design is used.

2.1.17 Sampling Design

Sampling design or sampling plan defines the procedure by which data could be collected from large population (Sharon 2010). There are 2 techniques of sampling by names a) Non random sampling or Non-probability sampling b) Random sampling or probability sampling.

Probability sampling or random sampling is the one in which each member of specific population has similar probability of being selected (Hunter and Dantzker 2011). There are four types of probability sampling techniques by name (i) Systematic sampling (ii) Clustered sampling (iii) Simple random sampling and (iv) Stratified sampling.

On the other hand, non-probability or non-random sampling technique is one in which samples are selected, based on their availability and personal judgment rather than in a random fashion (Clark and Adler 2010). The 4 types of techniques of non-probability are (i) Judgmental sampling, (ii) Quota sampling (ii) Snowball sampling and (iv) Convenience sampling.
2.1.17.1 Sampling design adapted

This research makes use of both non-probability and probability techniques of sampling since this research does both qualitative and quantitative analysis. According to (Henges 2008), for quantitative analysis the most prevailing strategy of sampling is probability sampling. Similarly, quantitative study relies upon probability sampling (White and Carvalho 1997). Hence in this study for quantitative analysis, probability sampling is used. Out of the 4 types of strategies of probability sampling, this study makes use of simple random sampling. (Merriam 2009) points out that for qualitative research the techniques of non-probability sampling are most suited for choosing samples. Therefore this research makes use of techniques of non-probability sampling. Out of these 4 types of strategies of non-probability sampling this study makes use of quota sampling.

2.1.17.2 Justification of sampling techniques used

This study uses simple random sampling for quantitative analysis since workers working at the construction site have common probability to be selected for this survey. In this quantitative analysis primary respondents are designated as workers and that to working at the 10 target construction sites.

Similarly, this study uses quota sampling for qualitative analysis. The quota sampling speciality is that it assures that the sample denotes characteristics in proportion to its widespread with the population (Daniel F.Chambliss and Russel K. Schutt 2006). In this study the primary respondents must exclusively be designated as managers and that too working at the 10 target construction sites.
2.2 DEFINITION OF SAFETY MANAGEMENT

The overall literature survey with respect to Chapter 4 provides Safety Management System Model for Construction Industry is presented in this section.

A systematic control of worker performance, machine performance, and physical environment is planned. The control includes both prevention and correction of unsafe conditions and circumstances. (Heinrich et al 1980).

A study conducted by Kandola (1997) contends that “a management system must enable the assessment of risks to be carried out and as a result, the study devises and implements adequate risk reduction measures and provides appropriate feedback mechanisms for further improvement”. Other researchers, such as Reason (1997), contend that “an effective safety management means actively navigating the safety space in order to reach and then remain within the zone of maximum resistance”. Finally, Mitchison and Papadakis (1999) contend that a safety management is an aspect of the overall management function that determines and implements the organisation’s safety policy. This involves a series of activities, initiatives, and programmes, which focus on technical, human and organisational aspects and refers to all the individual activities within the organisation. Moreover, these activities are associated with the concept of continuous improvement through ‘control loops’, which involves planning, organising the work, implementing, evaluating, checking the outcome against the plan and adjusting/taking corrective action.

As mentioned in the International Civil Aviation Organization (ICAO) Safety management happens to be a organized approach which is utilized in managing safety, together with organizational structures,
accountabilities, policies and measures. Safety Management is a systematic approach in which the activities that are undertaken are defined by safety management undertaken by an organization in order to achieve acceptable and tolerable safety.

Safety management has its own definition from company to company and from one organization to other but the final and ultimate goal is to reduce the level of damage well before it occurs or at least soon after it occurs so as to lessen the intensity of damage (Hinze 1997).

Levitt and Samuelson (1993) said that safety constitutes the major role in any organization and especially in those where the negligence of safety management may cost lives of people.

2.2.1 Safety Management in Construction Industry

Today, the Construction Industry in India is very complex and large. The rapid growth in construction industry has led to fall in terms of health and safety aspects of the workers. Accidents in the construction sites that occur usually due to the lack of communication among the workers involved from various departments. Safety Management is the key to provide safety measures that can be implemented on the construction sites.

The main factors that affect safety performance include lack of training, poor safety awareness of top management, reckless operations, reluctance to input resources to safety and poor safety awareness of project managers.

Construction accidents cause panic among the workers, delay in project progress, cost due to accident, reputation of construction industry and
affect the overall output (Mohamed 1999). In developed countries, governments attempt to address the problem by implementing legislation which punishes infracting companies or persons. In the European Union, for example, fines may be applied (New Civil Engineer International 2000a). In the USA infringements may lead to imprisonment as well as to fines (Engineering News Record 2001a). A complementary approach in the USA is for Government to exhort the construction industry to improve its safety record (Engineering News Record 2001a).

In developing countries, appropriate legislation quite often exists but it is frequently not applied in the case of infringement of laws, probably because construction workers are often migrant, low-paid, are not afforded union-protection and are held in low esteem by the society in which they live. Another factor which influences attitudes to safety and health is cost (Koehn and Reddy 1999).

Both developed and developing countries have recognized the necessity of improving occupational safety and health management on construction sites, particularly to reduce the number of occupational accidents. As a result, a few organizations have started shifting from a reactive to proactive approach towards safety (Weibye 1996, Kandola 1997 and Crawley 1999).

Key factor affecting safety management are the lack of the provision of safe working conditions, safety training, effective control of site hazards by the main contractors and specific responsibilities for managers and workers Jannady (1996).
However the introduction of legislation alone cannot be the solution, with an improvement in the cultural approach being essential to achieve workplace safety (Blockely 1995).

Many construction industries around the world are showing an interest in the concept of construction safety management as a means of reducing the potential for large scale disasters, as well as accidents associated with routine tasks. The causes of the accidents are not only the carelessness of the workers; sometimes accidents happen due to the failure of control, which is the responsibility of management. Thus the shift of the focus on the accidents has been driven by the awareness that organizational, managerial and human factors, rather than purely technical failures, which are prime cause of accidents (Weiek et al 1999).

The development of a safety management system is seen as essential for the control of risk. Lai et al (1996) suggests that safety management should be proactive rather than reactive, and that management should assess the adequacy of its safety management effort through safety performance audits.

The successful safety management in any industry involves six steps: a) Planning; b) Developing; c) Organizing; d) Implementing e) Measuring and f) Auditing / Reviewing.
Figure 2.3 Safety Management System

The above Figure 2.3 describes the process of safety management system. There are seven important points for the successful planning: Information, Monitoring/reporting, Knowledge/expertise, Co-ordination/Communication / feedback, a commitment to safe practice, Training and Effective management.

2.2.2 Characteristics of Safety Management Systems

Ferret and Hughes (2008) have described that there are four basic elements, general to all occupational health and safety management systems. Safety management systems hold the different activities of the system together with the detailed arrangements and actions required to distribute those activities. The 4 key characteristics of a successful occupational health and safety management system are a) An optimistic health and safety culture
b) The participation of all stakeholders c) An efficient review d) Repetitive upgrading.

2.2.3 Need for Safety Management in Construction Industry

Modern accident causation models are based on the assumption that the ultimate causes for accidents and incidents are in the management decisions and organizational practices. The systematic and planned top management driven activity that aims at controlling the health and safety hazards is usually called safety management. The primary aim of safety management is to intervene in the causation process that leads to accidents and incidents Booth and Lee (1995). This includes, above all, the active recognition of both visible and latent hazards. However, safety management is more than just a hazard identification system. It is an overall system for ensuring that the safety activities are properly planned, effectively implemented, and that the follow-up system is arranged. Typically safety management includes activities like risk analyses, arrangement of safety training, accident and near-miss investigations, safety promotion, and assessments of human reliability. In an effective safety management system these activities are assigned to all the different hierarchical levels of the organization. (Booth and Lee 1995, Grimaldi and Simmonds 1975). Safety management has many parallels with the other organizational management activities. For example, Total quality management (TQM) and environmental hazard management have many similar elements with safety management (Krause and Hidley 1989, Weinstein 1996).

One of the latest safety management system models is presented in the British Standard BS 8800 (1996). It presents both the steps for creating a safety management system and methods for organizing the safety activities in practice. According to the BS 8800, 1996 standard, the main development
steps are: a) Initial and periodic status review b) Preparation of the safety policy c) Organizing of the activities d) Planning and implementation e) Measurement of the performance and Auditing.

Booth and Lee (1995) have defined the key functions of safety management as follows: Policy and planning, Organization and communication, Hazard management, Monitoring and review. In this model, the policy and planning includes setting of the safety goals, determination of the safety objectives and priorities, and preparation of the working program to achieve the objectives. Organization and communication includes, among others, the determination of responsibilities, and the establishment of a two-way communication system to all organizational levels. Hazard management includes the determination and implementation of the methods for hazard identification, risk assessment, and control measures. The suitability of these methods should then be evaluated on a regular basis. Finally, monitoring and review ensures that the steps are in place, in use, and work in practice.

According to Mincks and Johnston (2004) several construction contractors are realizing the economic benefits of a proactive safety management program. Consistent savings can be made to the insurance and compensation premiums of workers by having a better experience rating of safety. This is an example where the costs of the project go beyond the apparent sudden advantage to the project itself. For previous projects the records of safety denotes on the rates paid for today’s project. This is a tie between the company wide performance and individual project.

