IDENTIFICATION OF THE ROOT CAUSES OF CONSTRUCTION ACCIDENTS:

METHOD-RELATED CAUSES

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Venkata Siva Ganesh Chintalapudi

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

SUPERVISORY COMMITTEE:

Eric Asa

Chair

Charles McIntyre

Selekwa Majura

Approved:

11/20/2014 Yong Bai

Date Department Chair

ABSTRACT

Safety in construction is a problem that has been gaining increased attention in recent years. Although lots of research is being done to address different aspects of improving safety, the challenge remains in narrowing the focus by identifying specific problems. This study attempts to find problems in safety by collecting data from construction sites and performing an analysis.

The data collection involved obtaining 205 incident investigation reports from a number of refinery and thermal power plant sites that belonged to the same contracting firm. Out of the 205 incidents, 120 were attributed to root causes that were method related.

A software model is proposed, with the aim to reduce a considerable amount of effort and time spent writing method statements. Very few activities are covered, and the most important advantage is that the method statement can be implemented more efficiently with accurate data, design and accessibility within the standards.

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1. INTRODUCTION

1.1. Background

The construction industry stands second in terms of its contribution to India's economy, only after agriculture. It is a highly labor-intensive industry and provides employment to a large rural population. At the same time, it is also one of the most hazardous industries and is generally known for a relatively high number of work-related accidents. Deadly construction accidents are quite common in India where the rules and procedures are often disregarded. Statistical data related to occupational injuries and fatalities are not available for India because the industry is widely disorganized. There is neither a dependable system available nor any organization to monitor the accident rates. The workers in this industry are comprised mostly of illiterate people who do not understand the risks to which they are exposed, and also, they are uninformed about their rights. This makes it expedient for contractors to exploit these workers to improve profitability. Due to globalization, there have been an increased number of international companies taking up infrastructure projects in India. As a policy, many of these international companies consider Health, Safety, and Environment (HSE) a matter of highest importance. They are even coercing Indian contractors to upgrade their safety norms and procedures.

There are a few major companies in the country which implement HSE better than other companies. This tiny number of contractors is also, obviously, the chosen ones for international projects in India. Although these contractors perform better than other Indian contractors, their safety performances are still a matter of concern. Even though they are professionally managed companies, they are terribly deprived of the awareness about the long-term benefits of Occupational Health and Safety (OHS) systems, which is evident because the companies' remain poor with implementing safety standards despite adopting certifications such as OHSAS 18001, etc. At most construction companies, HSE is generally given the lowest priority. For the few companies which do establish systems for OHS management, they do not get the necessary support or cooperation from existing departments. By and large, only after some untoward incident occurs do contractors begin to take action. In other words, contractors are reactive rather than being proactive. The monetary and legal liabilities for poor safety practices are huge. It does not end with a loss of lives or personal sufferings, but it causes project delays and a loss of productivity, legal suits and revenue losses, reduced employee morale, and affects the overall image of the company in terms of winning contracts. Moreover, as the safety standard goes higher, it seems prudent for the contractor to ensure, by whatever means, that the safety in its organization and at project sites is the best.

1.2. Objectives of the Research

- Classify construction incidents by root causes assigned by the investigators
- Develop a software model to facilitate Method statements**,** in order to meet the urgent needs of bringing a marked improvement to the construction industry's current safety practices.

1.3. Scope

One of India's major construction companies was available to offer accident data for this research. The company had a number of contracts in different parts of the country, providing sufficient data for reasonable analysis. Because the available data were limited to a particular kind of construction project, refinery and power-plant construction, the analysis and results only pertain to these kinds of projects. Also, while safety is normally accompanied by health and environmental principles, and together, the three are considered equally important, this study limits itself to safety principles.

1.4. Research Methodology

The major phases of the project are shown in Figure 1. The approach to achieve the research objectives had a mix of literature review as well as studying the safety documents, accident investigation reports and proposed software concept.

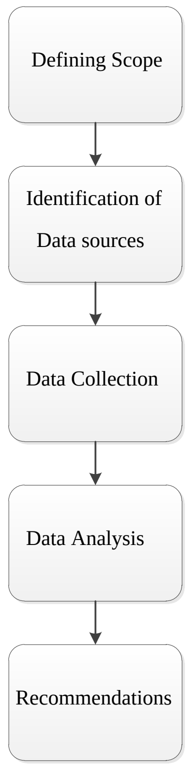

Figure 1. Major Phases of the Project

1.4.1. Defining the Scope and Identifying Data Sources

A review of the available literature related to construction safety and discussions with experts in the field helped to decide the project’s scope and to choose the type of data to collect. Incident analysis reports were both accessible and useful.

1.4.2. Data Collection

Data were collected from the available source, one of the major construction contractors for refinery and power-plant projects. Accident investigation reports were abundant in number but they were unorganized. The accident reports included fatalities, near misses, dangerous occurrences, lost-time injuries, and minor incidents. Data were available from 5 sites, with 3 sites contributing the most incidents, possibly due to the number of years those sites had been in operation.

1.4.3. Data Analysis

The observations and nonconformities mentioned in the reports were related to the corresponding clauses in the OHSAS 18001:2007 standard. The analysis was comprised of gathering the root causes of the unsafe conditions that existed during the accidents from the accident descriptions and then coding these root causes into broader cause categories. Later, the causes were ranked based on the number of incidents to which they were attributed in order to identify the most significant causes. It was found that method-related causes played a major role.

1.4.4. Recommendations

Finally, a plan for improving how method statements are written is suggested through this research.

1.5. Organization of the Paper

The paper is presented in five chapters. The remaining four chapters are organized as follows. Chapter 2 reviews the literature of earlier works related to the present research. It discusses the various problems that were addressed and the different methodologies adopted by them, summarizing the findings in four subsections. Chapter 3 gives a detailed description about the methodology for data collection and analysis. It reveals the findings of the research and discusses the problem identified in detail. Chapter 4 proposes the Software Concept for Method Statements. Chapter 5 presents Conclusions.

2. METHOD STATEMENTS FROM A STRATEGIC PERSPECTIVE

2.1. Factors Affecting Safety in Developing Countries

Construction is always a risky task because of outdoor operations, work-at heights, complicated on-site plants, and equipment operation coupled with workers' attitudes and behaviors towards safety (Choudhry and Fang 2008). Construction is much more unsafe than manufacturing. This is partly due to the more hazardous working methods and machines employed in construction (Helander 1991). These situations at construction sites expose workers to lots of risks. Many safety hazards are specific to the particular job classification, and typically, construction workers underestimate the hazards with their own work.

This affects the motivation for adopting safe work procedures (Helander 1991). Research has been done to identify problems for construction safety all over the world. Some research findings from developing countries also apply to Indian sites. Kartam et al. (2000) have observed, at Kuwaiti construction sites, that the problems arise due to disorganized labor, poor accident record-keeping and reporting systems, extensive use of foreign laborers, extensive use of subcontractors, a lack of safety regulations and legislation, the low priority given to safety, the small size of most construction firms, competitive tendering, and severe weather conditions during the summer. Tam et al. (2004) conclude from their research of Chinese construction companies that the main factors affecting safety performance include top management's poor safety awareness, lack of training, project managers' poor safety awareness, reluctance to input resources for safety, and reckless operations. One study in Taiwan (Cheng et al. 2010) also identified problems that included not valuing the importance of safety measures implemented at workplaces, not giving sufficient safety education to new workers, and not hiring well-trained safety and health personnel to implement safety measures. A high standard of safety was found in Thailand construction projects, where all 16 critical success factors identified from a literature survey, are given attention (Aksorn and Hadikusumo 2008). These critical success factors were given by them under four dimensions: worker involvement, safety prevention and control systems, safety arrangement, and management commitment.

2.2. Construction Accidents and Causative Factors

Construction-site accidents are very common because the sites are highly risk prone. The likelihood that an accident will have severe consequences increases when it involves vehicles, scaffolding, structures, or ladders (Lopez et al. 2008). Specific training for scaffolding and other equipment is not well administered in many places. Halperin and McCann (2004) have pointed out that most scaffold-competent persons do not have adequate training to allow them to ascertain when a scaffold is unsafe. A large proportion of construction accidents are due to workers falling.

Occupations such as construction laborers, roofers, carpenters, and structural metal workers are commonly involved in falls, and these hazards should be specifically addressed through fall-prevention efforts (Huang and Hinze 2003). Recording accidents and near misses is vital for analysis because the reports could highlight the causes towards which prevention efforts can be directed. Different approaches have been used to find the causes of construction accidents. In a study by Cheng et al. (2010), 1,347 occupational accident and fatality reports were subjected to statistical analysis and data-mining association rules. The results showed that both workers and management had insufficient awareness about safety issues and potential hazards. Most accidents were found to stem from a combination of

i. Management's failure to implement adequate safety measures to protect workers against
ii. Potential hazards in the working environment and

iii. The many unsafe acts committed by workers themselves.