An effective accident prevention program and project safety denotes the individual project but it has an even greater effect on the company wide performance record. Safety management is denoted by the safety plans implementation, appropriate equipment in work tasks, application of safety
procedures, provision of proper secure equipment, motivation of jobsite safety meetings and the management of significant hazardous substances on the jobsite (McClelland 1985). The major aim of the safety management is to prevent all accidents to the jobsite. Profitable and well run construction organizations have a fairly effective program for safety management (Jonson 1982). The areas of performance benchmarking denote that with above average net earnings the contractors have strong skills of leadership. They embrace strategic planning, combine risk management and market themselves effectively into the organization operations (Cooke et al 1998). Zero injury is related directly to highly profitable construction operations. This is a philosophical and cultural issue that cannot be delegated to a safety engineer from a service provider (Miramontes and Hugh 2004).

Threat of death or be heavy injury and safety of this exists within the construction industry because of its disorganized nature, the uncertainty in it and technically complex nature of the work in this industry. Added to this the uncontrollable environment in which the production of this work takes place; the practices to involve the employers and the way they are hired and above all these the financial and time pressure of the project corresponds the majority of hazards in this construction business (King and Hudson 1985).

Stephen C.K. Yu and Bob Hunt (2002) had given the fact that the effectiveness of safety management system (SMS) has reached a no improvement plateau in most organisations in Hong Kong, those involved in SMS would agree that change is needed to give safety a continuous improvement momentum. The concept, principles, tools and practices of total quality management (TQM) can be the mean to obtain such a change. This paper is an attempt to apply the TQM concepts and techniques in a systematic manner into a SMS. First, the problems of a compliance oriented SMS
adopted by most organisations in Hong Kong are summarised. Then, the needs and rationales for the establishments of TQM based safety management brief, which will ultimately determine the back bone of a Safety Management System, are illustrated below in Figure 2.4.

![Figure 2.4 A conceptual framework of Safety Management System adopted by most organisations in Hong Kong](image)

The model for IMS implementation proposed by Alena Labodova (2004) uses the methodology originally developed for Occupational Health Safety Management System (OHSMS).

This methodology consists of seven steps as shown in Figure 2.5: 1) Description of the production system installations and the surrounding environment 2) Identification of sources of hazard and possible target systems 3) Scenarios 4) Evaluation of risk 5) Setting-up the objectives 6) Definition of means of prevention and protection 7) Management of risk.

If this “seven steps” procedure is compared to the Plan- do- check - act (PDCA) based OHSMS scheme, it can be seen that all “Risk management steps” can be related to the PDCA flow-chart, but they do not cover the whole
PDCA Scheme. Some necessary steps must be added, especially monitoring, audits, management review and the principle of continuous improvement.

**Figure 2.5  The combination of risk analysis (“seven steps”) and OHS management spiral**

International labour organisation (ILO) (2011) describes the Occupational Safety Health Management System approach which gained support by following the wide endorsement and success of the International Organization for Standardization (ISO) standards for quality (ISO 9000 series) and later for the environment (ISO 14000 series). This model (as shown in Figure 2.6) is based on systems theories developed primarily in the natural and social sciences, but is also similar to business management mechanisms. Four elements common to general systems theories are: input, process, output, and feedback.
Figure 2.6 ILO Continual improvement cycle

Figure 2.7 OHSAS 18001:2007 standard requirements
OHSAS (Occupational Health and Safety Assessment Series) 18001 focuses on the identification, elimination, and continual improvement of hazards and risks within the work environment. The OHSAS management system methodology is based on planning for hazard identification, risk assessment, and risk control. The OHSAS 18001 Health and Safety Management System (HSMS) as shown in Figure 2.7 incorporate ISO management system elements to address these risks. Many organizations are implementing an Occupational Health and Safety Management System (OHSMS) as part of their risk management strategy to address changing legislation and protect their workforce.

An OHSMS promotes a safe and healthy working environment by providing a framework that allows organizations to consistently identify and control its health and safety risks, reduce the potential for accidents, aid legislative compliance and improve overall performance.

2.2.4 Evaluation of Safety Management System Effectiveness

The effectiveness and adequacy of the safety management system should be evaluated on a regular basis. Different evaluation methods can be used for assessing the different aspects of the safety management system. The most commonly used methods are: 1) Measurement of safety performance 2) Safety audits 3) Management reviews.

1. Measurement of Performance

Measurement of safety performance is a means of monitoring the extent to which the safety policy and safety objectives are being met, and it includes both the proactive measurement tools and the reactive tools. Proactive monitoring is used for checking compliance with the company’s planned health and safety activities, while reactive monitoring is used for the
investigation, analysis, and recording of the management system failures, including accidents and incidents (BS 8800 1996).

2. Safety Audits

A safety audit can be done in several ways, by different people in the organization, and it can cover many different activities. In everyday language also risk analyses, technical inspections, and other plant level routine assessments are often called audits. However, when a safety audit is understood similarly to a quality system audit, it is an assessment of the management system. This assessment has two goals: it should verify that the minimum legal requirements are met, and that the current safety efforts are effective and sufficient. (Glendon 1995).

3. Management Reviews

The need to modify and further develop the safety management system can be distinguished in management reviews. A management system may work as planned, but any internal or external changes may require to redesign the system. Findings from the safety performance measurements and from the safety audits are the main sources of information for the management reviews. A good review system ensures that the company can learn from experience, improve performance, develop the health and safety management system, and respond to changes (Successful ... 1997).

2.2.5 Summary of the Literature Review on Safety Management System

The summary of literature survey on safety management system is presented in Table 2.2.
<table>
<thead>
<tr>
<th>Year</th>
<th>Author</th>
<th>Key points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Definition of safety management</strong></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>Levitt and Samuelson</td>
<td>Negligence of safety management may cost lives of peoples.</td>
</tr>
<tr>
<td>1997</td>
<td>Hinze</td>
<td>Ultimate goal is to reduce the level of damage well before it occurs or at least soon after it occurs so as to lessen the intensity of damage.</td>
</tr>
<tr>
<td></td>
<td>ICAO</td>
<td>Safety management undertaken by an organization in order to achieve acceptable and tolerable safety</td>
</tr>
<tr>
<td></td>
<td><strong>Safety Management in Construction Industry</strong></td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>Mohamed</td>
<td>Accident at construction site will hamper the project schedule, panic among the workers, reputation of constructions industry will go down and overall cost of construction will go high.</td>
</tr>
<tr>
<td>2000a</td>
<td>New Civil Engineer International</td>
<td>In European nations, if legislation is not followed, then fine will be imposed on the organization.</td>
</tr>
<tr>
<td>2001a</td>
<td>Engineering News Record</td>
<td>In USA, If legislation is not followed, then fine and imprisonment will be imposed on the organization. A complementary approach in the USA is for Government to exhort the construction industry to improve its safety record</td>
</tr>
<tr>
<td>1999</td>
<td>Koehn and Reddy</td>
<td>In developing countries, legislation exists but frequently it is not applied in case of infraction of law because of workers are migrants in nature, low paid, not protected by union.</td>
</tr>
<tr>
<td>1996</td>
<td>Weibye</td>
<td>Organizations are started from reactive approach to proactive approach.</td>
</tr>
<tr>
<td>1997</td>
<td>Kandola</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>Crawley</td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>Jannady</td>
<td>Key factors affecting safety managements are</td>
</tr>
</tbody>
</table>
|      |      | a) Workplace condition  
b) Workers training  
c) Responsibility of manager and front line supervisor  
d) Controlling of hazards. |
| 1995 | Blockely | Introduction of legislation alone will not be a solution for the problem, a safety culture should be developed to improve the safety at work places. |
| 1999 | Weick et al | The causes of the accidents are not only the carelessness of the workers. Sometimes accidents happen due to the failure of control, which will be a responsibility of the management. |
| 1996 | Lai et al | 1) Safety management should be proactive rather than reactive.  
2) Management should assess the adequacy of its safety management effort through safety performance audits |
| 2011 | Labour | Successful safety management system consists of following 6 steps 1)planning  2)developing 3)organizing 4)implementing 5)measuring and 6) audit / reviewing |
Table 2.2 (continued)

<table>
<thead>
<tr>
<th>Characteristics of Safety Management</th>
</tr>
</thead>
</table>
| 2008       | Ferret and Hughes | Four key characteristics of a successful occupational health and safety management system are as follows:  
|            |                  | - An optimistic health and safety culture  
|            |                  | - The participation of all stakeholders  
|            |                  | - An efficient review  
|            |                  | - Repetitive upgrading. |