Construction-project features, such as the project nature, method of construction, site restriction, project duration, procurement system, design complexity, level of construction, and subcontracting, contribute to accidents, and that the features' contribution is through the introduction of proximal accident causal factors in the construction process (Manu et al. 2010). Abdelhamid and Everett (2000) proposed a model called the Accident Root-cause Tracing Model (ARCTM) in order to better identify the root causes by classifying them into three categories. The model is a series of questions which should be asked when an accident occurs so that identifying the wrong root cause is eliminated. They collected data of accident reports and studied the narratives of the accidents. Their model was applied on these data to identify root causes that are different from the ones that were actually mentioned in the accident reports.

Chi et al. (2007) also used a classification coding system in their analysis of 255 electrical fatalities. However, in one research study (Shapira and Lyachin 2009), using accident frequencies to identify factors that affect tower cranes' safety was rejected since the authors believed that many accidents go unreported.

Ale et al. (2008) used a tool called Story-builder to systematically analyze and classify past accident data to gain quantitative insights about the causes and consequences of accidents. The importance of precursors and near misses to improve the safety margins and prevent accidents has been emphasized by Wu et al. (2010).

The modified loss causation model (MLCM) for accidents, presented by Chua and Goh (2004), was meant to facilitate feedback for the safety management system that failed during the accident and for the safety planning process with future construction projects. In order to achieve the two levels of feedback, the MLCM was designed to provide a systematic and logical structure for both incident investigation and safety planning such that, if the MLCM was applied consistently, the depth and breadth of both the processes would be ensured. By using the MLCM, incident-investigation information could be retrieved and utilized for safety planning.

2.3. Safety Management System

There is increased interest with systematic approaches to manage occupational health and safety as an organizational strategy for the prevention of work-related injuries, ill health, and fatalities. Safety standards and environmental standards, such as OHSAS 18001:2007 and ISO 14001, are being implemented in many countries to improve safety performances.

The main objective of the Occupational Health and Safety Management System (OHSMS) certification scheme is to encourage and enhance safety awareness, to promote safe work practices, and to raise the safety standards of the construction industry (Teo et al. 2005). Bottani et al. (2008) found, through an empirical investigation, that companies adopting safety management systems exhibited higher performance for all the topics encompassing company attitude to

(i) Define safety and security goals, and communicate them to employees;

(ii) Update risk data and perform risk analysis;

(iii) Identify risks and define corrective actions; and

(iv) Develop employees’ training programs.

While the principles behind safety management are fairly simple in concept, it is during the implementation of such a program that construction companies may encounter their most difficult obstacles (Wilson 2000). Issues such as cooperation from others are vital, yet profoundly ignored, by construction companies which is why seemingly simple problems continue to exist. There are various aspects of safety management. Some of the research done on these is given in the next sections.

2.3.1. Hazard Identification and Risk Assessment

Hazard identification and risk assessment are important to avoid construction accidents because the causes can only be eliminated after becoming aware of them. Identifying hazards and their corresponding control measures provides the foundation for a safety program and essentially determines the scope, content, and complexity of a successful OHSMS (Mearns and Flin 1995). Makin and Winder (2008) developed a conceptual framework to ensure that an OHSMS brings together the merits of the three main control strategies for dealing with workplace hazards: safe place, safe person, and safe systems.

However, hazard identification is often not properly done at construction sites. Carter and Smith (2006) collected and analyzed method statements from three UK construction projects. They found that only 6.7% of the method statements identified all the hazards that should have been noted. In the area of risk assessment, a few models have been suggested. One model (Jannadi and Almishari 2003) was a method of estimating risk that gives convincing results that are known to be sufficiently reliable and accurate to serve as a basis for managerial decisions. Another risk assessment model by Fung et al. (2009) used MS Excel software and a large amount of historical data about the risk levels of different work trades to provide quantitative risk assessment. Moriama and Ohtani (2008) also suggested a risk-assessment tool which includes human-related elements.

2.3.2. Safety-Culture and Safety-Climate Assessments

The safety culture will ascertain and reflect the effectiveness of a safety management system at any construction site. Developing a positive safety culture can be an effective tool for improving safety at any construction site (Choudhry et al. 2007). Available literature shows the use of surveys and statistics to assess safety culture/climate-related theories.

In Dingsdag et al. (2008), questionnaire data from workers on construction sites suggested that workers' perceptions about the primary characteristics of a safety culture validated the accepted precepts of a safety culture found in safety-culture theory, such as communication, and was at variance with several safety critical leadership positions. Mohamed (2002) used a questionnaire-based model to assess the safety climate at construction sites, corroborating the importance for the role of management commitment, communication, workers' involvement, attitudes, and competence, as well as supportive and supervisory environments, in achieving a positive safety climate.

2.3.3. Design Approach to Safety

The associated risks contributing to incidents are sometimes linked to the construction projects' design phase. Such risks, according to some researchers, can be reduced or eliminated by designing for construction safety. Behm (2005) analyzed 224 fatality investigation reports and a link to the construction-safety concept's design was determined. The results showed that 42% of the reviewed fatalities were linked to the concept. Other research (Gambatese et al. 2008) was conducted to confirm the findings of this study which revealed a link between construction-site fatalities and the construction-safety concept's design. An expert panel established to review a sample of the 224 fatality cases from the previous research was in agreement for 71% of the cases reviewed, giving further evidence about the design's influence on construction-site safety. A design tool has also been developed (Gambatese and Hinze 1999) to assist designers in identifying project-specific safety hazards and to provide best practices to eliminate the hazards.

2.3.4. Behavior-Based Approach to Safety

Workers' risk-taking behavior is a significant contributor for most accidents (Johnson et al. 1998). Mullen (2004) has identified factors that influence unsafe behavior at construction sites as follows:

1. Organizational factors, such as socializing influence, role overload, and performance over safety
2. Safety attitudes and perceived risk's
3. Image factors, such as macho syndrome and competence
4. Avoiding negative consequences, such as teasing and harassment from co-workers, and
5. Fear of losing the position

Al-Hemoud and Al-Asfoor (2006) pointed out that there is clear evidence that behavior-based safety initiatives centered on the positive-performance feedback technique are effective for improving and maintaining the safety behavior. Lingard (2002) concluded that first-aid training can have a positive, preventive effect and could complement traditional occupational health and safety training programs.

However, a behavior-based safety management program in the Hong Kong construction industry (Lingard and Rowlinson 1997), which introduced the techniques of performance measurement, participative goal setting, and the provision of performance feedback in a carefully controlled field experiment at seven public-housing construction sites, obtained mixed results. Behavior-based safety techniques were highly effective in bringing about improved performance for site housekeeping, but significant improvements with access to heights were only observed at two of the seven sites, and there was no significant improvement in the use of bamboo scaffolding during the experimental intervention. The results indicated that behavior-based safety-management techniques are not universally effective in bringing about improved safety performance in the Hong Kong construction context. Other factors, such as management's commitment, the ability to meet goals, goal rejection, hazard perception, and recognition, were stated as possible causes for deviation from the expected result. These factors should be well established for behavior-based safety training to work.

2.3.5. Software-Based Safety Management

Bansal (2010) proposed a GIS-based, navigable, 4D animation for the safety-planning process that facilitates an easier understanding of the construction sequence and predicts places and activities which have a higher potential for accidents. This approach integrated safety-code provisions and expert recommendations with components or activities that make safety planning more realistic.

A similar study (Benjaoran and Bhokha 2010) developed an integrated system for safety and construction management that incorporates safety measures into early designs and plans. A rule-based algorithm was formulated to automatically detect working at hazardous heights in designs and plans and to responsively advise proper safety measures. These integrated safety measures are also visualized via the 4D CAD model that clearly notifies the participants.

Lee et al. (2009) proposed a mobile safety-monitoring tool that consisted of a mobile-sensing device for detecting the worker's approach, transmitter sets and repeaters for sending the detected information to a receiver, and exclusive software for interpreting this information which could be used to decrease the potential for fall accidents.

Carter and Smith (2006) introduced an IT tool called "Total safety" to create method statements which supposedly improve the level of hazard identification for construction projects.

Cheung et al. (2004) designed a web-based safety monitoring and assessing system called CSHM (Construction Safety and Health Monitoring) that helps project managers and administrators to assess safety and health performance in a timely manner. CSHM's primary purpose is to reduce occupational accidents by directly observing and instantaneously assessing the data submitted in order to take fast, educated preventive and corrective measures.

2.4. Summary and Points of Deviation

The literature review was presented to elucidate the factors affecting construction safety by looking at some work done in developing countries, some investigations done on accident data, and different methodologies that are generally adopted for such research. There are different approaches for safety management and few of the IT-based software programs developed for safety were mentioned in the literature review. Of particular importance is the fact that there is not enough emphasis on preventing unsafe methods with any of the safety-management strategies. Factors influencing unsafe behavior have been studied; many research studies have tried to address this issue with different solution concepts. Efforts are being made to train workers and to modify their behavior as seen in the literature. Unsafe acts and unsafe conditions are not necessarily due to individual behavior. There is so much scope for research to improve the methodologies adopted for work by addressing other factors apart from behavior. Similarly, the solution concept, a software program, assumes a slightly different concept for method statements, not the one that identifies hazard, as will be discussed in detail later.