<table>
<thead>
<tr>
<th>Need for Safety Management in Construction Industry</th>
</tr>
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<tbody>
<tr>
<td>1995</td>
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<td>1995</td>
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<tr>
<td>1995</td>
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<tr>
<td>1996</td>
</tr>
</tbody>
</table>
| 1996       | Weinstein        | Safety audit assessment has two goals:  
|            |                  | 1) It should verify that the minimum legal requirements are met, and  
|            |                  | 2) The current safety efforts are effective and sufficient |
| 1996       | BS 8800          | Steps for creating a safety management system and methods for organizing the safety activities in practice. The steps followed are  
|            |                  | 1) Initial and periodic status review, 2) Preparation of the safety policy, 3) Organizing the activities, 4) Planning and implementation, 5) Measurement of the performance, and 6) Auditing. |
| 1995       | Booth and Lee    | Key functions of safety management are as follows:  
|            |                  | Policy and planning, Organization and communication, Hazard management, Monitoring and review. |
| 2004       | Mincks and Johnston | Proactive safety management approach |
| 1985       | McClelland       | Safety management is denoted by the safety plans implementation, appropriate equipment in work tasks, application of safety procedures, provision of proper secure equipment, motivation of jobsite safety meetings and the management of significant hazardous substances on the jobsite. |
|            | and Bob Hunt     | |
| 2004       | Alena Labodova   | The integrated management system model is developed based on occupational health safety management system.  
|            |                  | It is developed for production plant. |
| 2011       | International Labour organisation (ILO) | ILO developed the safety management system for continual improvement. The following steps are followed for developing continual improvement  
|            |                  | 1) Policy 2) Organizing 3) Planning and implementation 4) Evaluation 5) Action for improvement. |
| 2007       | OHSAS 18001:2007 | OHSAS management system methodology is based on planning for hazard identification, risk assessment, and risk control. |
In Table 2.2 shows the summary of literature review on safety management system, Heinrich et al (1980) defined the safety management as systematic control of worker performance, machine performance and physical environment. Previous studies (Levitt and Samuelson 1993) had found that safety constitutes the major role in any organization and especially in those where the negligence of safety management may cost lives of people. Presently, organizations have started moving from reactive approach to proactive approach (Weibye 1996; Kandola 1997; Crawley 1999; Lai et al 1996; Mincks and Johnston 2004).

Jannady (1996) found that key factors affecting safety management are the lack of the provision of safe working conditions, safety training, effective control of site hazards by the main contractors and specific responsibilities for managers and workers. Labour (2011) provides successful safety management system: Planning, developing, organizing, implementing, measuring and audit / review. BS 8800 (1996) had defined the safety management model in following steps: Initial and periodic status review, Preparation of the safety policy, Organizing of the activities, Planning and implementation, Measurement of the performance and Auditing. ILO (2011) and OHSAS 18001:2007 had developed safety management model based on the BS8800. Stephen C.K. Yu and Bob Hunt (2002) approach was to apply Total Quality Management principle into safety management systems, so that the continuous improvement in implementation of safety management system could be monitored.

Based on the literature review, it is found that, most of the studies in the areas of construction safety management have been reported from developed countries. Safety management model, developed by past
researchers is only the framework which does not explain the details of steps to be followed by site management on safety aspect and are general in nature. So it required to develop a detailed safety management model, which will enable the site management to quickly understand and implement the model to reduce the accident rate in construction industry. In developing countries like India being a large country and faster development of infrastructure with high population is a suitable place for safety related research. Review of literature reveals that there is not enough research evidence from India on safety management model development. In developed and developing countries site based safety management model is not developed. So this has motivated the researcher to develop a new safety management model based on the past research. The present research developed a new safety management model, which can be made as generic and applicable for both developed and developing countries. Based on this review a site based total construction safety management model is developed in the present research work.

2.2.6 Research Problem

Based on the literature review carried out, it was found that both developed and developing countries have recognized the necessity of improving occupational safety and health management on construction sites, particularly to reduce the number of occupational accidents. As a result, a few organizations have started shifting from a reactive to proactive approach towards safety (Weibye 1996, Kandola 1997 and Crawley 1999).

Key factors affecting safety management are the lack of the provision of safe working condition, safety training, effective control of site hazards by the main contractor, managers and workers (Jannady 1996). Labour (2011) approach on the successful safety management in construction
involves six steps: Planning, developing, organising, implementing, measuring and auditing/reviewing.

It is an overall system for ensuring that the safety activities are properly planned, effectively implemented, and that the follow-up system is arranged. Typically safety management includes activities like risk analyses, arrangement of safety training, accident and near-miss investigations, safety promotion and assessments of human reliability. In an effective safety management system these activities are assigned to all the different hierarchical levels of the organization. (Booth and Lee 1995, Grimaldi and Simmonds 1975). Effectiveness and adequacy of the safety management system should be evaluated on the regular basis by following evaluation methods 1) Measurement of safety performance 2) Safety audit 3) Management review

BS8800 (1996) had developed the safety management model. The steps followed were similar to Labour (2011). Booth and Lee (1995) have defined the key functions of safety management as follows: 1) Policy and planning 2) Organization and communication 3) Hazard management, 4) Monitoring and review. Stephen C.K. Yu and Bob Hunt (2002) used TQM principle for developing safety management system. It involves the following steps: 1) Safety policy and safety plan 2) Hazard identification and control plans 3) Safety management practices 4) Incident investigation and emergency plans 5) Safety communication and documentation 6) Safety programme evaluation and audits.

Alena Labodova (2004) developed safety management on seven steps using PDCA cycle. But this model is applicable for manufacturing units. International labour organisation (ILO) and OHSAS 18001:2007 had defined the safety management model based on BS8800 with a few improvements.
But none of the literature had brought out site based safety management model. So there is a need for developing a new model for site based total safety management. Total construction safety management was also developed based on PDCA cycle.

The PDCA Cycle is a checklist of the four stages which you must go through to get from 'problem-faced' to 'problem solved'. The four stages are Plan-Do-Check-Act, and they are carried out in the cycle illustrated below. The concept of the PDCA Cycle was originally developed by Walter Shewhart, the pioneering statistician who developed statistical process control in the Bell Laboratories in the US during the 1930's. It is often referred to as 'the Shewhart Cycle'. It was taken up and promoted very effectively from the 1950s on by the famous Quality Management authority, W. Edwards Deming, and is consequently known by many as 'the Deming Wheel'.

![PDCA Cycle Diagram](image)

**Figure 2.8 Plan do check act cycle**

Use the PDCA Cycle to coordinate your continuous improvement efforts. It both emphasises and demonstrates that improvement programs must start with careful planning, must result in effective. The four phases in the Plan-Do-Check-Act Cycle (Figure 2.8) involve:

- **Plan**: Identifying and analyzing the problem.
- **Do**: Developing and testing a potential solution.
• Check: Measuring how effective the test solution was, and analyzing whether it could be improved in any way.
• Act: Implementing the improved solution fully.

In the past research, general safety management model had been developed, but none of the research paper had brought out the details on steps to be followed in the safety management systems on construction site. It was also felt that the past researchers had attempted to explain the steps to be followed, but not in details. So this present research had analysed past researcher models and proposed a detailed framework model for safety management at construction site. The developed model in this research explains each step in details and developed a few forms for easy implementation at site.

2.2.7 Need for Total Safety Management in Construction Industry

The following discussion attempts to establish the need for total safety management in the construction industry. The researcher has endeavored to discuss current safety scenario and safety related issues in order to justify the argument that today’s construction industry, although thoroughly controlled by safety legislation and regulations, still demands an improved safety environment for at least two reasons: 1) reducing the accident rates and 2) improving safety performance through audit and review methodology.

The researcher further argues that as today’s construction projects are growing in complexity, in order to succeed on the global level, construction organizations must not approach construction safety and health as just another step in avoiding unwanted accidents, but as a strategic tool, that if implemented effectively, will have the potential to maximize
competitiveness and profit. This strategic approach to safety can be accomplished via a past researcher literature based safety program i.e. a Total Safety Management (TSM) program for the construction industry.

2.2.8 Research Methodology

In this thesis work, the newly developed model is based on the similar method used by past researcher and to make an effective site management tools, few aspects were included based on literature survey. This model is based on Plan- do- check- act cycle.

2.3 PERFORMANCE MEASUREMENT IN RELATION TO CONSTRUCTION SAFETY

An organization measures the performance to determine whether targets or objectives are being met. Performance monitoring may take place in numerous areas, such as environmental aspects, finance, production, and safety and health of the workers. In an enterprise and/or organization, the performance measurement is an important aspect of evaluating and monitoring occupational health and safety (OHS) performance.

Tarrant (1970) said that to access the level of safety in any organization, a safety performance measurement is essential. Safety performance measurement management involves identifying and controlling of hazards and risk, planning, detect failure and monitoring /reviewing performance. This includes a detailed study and examining site, person at work, procedure and individual behavior.

Safety Performance measuring is the primary objective to provide the feedback mechanisms and that will helps in encouraging continues improvement. The critical issue in the feedback mechanism is capturing the
right source of information. The most error in feedback mechanisms on safety performance is based on accident frequency rates as the indicator of performance (Krause 1991; Mitchell 1998, O’Brein 2000 and Jaselkis 1996). The earlier performance measurement techniques had one major disadvantage of conventional safety measures is that they are retrospective, measuring unsafe behavior after it has occurred (Rockwell and Bhise 1970; Tarrants 1970).

Past studies had found that safety performance measurement using the outcome or data measures does not provide a true measure of safety (Ahmad et al 1999). The use of LTI (Lost Time Indicators) means that near misses or incidences which have possible chance to cause the injuries, go unnoticed. Proactive performance indicator is needed to measure the safety before the accidents occur. This indicator gathers information about people’s behaviour (sometimes unsafe and safe acts); examining written documents, reports and records; talking to people about their experiences, views and opinions (Hughes and Ferrett 2008). Such type of indicators is used to develop the preventive measures.

To improve the construction safety performance, Jaselkis (1996) provides the analysis of numerical profiles and projects of companies with various levels of safety performance. The measures of safety performance were related to severity rate, lost time incident rate, recordable incident rate and illness with and without lost working days. At the construction sector level, the Experience Modification Rating (EMR) and Recordable Incidence Rate (RIR) were used to measure the safety performance.

Recordable Incidence Rate (RIR) is used to classify the projects. This approach is used to rating the project in three ways by outcomes that
categories average, below average and outstanding projects. The safety tends
to be a qualitative in nature and it addresses “what factors are important for
success” as opposed to “how much is appropriate to achieve successful
outcomes”.

The safety performance indicator must provide clear information
about the safety performance to those with authority and responsibility to take
the action. Both activity indicators and outcome indicators consist of two key
components: ‘what is being measured in’ and ‘how the indicator is being
measured’.

In Alberta, US construction industry measured the impact of safety
inspections on the government site to find the work related death and injuries
(Auld 2001). It was found that the safety inspections reduce the fatalities in
piling, concretes and services etc. According to Auld (2001), the safety
inspections are needed to reduce the risk of injuries and accidents.

Safety performance was measured under two elements: Safety
results and Safety activities. Safety activities are to measure the safety and
accident prevention programme, such as: Weekly safety training, Weekly site
safety inspections, Frequent and regular inspections by the safety department,
Accident investigation and injury reporting. The Safety results were measured
by the IR (Incidence Rate).

In the 1980s participative performance management programme
called TUTTAVA was developed (Saari 1994). The programme aims to
improve order and tidiness. The key elements in this programme are the
following: (1) Behavioral targets have links to many production goals which
most people would like to improve. (2) The implementation is carried out by
teams representing employees and supervisors, as well as the management. (3) Technical and organizational obstacles that prevent individuals from acting according to the targets are removed. (4) The feedback is based on the observation of conditions following behaviour, rather than on behaviour itself. The TUTTAVA programme has been successfully implemented in hundreds of companies. It is difficult to measure safety reliably at a construction site, because the work environment changes continuously. For instance, the observation system in the TUTTAVA is based on fixed observation points, which is not practical when it comes to the changing work environment at a construction site. In addition, besides the main contractor, there are usually many sub-contractors at a construction site. This may prevent the feedback from being experienced personally. It is not unusual to blame the other contractors for leaving places in disorder. These are some of the problems that have to be solved when implementing performance management programmes at construction sites.

The new TR (Building Construction safety) observation method was developed in 1992 (Laitinen et al 1996). When developing the TR observation method, they kept in mind that the same method should also be usable for the site personnel in internal inspections. The aim of this study was to determine whether the weekly inspection routine could be replaced with a more effective weekly audit system that is based on the TR observation method, on the participation of workers, and on the principles of performance management.

Laitinen and Ruohomäki (1996) studied a new method for weekly inspections, based on participation and the principles of performance management, was tested at two construction sites. Eight safety rules were formulated together with the safety personnel of the company. Once a week the supervisor and the workers safety delegate observed the safety level, using
a standard observation method. After baseline observations, an information
meeting was organized for all workers, and thereafter the safety index of each
weekly observation round was marked on a large graph on the wall of the
dining room. The safety index rose from the baseline of 60% to 89% during
the feedback at site 1. At site 2 the index rose from 67% to 91%. The stage of
the construction process had no significant effect on the results; the index
level of 90% was achieved at all stages of the process. The most visible
change was an improvement in order and tidiness. The sub indexes
concerning protection against falling, machine safety, scaffoldings and use of
personal protective devices improved to nearly 100%, which should prevent
severe injuries in particular. The new audit method with weekly graphic
feedback could well be a method for the construction industry to reach a
radically higher safety level.

Laitinen et al (1999) describes that, safety inspectors carried out
monitoring visits to 305 building construction sites, and the results were
compared with the accident figures of the same sites. The average number of
observations per site was 144, and the observed safety aspects were: working
habits, scaffoldings and ladders, machines and equipment, protection against
falling, lighting and electricity, and order and tidiness. Each item was scored
as ‘correct’ if it met the safety standards, otherwise the item was scored as
‘not correct’. The safety index was calculated as a percentage of the ‘correct’
items related to all the observed items. Only some hours of training were
needed for making reliable observations, when the observers already knew the
safety standards. Also the validity proved to be good. The method is used by
the site personnel as an internal weekly safety inspection and feedback tool.

Trethewy (2003) in his research monitored the implementation of a
series of management interventions designed to improve subcontractor safety
performance on Australian construction sites. At the same time the influence
on safety performance and subcontractor attitudes and perceptions of risk based on feedback, strong management commitment, and improvement in documented safety systems, was assessed. International and Australian practices in subcontractor occupational health and safety (OHS) management were identified to determine weaknesses in Australian construction industry practices. Traditional OHS outcome performance levels based on injury rates failed to correspond with the performance levels determined by the behaviour-based positive performance measurement technique used. The research findings identified that a mix of Positive Performance indicator and traditional outcome measures provided the basis for improved OHS performance appraisal of a construction project.

However, it is important to work towards the goal of zero incidents and zero accidents. At present, the construction sector safety activities are inconsistent, uncoordinated and untargeted with the compliance of minimum standards rather than the best practice (Site Safe 2000). The risks in the hazards need to be avoided at source, if it is not possible, it must be controlled and risk against the workers must be considered to protect them (Lan and Arteau 1997).

There are limited approaches to measure the performance of safety in construction. The examples cited below are representatives of the alternative theme found in the literature reviewed during this particular study.

Harper and Koehn (1998) described that construction industry on an average has a higher rate of occupational injury than most other industries. However, steps can be taken to reduce worker risk through the effective management of controllable factors. These controllable factors can be
managed through an aggressive safety program with emphasis on hazard awareness, safer work practices, and employee involvement.

Hinze and Gambatese (2003) concluded that speciality contractor safety performance was consistently influenced, in part, by a number of factors. The factors shown to positively affect safety performance include minimizing worker turnover, implementing employee drug testing with various factors initiating the testing, and training with the assistance of contractor associations. Safety incentive programs were not necessarily associated with better safety performance. Growth in company size was found to be associated with improved safety performance as well.

Huang and Hinze (2003) identified the root causes of fall accidents and any additional information that might be helpful in reducing the incidence of construction worker falls in the future.

Primary and secondary prevention measures can be used to prevent falls or to mitigate the consequences of falls and are suggested for each type of accident. Primary prevention measures would include fixed barriers, such as handrails, guardrails, surface opening protections (hole coverings), crawling boards/planks, and strong roofing materials. Secondary protection measures would include travel restraint systems (safety belt), fall arrest systems (Safety harness), and fall containment systems (safety nets) (Chi et al 2005). Toole (2002) suggested that specific site safety responsibilities be assigned on future projects based on each group’s ability to control the factors needed to prevent eight root causes of construction accidents. De la Garza et al (1998) analyzed the compensation practices in US, and decided to analyze the data on four key performance indicators: Loss Time Injury Frequency Rate (LTIFR), Recordable Incident Rate (RIR),
Experience Modification Rate (EMR), and Workers Compensation Claims Frequency Indicator (WCCFI). The analysis of data found the accident records, average incidence rates, and communicate or interact with injured workers.

Lin and Mills (2001), tested the correlation between OHS (Occupational Health and Safety) performance of the Australian construction sector and variables such as training of employees, attitude of company management, company size etc. It also suggested worker’s compensation, educating employees and impacts on the business.

Marsh et al (1995) described the development and effects of behaviorally based management techniques in improving construction site safety. The measures included four categories of measurement: access to heights; site housekeeping (site tidiness); scaffolding; and use of personal protective equipment (PPE) – with PPE used as a control. The results showed that: safety behaviour can be objectively and reliably measured; goal setting and feedback can produce large improvements in safety performance; the commitment of site management appears to enhance their effectiveness.

Rockwell and Bhise (1970) discussed an active and a passive procedure methods for assessing safety performance in the workplace. The active system evaluates safety performance based on information obtained through the co-operation of workers, whereas the passive approach uses behavior and environment sampling studies developed from an analysis of historical data. Each procedure involves eight major steps: identification of unsafe acts/conditions; scaling of these acts/conditions according to a hazard index; frequency analysis; designing a scheme for measuring frequency of unsafe acts/conditions and joint occurrences; developing a scheme for
obtaining safety performance scores, collecting data; evaluating scores, and developing standards and control charts. The active procedure, augmented by occasional cross-checking with the passive procedure, appears to be an effective tool for assessing and controlling safety performance.

Tam et al (1998) studied the safety attitudes, practices and characteristics of construction firms in Hong Kong and their relationship to safety performance on construction sites. Forty-five construction companies are compared and studied. Each company adopted different safety management strategies. The 45 companies were composed of 11 small, 25 medium and 9 large scale construction firms. Construction firms' safety performance is measured by site casualty rates. The study concludes that the provision of safety training, the use of directly employed labour, the use of post-accident investigation as a feedback, and promoting safety practices by safety award campaigns and incentive schemes, are the most effective tools in mitigating site casualties.