3. PROBLEM DEFINITION

3.1. Overview

Identifying problem areas for construction safety depended on studying confidential data, and only limited information was available. As already mentioned, only one company was available to share documents. Incident-investigation reports were collected and studied.

3.2. Investigating the Incident Reports

Incident investigation is an important tool for preventing the reoccurrence of incidents and also for identifying opportunities for improvement (BSI). Because there were limitations to incident, investigation reports were obtained for study.

3.2.1. Data Collection and Analysis

The incident data were obtained from 5 construction sites which, again, included both refinery and power-plant construction projects. The reports were available for incidents that took place from 2006 to 2009. The reports were not organized, and they, first, had to be sorted based on the incident type. Two hundred and five reports were initially collected and included incidents under five types: fatality, near miss, dangerous occurrence, lost-time injury and medical treatment and first-aid cases. The last two categories were combined into one category called "minor incidents" for the purpose of this research. The number of minor incidents contributed the most, about 41% of the reports, followed by lost-time injury cases with 39%. The number of incidents and the percentages for each type are given in Table 1 and Figure 1, respectively.

Table 1. Types of Incidents: Numbers

Type of Incident	**Number of Cases**
Fatality	7
Lost-time injury	79
Minor incidents	84
Dangerous occurrence	12
Near miss	23

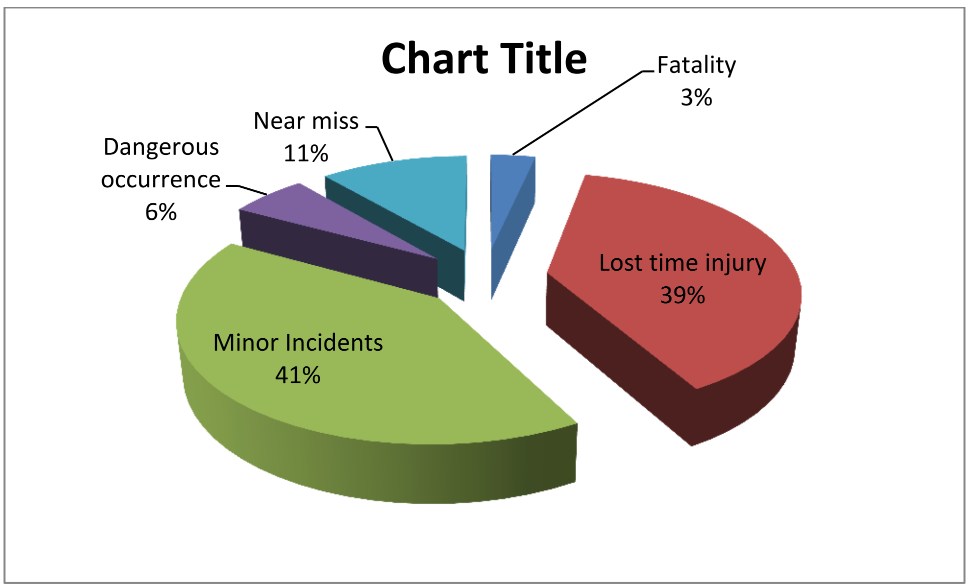

Figure 2. Type of Incidents: Percentages.

Based on the description of the incidents and the direct causes mentioned in the incident-investigation report, the nature of the incidents was found. The incident nature fell into 5 categories: fall, struck-by, caught-in-between, electrocution, and others. It was seen that many incidents were struck-by incidents, surprisingly a lot more than the number of fall incidents at these sites. Table 2 and Figure 3, respectively, give the number and percentages for the cases in each category. A list was prepared with the types and nature of the incidents. The direct causes, root causes, and actions taken were also noted.

Table 2. Nature of Incidents- Numbers

NATURE	NUMBER OF CASES
Struck-by	123
Caught in between	45
Fall	27
Electrocution	2
Others	8

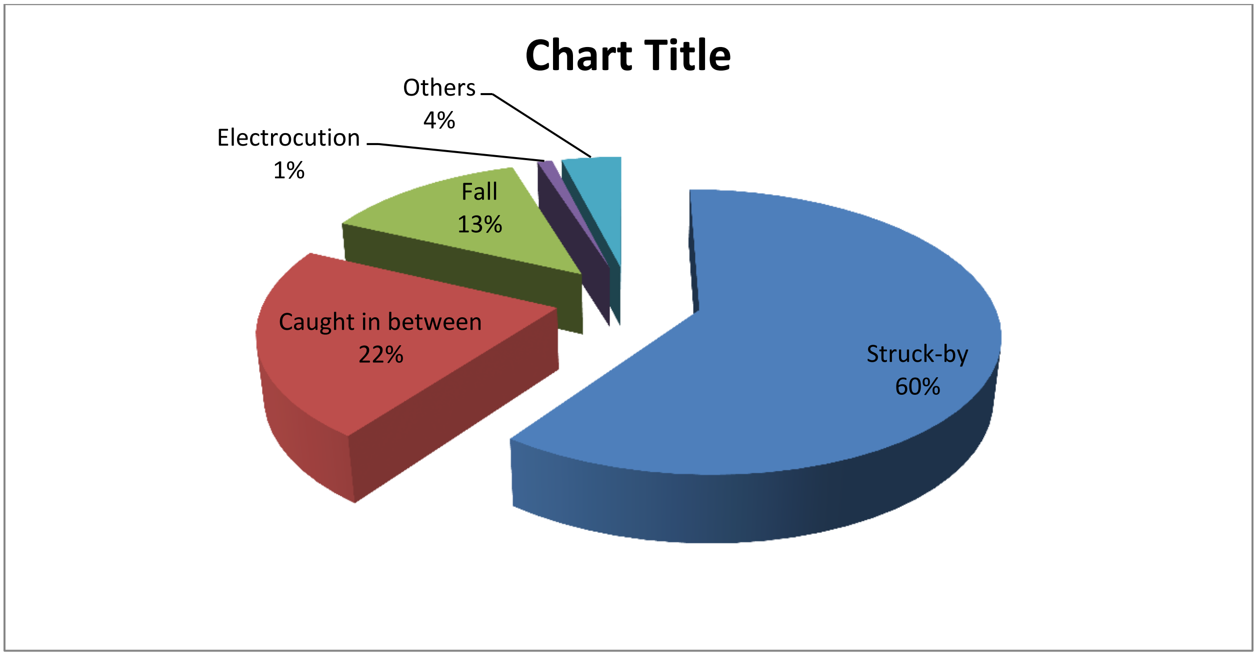

Figure 3. Nature of Incidents- Percentages

3.2.2. Identifying Root Causes

Although some reports identified specific and exact root causes, the root causes identified with many incident reports did not properly address why the incidents occurred. They were incriminating the workers and supervisors in many cases, stating that the root causes were due to "workers being careless" or due to "improper supervision," but there were not many remarks directed at the management, obviously not wanting to blame the company's own system. A very common pattern in the root-causes section seemed to blame the supervisors. For example, if the root cause of an incident was identified as poor supervision, it does not tell what the supervisor should have looked for or what the supervisor should have done. Supervision, perhaps, is the root cause sometimes, but an incident investigation should be able to identify what cause have been eliminated by the supervisor. A section for writing the direct causes should have taken care of this, but it did not. Other recurring statements were "lack of alertness" or "carelessness of the worker." As an inherently risky job, construction cannot be expected to become safer by making the workers more careful. They need to be careful, and that part is supposed to be taken care of by regular pep talks and induction trainings. When an incident happens, the causes are generally much more than the victims' "lack of alertness." The point of investigating incidents is to address the causes.

This kind of investigation left fewer opportunities to find the actual problems in the management system that need attention, let alone making proactive decisions. Hence, it was decided to use the incident description and to arrive at the root causes, not for the incident that happened but, rather, for the unsafe conditions or unsafe acts that existed at the time of the incident. The descriptions are assumed to be accurate, and only one dominant root cause was noted in each case. For example, one case was a lost-time injury involving a worker who fractured his leg. The description of the incident as given in the report was as follows;

One structural beam was lifted inside the pipe rack using chain pulley block. After lifting it was not matching and required to be trimmed. Hence, the beam was lowered and was kept on just one wooden runner near the center. Further packing was being arranged by the co-workmen. In the meantime, the victim sat on the beam. (Horseplay) Due to this the beam toppled and trapped victim's leg resulting in the injury.