Edwin Sawacha et al (1999) discussed factors influencing safety on construction sites. The impacts of the historical, economical, psychological, technical, procedural, organizational and the environmental issues are considered in terms of how these factors are linked with the level of site safety. The historical factor is assessed by the background and characteristics of the individual, such as age and experience. The economic factor is determined by the monetary values which are associated with safety such as hazard pay. The psychological factor is assessed by the safety behavior of fellow workers on site including supervisors. The technical and procedural factors are assessed by the provision of training and handling of safety equipment on site. The organizational and environmental factors are assessed by the type of policy that the management adopts to site safety. The top five important issues found to be associated with site safety were: (1) management
talk on safety; (2) provision of safety booklets; (3) provision of safety equipment; (4) providing safety environment and (5) appointing a trained safety representative on site.

Thanet Aksorn and Hadikusumo (2008) identified 16 critical successes factors (CSFs) of safety program from safety literature and previous research and these were thereafter validated by construction safety professionals. The result showed that the most influential factor is management support. Furthermore, using factor analysis, the 16 CSFs could be grouped into four dimensions: worker involvement, safety prevention and control system, safety arrangement, and management commitment. In order to validate the findings, three case studies were further conducted to test the effect of those success factors on construction safety performance.

Mohammad S. El-Mashaleh et al (2010) reported empirical data collected from 45 construction contractors. On a scale of 0–1.0, Data Envelopment Analysis (DEA) assesses the relative efficiency of every contractor relative to the rest of the contractors in terms of safety performance. For inefficient contractors, Data Envelopment Analysis (DEA) provides quantitative guidance on how to become efficient.

Hinze (1981) said that environment of construction workers influences their susceptibility to injury. A study of construction and road maintenance crews in Missouri, USA shows that the safety performance of individual workers depends substantially on how the worker responds to the work environment, particularly the mental work environment.

Hinze and Wilson (2000) said that in the past decade the terms “zero accidents” and “zero injuries” have been used a great deal by construction firms espousing their commitment to safety.
2.3.1 Performance Measurement in Relation to Positive Performance Indicator and Negative Performance Indicator

Performance Measurement must be enabled as a management tool in organization to clarify goals. The regular measurements of the outcomes (results) and efficiency of programs or services is known as Performance Measurement (Hatry 2006). To improve the service quality and program regular monitoring is necessary (Wholey and Hatry 1992). Performance Indicator is the numerical measurements for the aspect of performance (e.g. efficiency, outcome or output) under consideration.

2.3.2 Positive Performance Indicator

Positive Performance Indicator (PPI) allows the measurement of activities undertaken to improve the performance. In other words, Positive Performance Indicator measures the action or activities that the organization has taken to achieve the targets. A Positive Performance Measurement (PPM) is a measure of activity to control damage and loss.

Positive Indicators used to measure relevant management, process, occupational health and safety (OHS) systems, and compliance with the OHS practices in workplace. Good performance against Positive Performance Indicator leads the organization to good outcome performance (Shannon et al 1997). Examples of PPI are: OHS (Occupational Health and Safety) trained employees percentage, number of safety audits.

Laitinen and Reohomaki (1996) found out a new method for carrying out the inspection at site (i.e., weekly inspection) and an internal safety inspection has to be carried out weekly on building construction sites in Finland. This procedure is widely believed to be ineffective, as illustrated by the high accident rates in the building industry. In this study, a new method for weekly inspections, based on participation and the principles of
performance management, was tested at two construction sites. Eight safety rules were formulated together with the safety personnel of the company. Once a week the supervisor and the workers’ safety delegate observed the safety level, using a standard observation method. After these baseline observations, an information meeting was organized for all workers, and thereafter the safety index of each weekly observation round was marked on a large graph on the wall of the dining room. The safety index rose from the baseline of 60% to 89% during the feedback at Site 1. At Site 2, the index rose from 67% to 91%. The stage of the construction process had no significant effect on the results; the index level of 90% was achieved at all stages of the process. The most visible change was an improvement in order and tidiness. The sub indexes concerning protection against falling, machine safety, scaffoldings and use of personal protective devices improved to nearly 100%, which should prevent severe injuries in particular. The new audit method with weekly graphic feedback could well be a method for the construction industry to reach a radically higher safety level.

The performance indicators are distinguished as micro and macro measures. Macro and micro indicators are used to measure effectiveness of safety system (Paterson 1998). Micro indicators are used to measure the individual performance of the management inputs. The micro measures are divided into the results and activity measures. Macro indicators are used to show how the results are measured. Macro measures are based on the incident or accident data and it helps in measuring the organizational site performance.

The following Figure 2.9 shows the clear view about the PPM that can be utilized in an organization to complement the outcome measures. The process of developing PPI includes: *implementation* – methods, procedures
and resources; results oriented – outcomes, products and outputs; related to process and relevant to organization workplaces.

Figure 2.9 Positive Performance Measures

Australian NOHSC (National Occupational Health and Safety Commission) in 1999 recommended the Positive Performance indicator (PPI) for the construction industry in five areas: Planning and Design includes planning and scheduling, site set up, percentage of incidents, design and percentage of design changes. Management Processes include rating of management commitment, percentage change in number internal OHS noncompliance and in assessment score for the sub-contractor’s OHS plans, percentage of reviews in planned formal management, percentage of site visits actual vs planned, and implementation of site safety plan. Risk Management includes proportion of identified hazards and items identified
through the safety walks, effectiveness of job safety analysis, proportion of unplanned down time and reported incidents, percentage of high risk hazards, and average time to rectify the hazards. **Psycho-social working environment** includes effectiveness of communication and percentage of employees assessed as competent OHS. **Monitoring** includes percentage change in number of corrective actions and audit scores.

PPI involves in measuring the safety management processes by process indicators and it may also measures the safety behaviours of workers. No research had used NOHSC indicator for implementation. The process indicators may measure the safety management processes like weekly site inspection. The weekly inspection is a new method evaluated by Laitinen and Ruohomaki (1996) in two constructions. By adopting both positive oriented (percentage of OHS trained employee) and outcome oriented (Loss Time Injury Frequency Rate) indicators of the OHS performance, an organization provided comprehensive view of their performance in following Figure 2.10.

![Figure 2.10 OHS performance measurement](image)

There are many safety and health activities conducted by organizations that are used to generate the additional measures of OHS. These indicators focused on ‘how successfully’ an organization or an enterprise is performing and managing in relation to the OHS.
Trehewy (2003) found the needs for the difference between two types of processes: Focus on the behavior of workers and those that measure management activity. To address the need of safety indicators in construction, an organization must implement a safety site environment measurement tools called the Site Safety Meter (SSM). This indicator provides a positive approach and it provides feedback on both structural and behavioral aspects of the safety system. There are six issues that are related to the construction site safety were identified as: Order and tidiness, ladders and scaffold, electrical and lighting, plant and equipment, protection against falling objects and fall by persons and working habits. In Sydney, the SSM was implemented in ten construction sites and SSM readings were taken out at intervals.

Advantages of using positive indicators of the OHS performance to the outcome indicators include: provision of immediate feedback about the management of OHS, provision for the immediate improvements made to OHS performance and the ability to evaluate and measure the effectiveness of OHS management.

Nithin Naik (2006) had followed a scheme based on a similar methodology used by past researchers and involved in process intervention, performance measurement and outcome evaluation. It involved performance measurement of processes for a substantial period during each of the project. The site safety meter was used for comparing the safety performance of two constructions project site. But this research had brought a few drawbacks in Site safety meter implementation. The contractor was never well accepted of implementing such tools. But this research had given a recommendation for future work.

1. This research had already developed a workable performance measurement framework, testing it on future construction projects
would be valuable. This would help to further confirm and refine the system so that it becomes generic to construction practices.

2. This framework could be implemented between sub-contractor and workers. The feedback on performance can be an effective basis for regular communication regarding the effectiveness of the safety management system.

3. Improve the type and method of feedback. For example feedback can be developed for a particular trade, which can help and focus on trade specific hazards.

4. This research has identified repetitive and random hazards found in site inspections. The repetitive hazards are related to daily housekeeping such as tagging and cleanliness of areas. The random hazards are related to injuries which only identified after the accidents. The research found that the repetitive hazards could be reduced by regular feedback. Future studies can be focused on understanding the percentage of reduction in repetitive hazards from such feedback. Future studies can also focus on understanding the percentage of random hazards as compared to repetitive hazards during the project.

5. This research found that only fewer numbers of injuries (30%) were explained by the changes in the number of identified hazards. Further work is needed to improve the safety inspection process, which identifies hazards. Such process can be more focused on identifying injury related hazards. Such changes in the safety inspection process can help to better correlate safety hazards and injuries.

2.3.3 Negative Performance Indicator

The negative indicators reflect or provide the results of the past activities or actions. The negative performances are measured by the outcome indicators. The negative indicators are also called as the outcome indicators.
Outcome indicators are used to collect the information and provide the results about the issue of concern (procedure, practice and programme that is being monitored, safety related policy) to the organization. Outcome indicators are also used to hide potential risks. Some examples of outcome indicators are: number of days lost, number of claims and claim costs. The Outcome indicators are focused on the loss measurement, such as LTIFR (Lost Time Injury Frequency Rate), fatality incidence rates, worker’s compensation.