This case listed "horseplay" as the direct cause of the incident. The root cause was the supervisor not bothering to caution the worker, as mentioned in the report. If the unsafe condition in this case is considered, the beam was placed on just one wooden runner. It was an unsafe condition that could have caused an incident even if the worker was not involved in any horseplay. Anybody could have been affected if he/she was in the vicinity of a beam on an unstable support. Hence, the actual root cause of this incident was noted as "insufficient support." Another case description is given below.

A group of workmen were unloading plywood received from supplier at main store. The plywood was stacked in the truck as shown in the figure. The workmen first removed the central horizontally stacked plywoods, leaving the side stacks leaning on the truck body unstable. When the victim was removing plywood from the side stack, 22 plywoods (each weighing 37 kg, total load around 800 kg.) fell on the victim, trapping his body below hip, resulting in the injury.

Figure 4. Unloading Stacks of Plywood from the Truck- Example Case

In this case report, the identified root cause was the lack of effective supervision. Just because the supervisor is there doing effective supervision, it cannot be assured that incidents will not happen. Either a safe method of stacking should have been stated or a safe method for unloading should have been stated. Hence, for this case, the actual root cause was noted as “improper method,” based on the incident description. In fact, improper method was one of the broadest categories. It was assigned as the actual root cause whenever an object was unsecured at height, whenever a makeshift arrangement was used, whenever slopes of excavations were not maintained, etc. although the reports sometimes did not state so.

In another case of a fatality, the victim had fallen through an opening on a high floor. The opening was uncovered because the gratings used to cover it were not tacked, so they had moved because of repeated walking. Although the reason for the grating's movement from its initial position was given as "victim taking shortcut," had the gratings been tacked, the unfortunate incident would not have happened. For this case, "improper walkway" was assigned as the actual root cause. When assigning root causes based on the incident narratives, it was not aimed at taking the blame off the workers. For example, in one case, a worker took a shortcut between two excavated pits instead of taking a wider pathway. In this case, the excavations were to be located there; there were warning signs, and the path between them was too narrow to be barricaded while the two excavations together had been hard barricaded. Hence, the root cause was mentioned as "human error." Similarly, all the case descriptions were studied, and based on the description; the "right" root causes were reached. The Appendix gives some examples about how different root causes were assigned while the reports had a different set of root causes.

3.2.3. Classifying Root Causes

As explained in the previous section, the root causes for each incident were reached through a careful study of the incident-investigation reports. The cause names were chosen to create broad categories to mix incidents together for the ease of making conclusions and identifying problems. The following causes were identified based on studying the reports and were tabulated against the number of cases for each type of incident: dangerous occurrence (DO), fatality, lost-time injury (LTI), minor incident (MI), and near miss.

Table 3. Classification of the Assigned Root Causes

Root Causes	DO	Fatal	LTI	MI	Near Miss	Grand Total
Improper equipment			1	2	2	4
Improper housekeeping			3	5	4	12
Improper maintenance	2				2	4
Improper signaling		1			1	2
Fatigue			1	1	1	3
Human error	2		9	2		13
Ignorance			2			2
Ignorance of use of PPE		1	1	42		44
Improper method			29	24	6	59
Improper planning	1					1
Improper stacking			8			8
Improper walkway		1	5			6
Incompetence		2	1			3
Inexperience					1	1
Inflammable material unsecured	1					1
Inspection/Precaution	1	1	4	1	2	9
Insufficient support		1	4			5
Lack of coordination			7	4		11
Lack of skill	2			1		3
Material component failure	3			1		4
No method to arrest the Molten metal					2	2
No proper traffic control			1			1
No signaling			1			1
Poor judgment				1		1
Rash driving			1			1
Space congestion			1			1
Work permit system not followed					3	3
Grand Total	12	7	79	84	23	205

Each of the root causes were then further grouped into men-related causes, machine-related causes, Material-related causes, or Method-related causes. This grouping is shown in the form of a fishbone diagram (Figure 5).

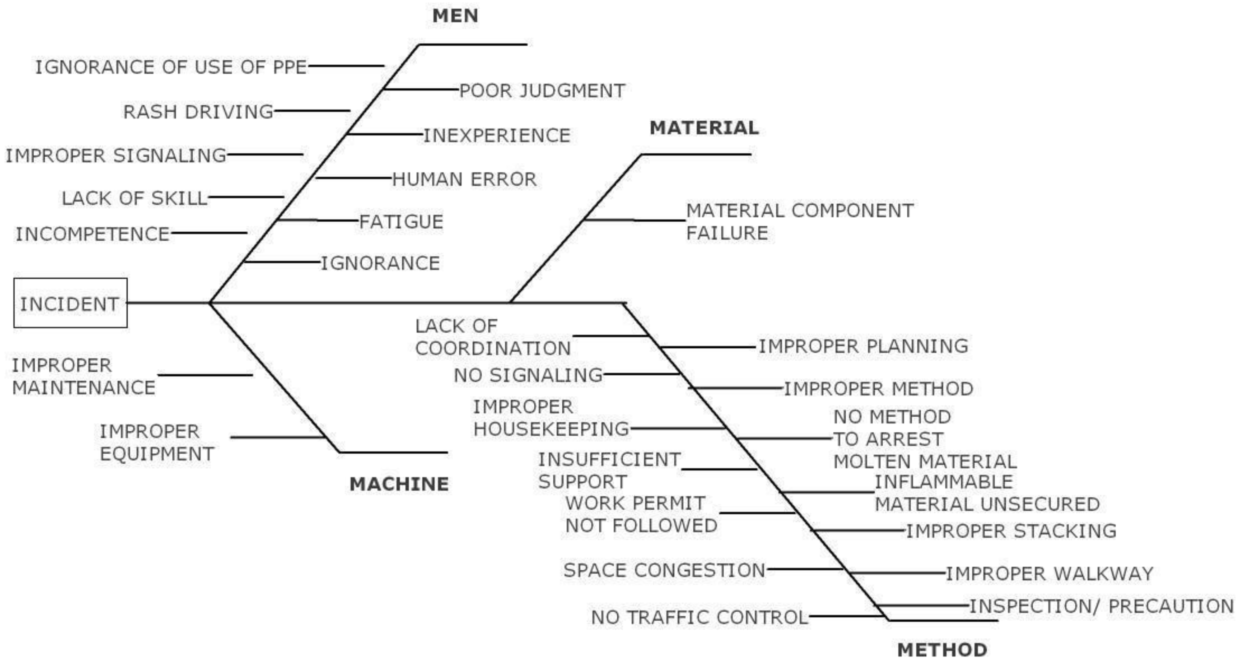

Figure 5. Fishbone Diagram Showing Different Categories of Root Causes

Table 4. Causal Factors- Numbers

Type of cause	DO	Fatal	LTI	MI	Near Miss	Grand Total
Machine	2		1	2	3	8
Material	3			1		4
Men	4	4	15	47	3	73
Method	3	3	63	34	17	120
Grand Total	12	7	79	84	23	205

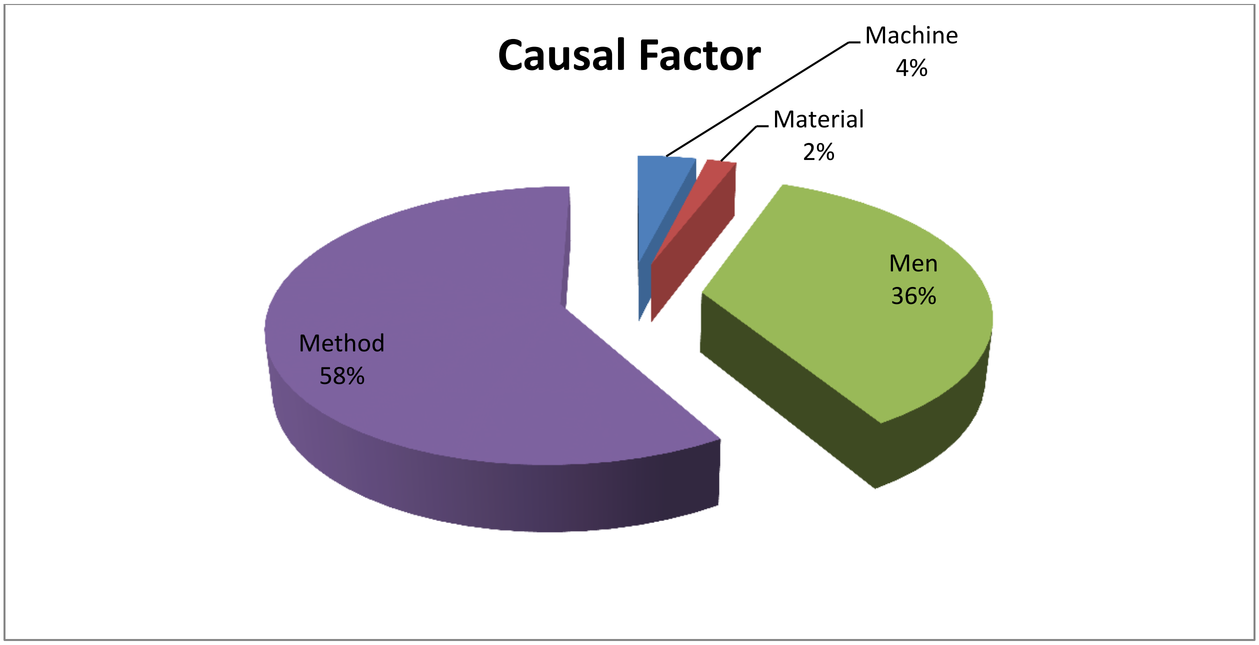

Figure 6. Causal Factors- Percentages

As seen from Table 4, the method-related root causes were greater in number; 120 of the 205 reviewed reports (about 58%) had a root cause which was related to the work method. Figure 3-5 shows the distribution of the causal factors in percentages.

3.2.4. Additional Data Collection

An additional set of incident data was collected to see if the same pattern of root causes continued to exist at the sites, by taking reports which were newer. Twenty-one incident reports, 3 fatalities and 18 lost-time injuries, were obtained, and a similar root cause analysis was done for all the reports. It was found that only 2 of the 21 cases had men-related root causes while the 19 remaining incidents had method-related causes. This shows that method-related causes are a serious threat to safety at the sites where this research was done.

3.3. Method-Statement Model

The possible causes for improper methods causing incidents were brainstormed by talking to experts in the field. The reason behind this is lack of or the poor design for the method statements, or their poor enforcement. A model was developed as shown in Figure 7. The model is explained in the subsequent paragraphs.

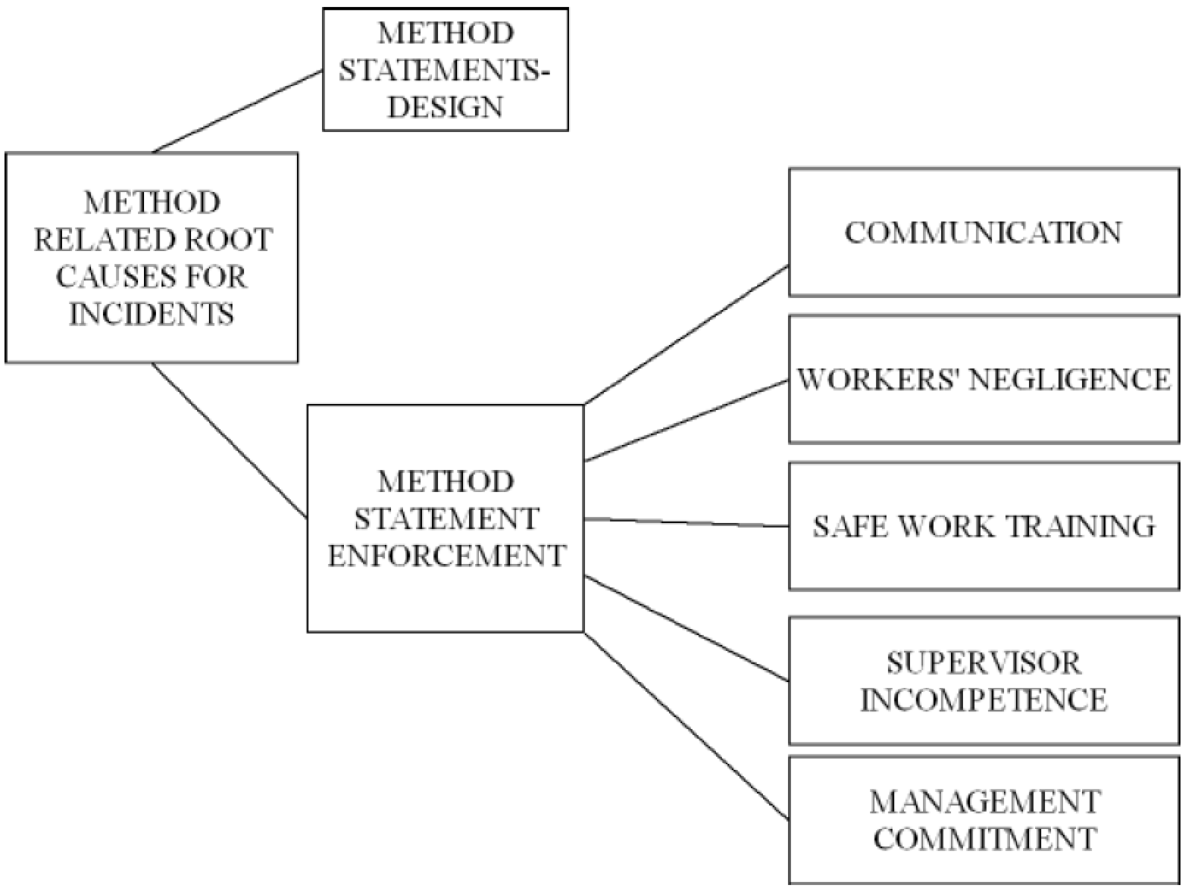

Figure 7. Method-Statement Model

3.3.1. Poor Design of the Method Statements

Method statements are documents that explain how an activity should be done, with what resources, and with what competencies. Poor design for the method statements is assumed as the problem base of improper methods being followed. At construction sites, method statements are generally made for a few critical activities only. Sometimes, a trade as dynamic as construction requires more, and a few method statements will be inadequate to execute a task safely. A good system should cover all the activities with higher priority for critical activities.

3.3.2. Poor Enforcement of the Method Statements

If the safe work methods are designed reasonably well, the only other way correct methods can get lost along the way would be a lack of or poor enforcement for the method statements. Poor enforcement could be explained by the following factors:

3.3.2.1. Management's Commitment

Management's commitment has a direct correlation with site safety as well as injury and illness rates (Abudayyeh et al. 2006). Method statements are nothing but a safety-management system that is implemented by the top management. Hence, the enforcement directly depends on the commitment of the managers.

3.3.2.2. Negligence of Rules and Procedures

Generally, the workers' repeated negligence of rules and procedures implies that the enforcement of using proper methods is low.

3.3.2.3. Work-Method Training

Appropriate safety education and training are one of the important factors that influence safety-program implementation (Aksorn and Hadikusumo 2008). To enforce safe work methods, training specific to the activity is required. Whether such a training system is present and, if so, whether it is adequate can only be understood from the workers' perceptions.

3.3.2.4. Communication

Communication is a significant predictor of safety behavior (Cigularov et al. 2010). There must be proper communication about the instructions and methods before and during the activity for the workers who do it. Thus communication is one of the main aspects of good enforcement.

3.3.2.5. Supervision

As seen from the incident-investigation reports, many incidents were attributed to a lack of or ineffective supervision. Since this is a serious problem.

3.4. Summary of Results

The analysis of incident-investigation reports showed that method-related root causes resulted in various injuries to workers, and this was confirmed by collecting more recent data from the sites. There is a need for a system which tells the workers what they should do. The method statement is one such system; this process is a step-by-step procedure for doing an activity. The supervisors’ duty is to ensure that these methods are followed. Unfortunately, method statements are neither well-designed nor properly enforced at all sites, in general, which is the main cause for most incidents. Therefore, it was inferred from the data analysis that method-related causes are most prevalent, and the focus area is the design and enforcement of method statements.

4. SOFTWARE APPLICATION FOR METHOD STATEMENTS

4.1. A Software Concept

One important problem with documentation is the process itself being very laborious and time consuming. Writing method statements is no exception, so a software model was created to reduce the time it takes to type each document. It is a well-known fact that the macros in Microsoft Excel and Visual Basic program software is used to quicken repetitive tasks done with MS Office products. Therefore, I created an application called Quick Write on the Visual Basic platform. The application was integrated with Excel to create method statements. The software design structure is shown in Figure 8.