According to Rose (1994), some outcome measures like Lost Time Injury Frequency Rate (LTIFR) are necessary but this measurement is not sufficient.

"Lost time is abused. One of the things you could do if you want to improve it [is to] stop the practice of regarding people who come back into work to do some other job as not being lost time. ... If you cannot do your normal job fully it's lost time whether you comeback in or not" - (Rose, 1994).

![Diagram](image.png)

**Figure 2.11** Cause/effect relationship between positive performance indicators and outcome indicators

The Figure 2.11 describes cause/effect relationship between positive performance indicators and outcome indicators. The Outcome indicators are: easily understood, easily compared for comparative purposes or benchmarking, linked with the safety performance and used to identify the trends.
2.3.4 Summary on Performance Measurement in Relation to Construction Safety

The summary of performance measurement in relation to construction safety is presented in Table 2.3.

Table 2.3 Summary on performance measurement in relation to construction safety

<table>
<thead>
<tr>
<th>Researchers and Year</th>
<th>Key points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tarrants (1970)</td>
<td>To assess the level of safety maintained in the organization, safety performance measurement is essential.</td>
</tr>
<tr>
<td>Lindsay (1992)</td>
<td>To measure safety maintained at organization, a study and examining site, person at work, procedure and individual behavior.</td>
</tr>
<tr>
<td>Krause (1991); Mitchell (1998), O’Brein (2000); Jaselkis (1996)</td>
<td>The primary objective to provide the feedback mechanisms and that will help in encouraging continues improvement. The most notable error in the feedback mechanism is only reactive indicators are taken.</td>
</tr>
<tr>
<td>Hughes and Ferrett (2008)</td>
<td>Proactive measures can used to assess the safety level.</td>
</tr>
<tr>
<td>Jaselkis, (1996)</td>
<td>The measures of safety performance were related to severity rate, lost time incident rate, recordable incident rate and illness with and without lost working days</td>
</tr>
<tr>
<td>Saari (1994)</td>
<td>The process for improving housekeeping, order and tidiness in companies was developed in the mid 1980s in Finland and is called “Tuttava”, a Finnish acronym for the words “safe and productive work habits”. The Tuttava programme is based on four key issues: employee participation, management/ employee support, systematic approach, and positive feedback. Tuttava consists of eight steps: form an implementation team, define good work practice, remove technical and organizational obstacles, design an observation checklist, measure the baseline, train employees, provide feedback, and finally following up.</td>
</tr>
<tr>
<td>Laitinen et al 1996; 1999</td>
<td>In 1992 and 1993, the Occupational Safety and Health Inspectorate of Uusimaa, in cooperation with the Finnish Institute of Occupational Health, developed a method for evaluating the occupational safety level on construction sites, the ‘TR method’. It is used to measure the main risk factors of the working environment as well as the safety of the employees' working methods, with observed items scored either as ‘correct’ or ‘not correct’. The TR method also gives indices on measured items: working habits; scaffolding; gangways and ladders;</td>
</tr>
</tbody>
</table>
Table 2.3 (continued)

<table>
<thead>
<tr>
<th><strong>Alternate theme to improve safety performance at construction site</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trethewy (2003)</strong></td>
<td>Identified that a mix of Positive Performance indicator and traditional outcome measures provided the basis for improved OHS performance appraisal of a construction project. The tool developed was based on TR method. The proposed tool was site safety meter.</td>
</tr>
<tr>
<td><strong>Harper and Enno Koehn (1998)</strong></td>
<td>To reduce the worker risk through effective management of controllable factors. The factors are hazard awareness, safe work method and employee involvement.</td>
</tr>
<tr>
<td><strong>Hinde and Gambatese (2003)</strong></td>
<td>Factors shown to positively affect safety performance include minimizing worker turnover, implementing employee drug testing with various factors initiating the testing, and training.</td>
</tr>
<tr>
<td><strong>Huang and Hinze (2003)</strong></td>
<td>To reduce the fall accidents and identify the root cause of fall accidents. The main root causes for hazards are always misjudged by worker.</td>
</tr>
<tr>
<td><strong>Chi et al (2005)</strong></td>
<td>Primary and secondary prevention measures can be used to prevent falls. Primary - fall prevention measures Secondary- Fall protection methods(e.g., Personal protective equipment)</td>
</tr>
<tr>
<td><strong>De la Garza (1998)</strong></td>
<td>Analyzed the data on four key performance indicators: Loss Time Injury Frequency Rate (LTIFR), Recordable Incident Rate (RIR), Experience Modification Rate (EMR), and Workers Compensation Claims Frequency Indicator (WCCFI)</td>
</tr>
<tr>
<td><strong>Marsh (1995)</strong></td>
<td>Behavior based system was used to improve the construction site safety performance. The measures included four categories of measurement: access to heights; site housekeeping (site tidiness); scaffolding; and use of personal protective equipment (PPE)</td>
</tr>
<tr>
<td><strong>Rockwell and Bhise (1970)</strong></td>
<td>Active and a passive procedure as a method for assessing safety performance in the workplace. Active system- Information obtained through the co-operation of workers Passive system- Behavior and environment sampling studies developed from an analysis of historical data.</td>
</tr>
<tr>
<td><strong>Tam et al (1998)</strong></td>
<td>Construction firms' safety performance is measured by site casualty rates. The provision of safety training, the use of directly employed labour, the use of post-accident investigation as a feedback, and promoting safety practices by safety award campaigns and incentive schemes, are the most effective tools in mitigating site casualties.</td>
</tr>
<tr>
<td><strong>Edwin Sawacha et al (1999)</strong></td>
<td>The following factors influencing safety on construction sites: Historical, economical, psychological, technical, procedural, Organizational and environmental issues. Organizational factor is the most influential factor that drives safety.</td>
</tr>
<tr>
<td><strong>Thanet Aksorn and Hadikusumo</strong></td>
<td>Identified 16 critical success factors (CSFs) : Clear and realistic</td>
</tr>
</tbody>
</table>
Table 2.3 (continued)

<table>
<thead>
<tr>
<th>Year</th>
<th>Factor</th>
<th>Key statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2008)</td>
<td>goals, good communication, delegation of authority and responsibility, sufficient resource allocation, management support, program evaluation, continuing participation of employees, personal motivation, personal competency, teamwork, positive group norms, personal attitude, effective enforcement scheme, safety equipment acquisition and maintenance, appropriate supervision, appropriate safety education and training. The 16 CSFs could be grouped into four dimensions: worker involvement, safety prevention and control system, safety arrangement, and management commitment.</td>
<td></td>
</tr>
<tr>
<td>Mohammad S. El-Mashaleh et al (2010)</td>
<td>Data Envelopment Analysis (DEA) provides quantitative guidance on how to become efficient</td>
<td></td>
</tr>
<tr>
<td>Hinze (1981)</td>
<td>Safety performance of worker depends upon how the work respond to working environment (i.e. mental work environment)</td>
<td></td>
</tr>
</tbody>
</table>

2.3.5 Summary on Performance Measurement in Relation to Positive Performance Indicator and Negative Performance Indicator

The Table 2.4 present the summary on performance measurement in relation to positive performance indicator and negative performance indicator.

Table 2.4 Summary on performance measurement in relation to positive performance indicator and negative performance indicator

<table>
<thead>
<tr>
<th>Researcher and Year</th>
<th>Factor</th>
<th>Key statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laitinen and Reohomaki (1996)</td>
<td>Safety inspection</td>
<td>Weekly audit was carried out and feedback was given to site to improve the safety performance.</td>
</tr>
<tr>
<td>Shaw, Blewett (1994)</td>
<td>OHS performance measurement</td>
<td>To reducing lost time injury frequency rate: The following four factors should function effectively in the organization: 1) Communication 2) Managing the hazard 3) OHS management 4) Training.</td>
</tr>
<tr>
<td>NOHSC (1999)</td>
<td>Positive Performance Indicator</td>
<td>In this, five areas are concentrated: 1) Planning and design 2) Management processes 3) Risk management</td>
</tr>
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Table 2.4 (continued)

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<table>
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<th></th>
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<tbody>
<tr>
<td></td>
<td>4) Psycho-social working environment</td>
</tr>
<tr>
<td></td>
<td>5) Monitoring</td>
</tr>
<tr>
<td>Trehewy (2003)</td>
<td>Safety inspection</td>
</tr>
<tr>
<td></td>
<td>Mix of Positive Performance indicator and traditional outcome measures provided the basis for improved OHS performance appraisal of a construction project.</td>
</tr>
<tr>
<td>Nithin Naik (2006)</td>
<td>Safety performance</td>
</tr>
<tr>
<td></td>
<td>Implemented site safety meter in construction site. Recommendation for future work.</td>
</tr>
</tbody>
</table>

Past researchers had attempted in taking any one of the factors for improving the overall safety performance of the site. Jasellis (1996) found that holding an appropriate number of safety meeting correlated with improvement in safety performance. De la glarza et al (1998) analysed workers compensation and found that contractor with poor record keeping practices have high accident rate. Lin and Mills (2001) found that company size, management practice and employee commitment to OHS are correlated significantly with safety performance.

From the literature, it is prominent that past studies (Trehewy 2003 and Latinen at al 1999) have found that there are tools to measure the overall safety performance of the site. But these (Latinen at al 1999) tools are found to have some drawbacks in implementation. So, Trehewy (2003) developed the site safety meter (SSM). It acts as site measurement and feedback tool, which was derived from a literature review of world best proactive and adapted for Australian conditions from previous work conducted in Finland. Site safety meter also successfully tested to measure site safety environment. SSM had brought improvement in the safety awareness among workers as a result of SSM and the use of visual feedback techniques to stimulate interest in the process and its objective. Nithin Naik (2006) implemented Site safety meter (SSM) in his research but there were a few drawbacks observed.
Performance measurement provides the key to monitoring the effectiveness of safety systems. It can also provide the basis for continuous improvement in management systems and practices. There is a need of tools to be generic for application to any construction industry for measuring safety performance positive performance and negative performance. The tools should be such that it should improve the overall effectiveness of safety management system. This research addresses all these drawbacks and future recommendations, stated by Nithin Naik (2006). A new model for safety performance measurement and outcome indicators has been developed in this research work.

2.3.6 Research Problem

1. In the past studies it was observed that the proactive performance indicator by Laitinen and Ruohomaki (1996) evaluated a new methodology of carrying out an inspection by using TR observation method. This studies has deliberated the following areas like observation, feedback method, behavioural, technical and organisation obstacles and weekly inspection.

2. In Australia NOHSC (1999) recommended 22 positive performance indicator to measure site safety. But no research had implemented to assess the effectiveness of NOHSC indicators.

3. Trethewy (2003) had devised a tool based on the past researchers methodology, with a few modification site safety meter was developed and successfully implemented in the site environment for measuring the safety performance. This tool found more significant improvement in the safety awareness among workers.

4. Nithin Naik (2006) said that Site Safety meter having a few drawbacks on implementation. His research suggested a few recommendations for future research work.
i) The site safety meter should be tested in future construction project and this would confirm and refine the system.

ii) Improvement is needed for feedback methods like between sub-contractors and workers, segregate the trade specific hazard.

iii) Repetitive hazard and random hazard are found out during inspection, % reduction on repetitive hazard and random hazard should be addressed and brought as feedback mechanism.

iv) Improvement is needed in safety inspection process, which should focus mainly on identifying the injury related hazard.

5. There are several problems faced by the contractors. Competition is high, driving down the price for the work performed and financial returns are directly related to the amount of work completed in the shortest possible time. This leads to work for long hours and ignoring chronic injury problems (Trethewy 2003, Wyatt 1997). Some of the other problems are language barriers and types of contracts, Andonakis (2003). Other than contractors’ dominance, there is a significant difference in the working environment of the construction industry when compared with other industries. Unlike the manufacturing industry, construction workers routinely carry out traditional work in new configurations. This involves workers from different organisations working around each other in a shared workplace. This situation requires more emphasis on efficient communication and co-ordination to achieve better safety standards. The challenges faced by the construction industry through prevalence of subcontractors, and a changing work environment will always exist due to the nature of the industry. But there is a need to manage these challenges to achieve better safety performance. There is also an immediate need to reduce the high number of fatalities.
6. In India almost no research had been carried out in the safety performance measurement in construction industry.

The literature review carried out states that, further research is needed in the above areas are:
1. Identifying the draw back in existing tools (Site Safety Meter).
2. If improvement is needed then a new tool should be developed based on similar methodology used in earlier research. In such a ways that it should address all the issues stated above and future research recommendations are stated by Nithin Naik (2006).

2.3.7 Site Safety Meter

Trehewy (2003) implemented a site safety environment measurement tool called Site Safety Meter (SSM). It acts as a site measurement and feedback tool, which provides the overall positive safety performance of a construction site. The tool was derived from a literature review of World Best Practice and adapted for Australian conditions from previous work conducted in Finland.

Site safety meter is an indicator, which is positive in its approach and provides feedback on behavioural aspect of a safety system. Consequently the SSM was developed for site safety appraisal by Safety Committees and supervisors. It provided feedback to workers on positive aspects of an individual site; in other words, “what is right”. Six categories of issues that relate to safety on a construction site were identified as: 1. Working habits, 2. Order and tidiness, 3. Electrical and lighting, 4. Scaffold and ladders, 5. Protection against falls (by persons) and falling objects and 6. Plant and equipment.
SSM was then implemented on ten construction sites in Sydney. The sites were all major building sites at various stages of construction and SSM readings were carried out at fortnightly intervals. The person (or group) who undertook the measurement walks around the site looking at all the indicators defined for the six categories recorded both “correct” and “not correct” items categorised under the six site rules. To measure an area, each item observed was scored as “correct” if it met the safety requirements of the defined criteria; otherwise the item was scored as “not-correct”. If the person conducting the measurement was not sure how to score an item, then it was not scored at all. The Site Safety Meter score for a construction site as a whole is calculated by dividing the number of correct items by the total number of items.

Drawbacks observed in existing performance measurement tools - site safety meter:

1. Only 6 categories of issues that relate to safety on a construction site are taken.
2. The person or group does measurement should have knowledge on the six categories in detail.
3. If the person conducting measurement was not sure how to score an item, then it was not scored at all.

2.3.8 Research Methodology

This research is based on a similar basic methodology used by past researcher and involved in performance measurement. The research methodology involved in identifying the draw back in existing tool i.e. Site Safety Meter and develop a new tool for performance measurement
framework with positive performance indicators, sub-contractor performance measurement, feedback mechanism and outcome measures.

2.4 SAFETY AUDIT IN RELATION TO CONSTRUCTION INDUSTRY AND ELECTRICAL SAFETY IN CONSTRUCTION SITE

2.4.1 Safety Audit

Safety auditing is a structured approach to control and reduce the accidents before its occurring. The safety audit is to evaluate the workspace, physical plant and management itself for the purpose of containment efforts and accident prevention (Ghani 1998).

2.4.2 Safety Audit for the Construction Industry

The audit is a methodical approach to evaluate procedures, practices for completeness and accuracy, and records (Hess 1998).

The operation of safety audit in construction sectors was recommended by the group and that must be carried out four times a year. The operation basically involves knowledgeable and trained inspectors from the Department of Occupational Safety and Health offices carrying the safety audit at the construction sectors (Birkmire et al 2007). The normal practice is that the group of 2 to 5 inspectors will visit any construction site in their area.

Laitenen and Ruohomaki (1996) used the observation method in their research to study the performance of internal weekly safety inspection that is compulsory to build construction sites in Finland. The aim of this study is to determine whether the weekly inspection routine could be replaced with a more effective weekly audit system.
Jannadi and Assaf (1998) used a standard checklist which consists of 18 elements. The aim of this study is to determine whether safety levels differ according to the size of the project. Each sub element was evaluated as ‘yes’ or ‘no’ depending on its existing in the job site. The elements score was calculated using a predetermined equation. Each project was scored by obtaining the average (using Likert scale) of the applicable element scores within that project.

Teo and Ling (2006) proposed a method to develop and test the tools that auditors may use to assess the effectiveness of a construction’s firm safety management system. The study consists of 15 steps. Surveys were conducted and safety experts were consulted. The Analytic Hierarchy Process (AHP) and Factor Analysis were used to assist in identifying the most crucial factors and attributes affecting safety.

2.4.3 Electrical Accident Statistics

James C. Cawley (2003) said that U.S. Labor Department’s Bureau of Labor Statistics (BLS) compiles the Census of Fatal Occupational Injuries (CFOI) from death certificates and other information for U.S. workers killed on the job. CFOI and Survey of Occupational Injuries and Illnesses (SOII) data show that 2,287 U.S. workers died and 32,807 workers sustained days away from work due to electrical shock or electrical burn injuries between 1992 and 1998. Overall, 44% of electrical fatalities occurred in the construction industry. Contact with overhead power lines caused 41% of all electrical fatalities. Electrical shock caused 99% of fatal and 62% of nonfatal electrical accidents. Comprising about 7% of the U.S. workforce, construction workers sustain 44% of electrical fatalities. Power line contact by mobile
equipment occurs in many industries and should be the subject of focused research.

Chia-Fen Chi et al (2009) study analyzed 255 electrical fatalities in the construction industry. Similar to our previous analysis of fatal falls, each electrical fatality was analyzed in terms of individual factors (age, gender, experience of the victim), task factors (performing task), environmental factors (wet area and confined space), management factors (company size measured by number of workers), source of injury, and causes for these accidents. These electrocution accidents were divided into five accident patterns: direct worker contact with an energized power line, boomed vehicle contact with an energized power line, conductive equipment contact with an energized power line, direct worker contact with energized equipment, and improperly installed or damaged equipment, to identify contributing factors for each. For each accident pattern, accident causes (failure to de-energize electrical systems, failure to maintain safe distances, improper use of personal protective equipment (PPE), poor work practice, accidental contact with exposed electrical parts, defective tools and equipment, lack of effective safety devices or unsafe environment) and prevention measures (safe work practices, insulation, guarding, grounding, and electrical protective devices) were developed based on the identified common scenarios.

From the review, it is very clear that there are very little data present on the Electrical safety on construction sites. In developing countries like India there were no research carried out.