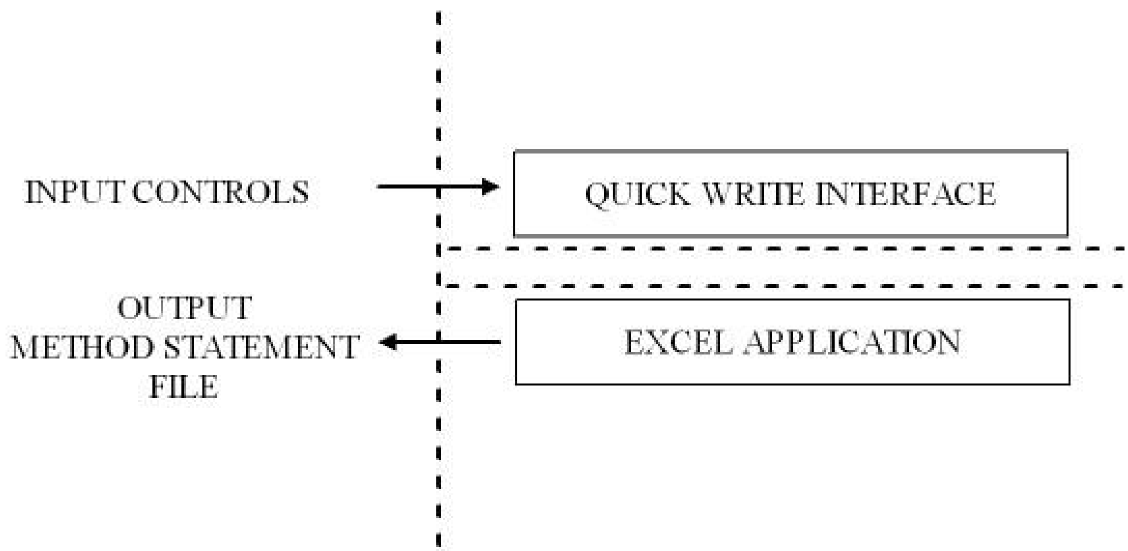

Figure 8. Quick Write Software Architecture

The intention of the software is not to intuitively write method statements but to facilitate writing the method statements with time-saving options. The interface consists of Visual Basic (VB) forms which take input, and the program behind the forms creates an Excel file based on the input data. The input is given by means of a textbox, a number of checked boxes, data grid view, and buttons. Most commands are given by clicking the mouse, and this process saves lot of time that could be wasted typing data in a Word file. The checked boxes are also lists from which the user can pick the items, so they avoid missing any of the requirements. Provisions are made in the software to add new requirements that are not listed in any of the checkboxes. There are also options to add files. A template file has already been created with all the necessary formatting. The software accesses this template to create a new method-statement file; the need for formatting is minimized, and more time is saved.

The following pages show a step-by-step demonstration to use the software for writing a method statement for the “Material Lifting by Chain Pulley” activity.

1. Main interface (Figure 9) pops up when opening the application. It has a textbox to type the name of the activity, a button to open a new form to select requirements, a button to add the scheme drawing, a button to add the material-safety data, a numeric box to select the number of persons who will be doing the activity, a button to select the personnel requirements, and two buttons to either approve or cancel the process. The operations can only be done in tandem, and alerts are prompted if tried to do otherwise.

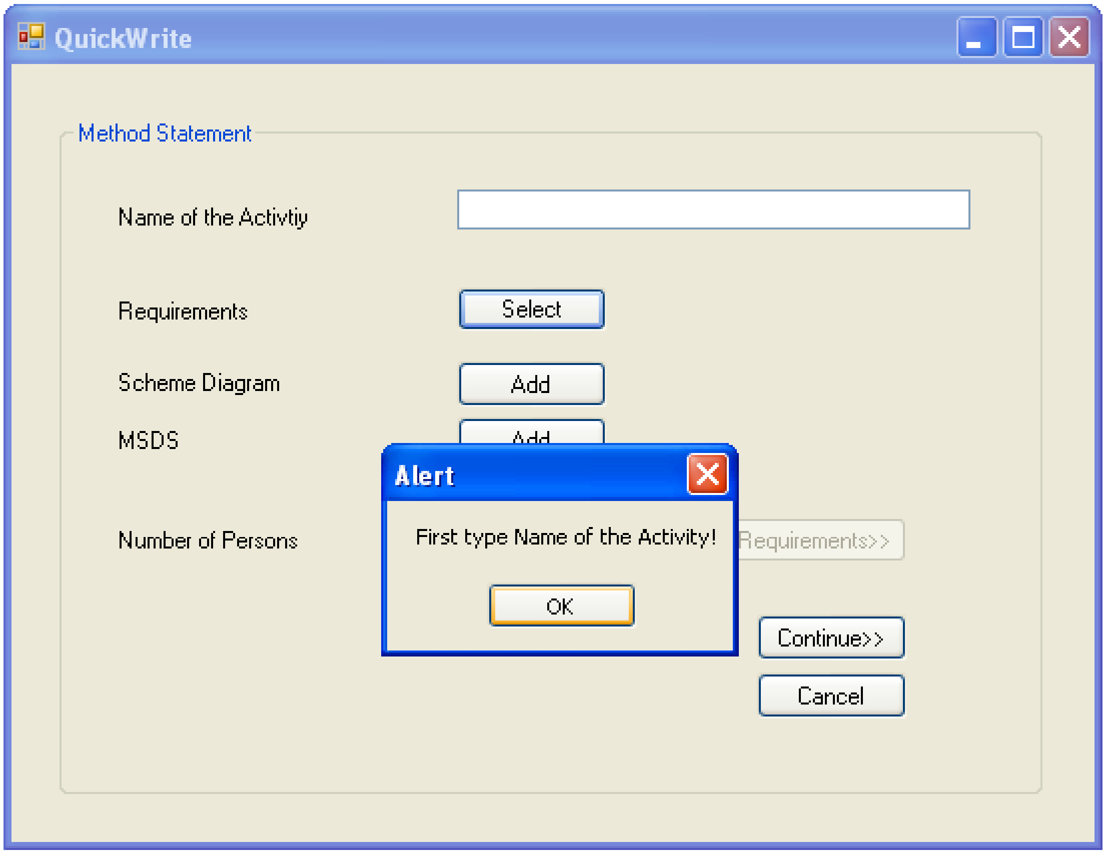

Figure 9. Main Interface

2. Name of the activity is entered in the provided box, and the "Requirements Select" button is clicked. This step will open a new form (Figure 10) with six checklist boxes, one for each of the following:

- Equipment and tools
- Certifications and authorizations
- Legislations and codes
- Precaution measures
- Contingency measures
- PPE

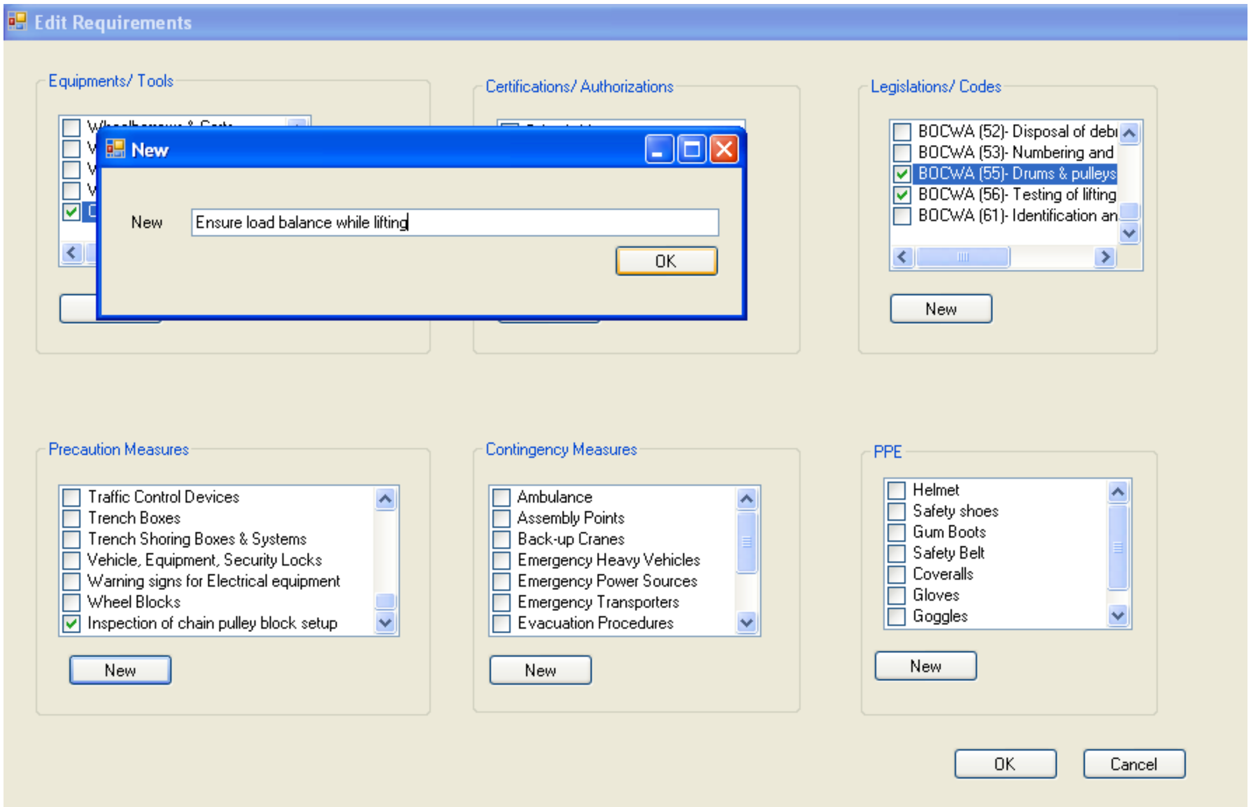

Figure 10. Form to Edit Requirements

3. At least one item in each checklist should be checked in order to proceed. Otherwise, a prompt alerts the user to select something. If an item is not available in the provided checklist, the item can be added by clicking on the "New" button provided under the respective box. After selecting all the necessary requirements, the "OK" button is clicked to close the form and to go back to the main interface (Figure 11).

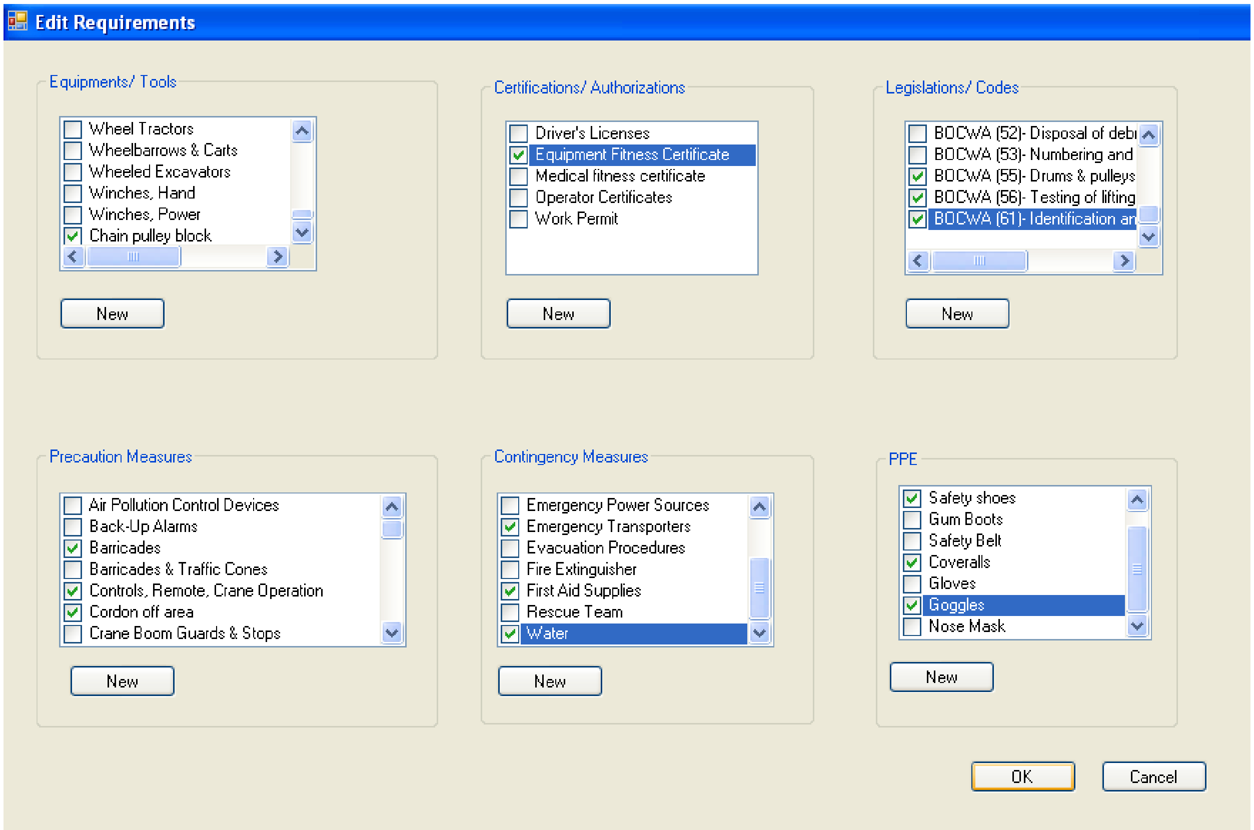

Figure 11. Accepting Requirements

4. The next step is adding the file that shows the scheme drawings and other instructions. Generally, a scheme drawing is required to be prepared for the activity; the drawing shows the access provisions, walkways, emergency escape, etc. By clicking the “Add” file next to Scheme, a file browser dialog opens, and the user can select the particular file (Figure 12).

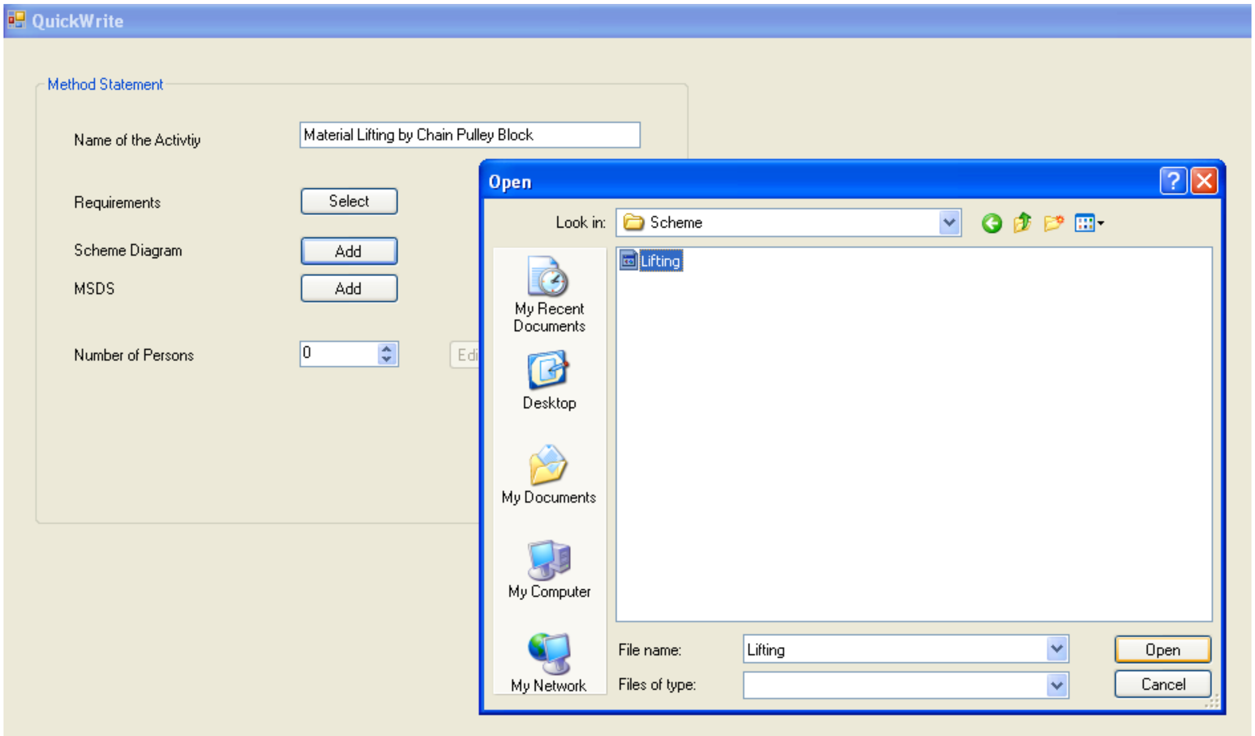

Figure 12. Adding Files

5. The same procedure is repeated to add the material-safety data file which contains details related to material handling and storage. Then, the number of persons who will be doing the activity is selected by scrolling the numeric textbox. If the number is 1 or greater, the "Edit Requirements" button is activated (Figure 13).