2.4.4 Summary on Safety Audit In Relation to Construction Industry and Electrical Safety in Construction Site

The summary for safety audit in relation to construction industry and electrical safety in construction site is presented in Table 2.5.
Table 2.5 Summary on safety audit in relation to construction industry and electrical safety in construction site

<table>
<thead>
<tr>
<th>Year</th>
<th>Author</th>
<th>Key points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>Ghani</td>
<td>Safety audit structured approach to control and reduce the accidents before it occurs (Proactive Steps).</td>
</tr>
<tr>
<td>1998</td>
<td>Hess</td>
<td>Safety audit is to evaluate the procedure, practices followed.</td>
</tr>
<tr>
<td>2007</td>
<td>Birkmire, Lay, McMahon</td>
<td>In a year 4 audits can performed and 2 to 5 inspector will visit the site for carrying out audit.</td>
</tr>
<tr>
<td>1996</td>
<td>Laitenen and Ruohomaki</td>
<td>Weekly safety inspection will be carried.</td>
</tr>
<tr>
<td>1998</td>
<td>Jannadi and Assaf</td>
<td>Standard checklist developed by 18 elements and assesses the project level.</td>
</tr>
<tr>
<td>2006</td>
<td>Teo and Ling</td>
<td>Develop and test the tools that auditors may use to assess the effectiveness of a construction’s firm safety management system. Analytical Hierarchy process is used for determining the factors.</td>
</tr>
</tbody>
</table>

ELECTRICAL ACCIDENT STATISTICS

<table>
<thead>
<tr>
<th>Year</th>
<th>Author</th>
<th>Key points</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>Chia-Fen Chi, Chong-Cheng Yang and Zheng-Lun Chen</td>
<td>Analyzed 255 electrical fatalities in the construction industries. All the electrical fatalities were analyzed based on the following factors a) Individual factor b) Management factor c) Task factor d) Environmental factor e) Sources of injury and f) Causes of accidents.</td>
</tr>
</tbody>
</table>

Ghani (1998) and Hess (1998) in their approach stated that safety audit is a proactive approach and it is also a systematic approach. Birkmire et al (2006) described that in a year 4 audits can be carried and 2 to 5 inspectors will carry out audit at site. Laitenen et al.(1996) described weekly inspection should be carried out and the observation may be entered in the specific format. So that we can monitor the safety performance by number of observations noted by the inspection teams. This approach will improve the safety performance of the site. Jannadi et al (1998) developed the checklist for performing the audit which consists of 18 elements. James C. Cawley et al (2003) had disseminated the information regarding electrical accidents in U.S. In U.S, electrical accident in construction sector is more than comparing any other sector. Chia-Fen Chi et al (2009) analyzed 255 electrical accident
based on the task factor, environmental factor, management factor, individual
t factor, source of injury and cause of accidents. Only very few past researchers
had done a research on this area in developed countries. In developing
countries, no literature was found on the electrical related accidents in
construction industry. So this had motivated researcher to look into it and find
out a methodology to reduce an electrical related accidents in construction
industry. A new designed, planned and executed electrical safety audit
method is presented in this research work.

2.4.5 Research Problem
2.4.5.1 Trends of Electrical Accidents

James C. Cawley (2003) said that U.S. Labor Department’s Bureau
of Labor Statistics (BLS) compiles the Census of Fatal Occupational Injuries
(CFOI) from death certificates and other information for U.S. workers killed
on the job. CFOI and SOII data show that 2,287 U.S. workers died and 32,807
workers sustained days away from work due to electrical shock or electrical
burn injuries between 1992 and 1998. Overall, 44% of electrical fatalities
occurred in the construction industry.

This trend continued for 2003-2007, with 52 percent of
occupational electrical fatalities occurring in construction. Electricians
sustained 47 percent of the electrical fatalities in construction followed by
construction laborers (23 percent), and painters, roofers, and carpenters with
6 percent in each occupation. Over the last five years, construction industry
rates have shown steady improvement from a high in 2003 (1.4) to its 2007
rate of 0.9 fatalities per 100,000 workers (Figure 2.12).
Figure 2.12  U.S construction industry, selected electrical fatality rates, by event, 2003-2007

However, it is important to remember that across the same period, the rate of electrical fatalities for all the private industries remained constant at 0.2. In the construction industry the rate of non-fatal electrical injury rose from 2003 (1.0) to 2005 (1.6) and declined in 2006 (1.1) (Figure 2.13). The electrical burn injury rate in the construction industry hovered between 0.5 and 1.0 from 2003 through 2007.
Figure 2.13 Rates of Non-fatal Electrical injury in the construction industry, by event, 2003-2007

Construction was one of the two industries (the other being the utility industry) in which the number of non-fatal electrical burn injuries exceeded the number of electrical shock injuries (Figure 2.14). There were 2,390 electrical burn injuries in construction and 1,710 electrical shock injuries.
Figure 2.14  Non-fatal electrical injuries, private industry, by nature of injury, 2003-2007


2.4.5.2  Electrical Accident in Indian Construction Industry

Construction industry is the second largest employer after agriculture, employing over 30 million people. Agrarian background, migratory nature and a very high degree of transitory employment characterize the profile of labour in construction industry. As per the background information we could understand that there is almost no research has been carried out on Electrical safety in construction site in India.
General adverse physical/environmental operating conditions and the associated high-risk potential makes construction different from the other industries. Among these operating conditions, most of them are unique to construction industry, have an influence on the safety performance.

**Temporary nature of work**

Construction works are generally temporary in nature. Hence most arrangements are planned and made for a short duration. This curtails application of normal safety standards and hence construction is prone to accidents. Further, the feelings that the work is for a short duration makes the employee to take unnecessary risks.

**Seasonal employment of workers**

Most of the labourers employed are agricultural workers who are unaware of industrial risks. They come to construction work only during off-season of their farming activity and return once the agriculture activity picks up. Due to this transient nature of workers, imparting safety training to them is not only difficult but also is generally ineffective.

**Time constraint**

Quick mobilisation of men, material and resources to remote sites is a challenging task considering quality of logistical support available. Problems are many in the event when heavy machinery is required to be moved over longer distances on poor road conditions. Invariably there will be delays in mobilisation of resources and subsequently the project time needs to be crashed to meet specific customer needs.
Legal aspects

Till 1996, there was no specific legislation applicable to construction industry. In the absence of statutory requirement adequate attention was not given to safety at construction sites. Building and other construction workers (Regulations of Employment and Condition of Service) Act was enforced on 1st March 1996. Based on this legislation, the State and Central Governments were expected to notify rules. Central Government has also notified Central Rules in November 1998. Few states are yet to form the rules. Thus notification and enforcement of rules is still lacking.

2.4.5.3 Major Causes of Accidents

As per the present study, following are the major causes, which lead to accidents at construction sites.

- Fall from height (45%).
- Fall of materials (13%).
- Electrocution (12%).
- Collapse of earth (4%).
- Run over/ hit by vehicle (10%).
- Caught in between and struck by object/ moving machinery (9%)
- Others (7%).

From the above statement it is clear that electrical related accident (i.e., electrocution which causes 12% of accident) stands 3rd position in Indian construction industry. The electrical safety is important, due to following risk evolving at construction site.

i. Construction sites present one of the most challenging environments to the safe use of electricity.
ii. Much of the work is done outdoors in all weathers - damp and wet conditions increase the risk and potential severity of shock. Sites are constantly changing as the work progresses, so there is always a temptation to improvise supply systems.

iii. Excavations, demolition work and routine construction activities may all result in damage to both the temporary site distribution system and/or the existing fixed installation.

iv. Cables and equipments are likely to be damaged by the movement of heavy plant and materials. During installation work sites are often congested, which makes the control of risk more difficult. There may also be confusion as to which parts of the temporary, existing or new installations are live, and which have been made dead.

v. The temporary site distribution system may be used by a wide range of people who often work for different contractors and who will have various needs and expectations.

vi. Contractors may provide their own tools and equipment, or use equipment provided by others. Effective management is necessary to ensure that all the equipment is suitable for use and is properly maintained.

This objective is to reduce these electrical related accidents happening at construction site by addressing all above issues.

Based on the accident statistics it was decided to improve the electrical safety at construction site. Exclusive Electrical safety Audit (ESA) was proposed for construction site and can be used to identify the hazard evolving at construction site on electrical aspects and mitigate the electrical hazard present in the construction site.
2.4.6 Research Methodology

Electrical Safety Audits (ESA) is to identifying potential electrical hazards to prevent or minimize loss of life and property is perceived seriously by many construction industries in the world over. General safety auditing is popular where the objectives and concepts are clear whereas ESA is a specialized area that is still in the process of being understood by many.

In India, the condition is still worse. Investigations of major fire incidents in various types of occupancies over a number of years show that nearly 40% of the fires are initiated by electrical causes such as short circuits, overloading, loose electrical connections, etc.

Our experience shows that either the top management or the electrical department initiates ESAs and not the safety department. The reason could be the lack of in-depth knowledge of safety officers in electrical aspects coupled with their limited involvement in electrical department’s day-to-day functions. Although electrical hazards will be identified and assessed in general safety audits, comprehensive electrical safety audits can provide a thorough review of the electrical system. This could identify potential electrical hazards, flaws in design system, maintenance system, etc.