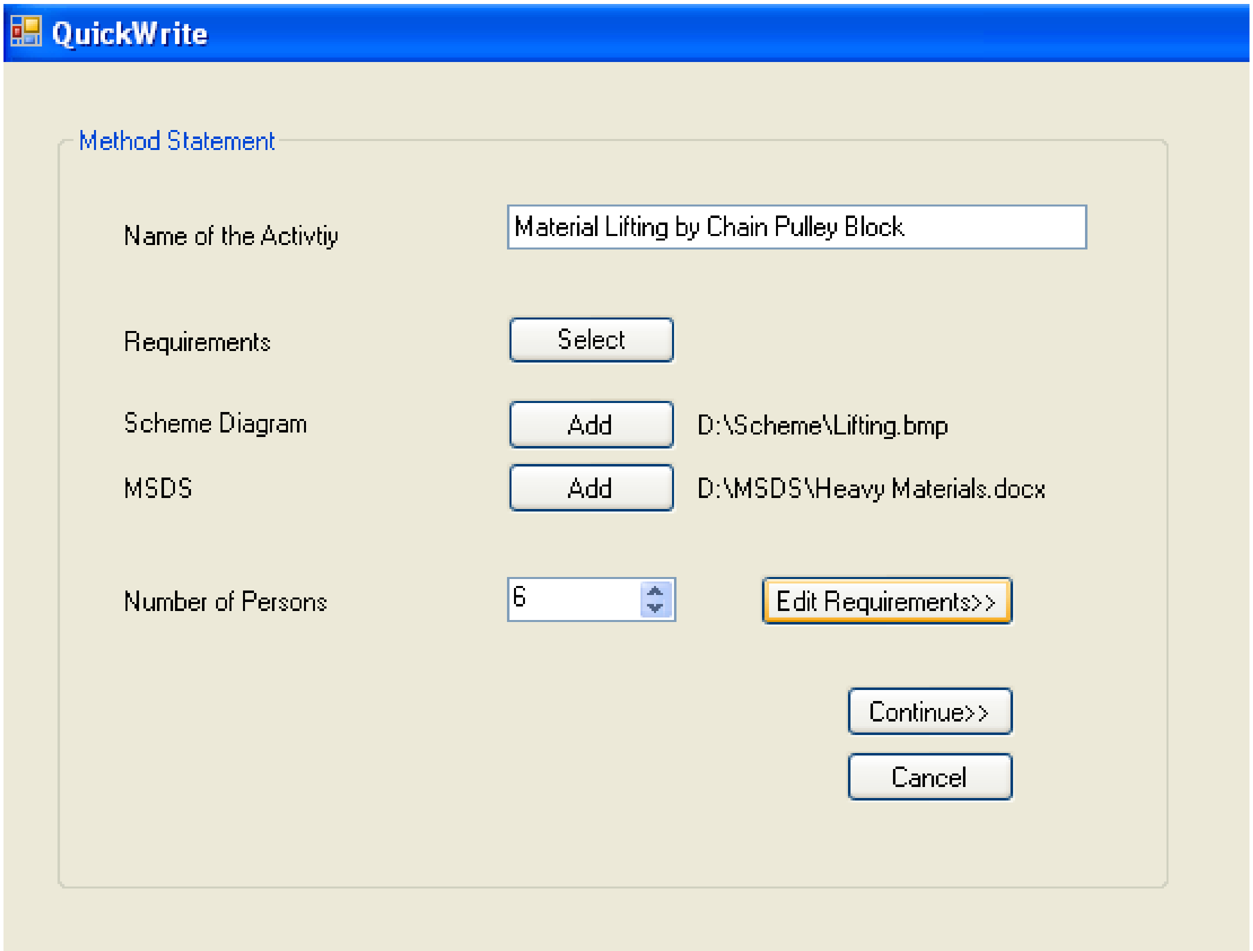

Figure 13. Editing Personnel Requirements

6. After clicking the “Edit Requirements” button, the form where the user can edit the name, qualifications, and training requirements for each person opens (Figure 14). This form has a data grid with four columns. The first column has the serial numbers, and names can be entered in the second column. Names can also be left blank to be completed later before the start of the activity. The “Qualification” column has a combo box containing different designations.

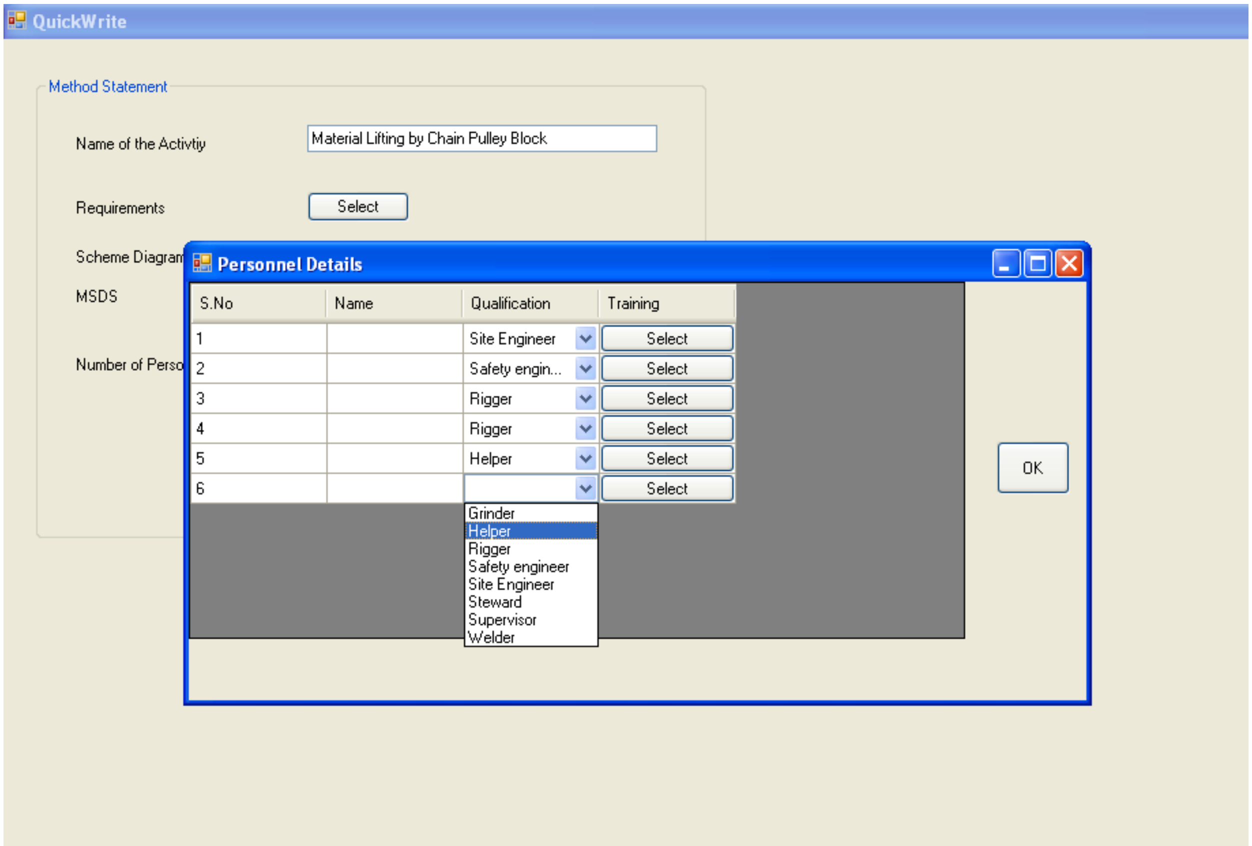

Figure 14. Entering Details

7. Each person's training requirements are added by clicking the button in the last cell of the corresponding row. This button opens another form (Figure 15) with a checklist box containing different training requirements. As before, a "New" button is provided to add any requirement that is not given. After clicking OK on Training Requirements and Personnel Details forms, the "Continue" button is clicked on the main interface (Figure 16).

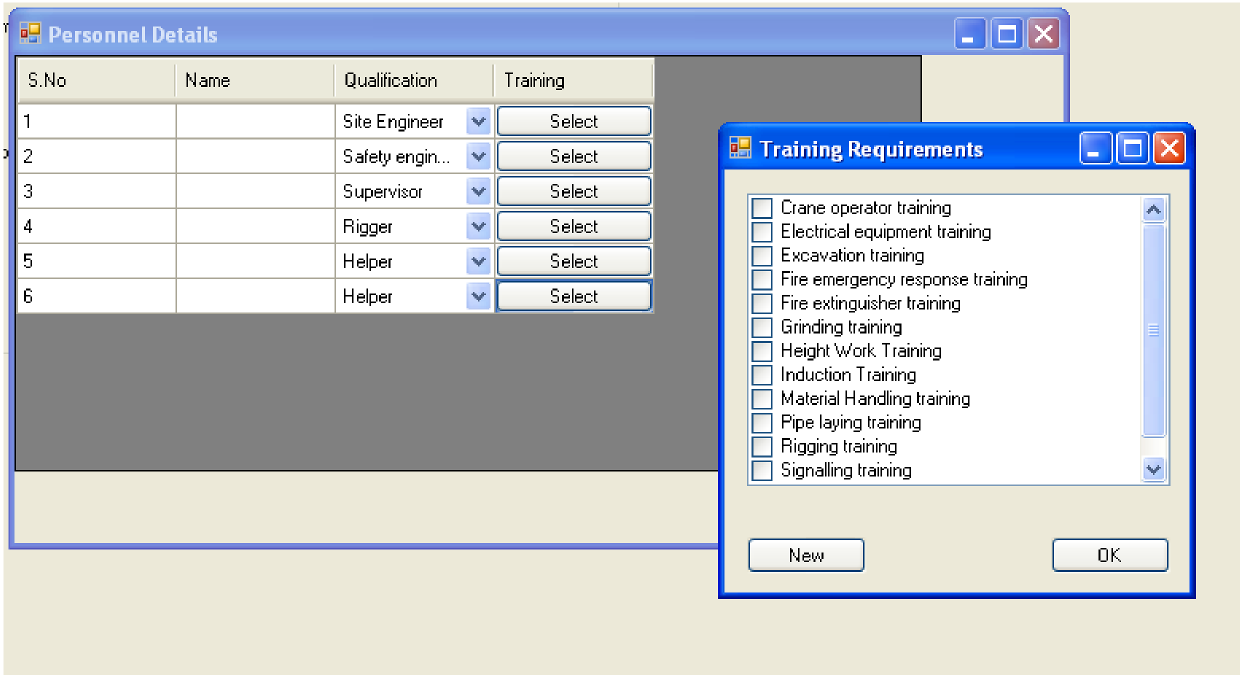

Figure 15. Editing the Training Requirements

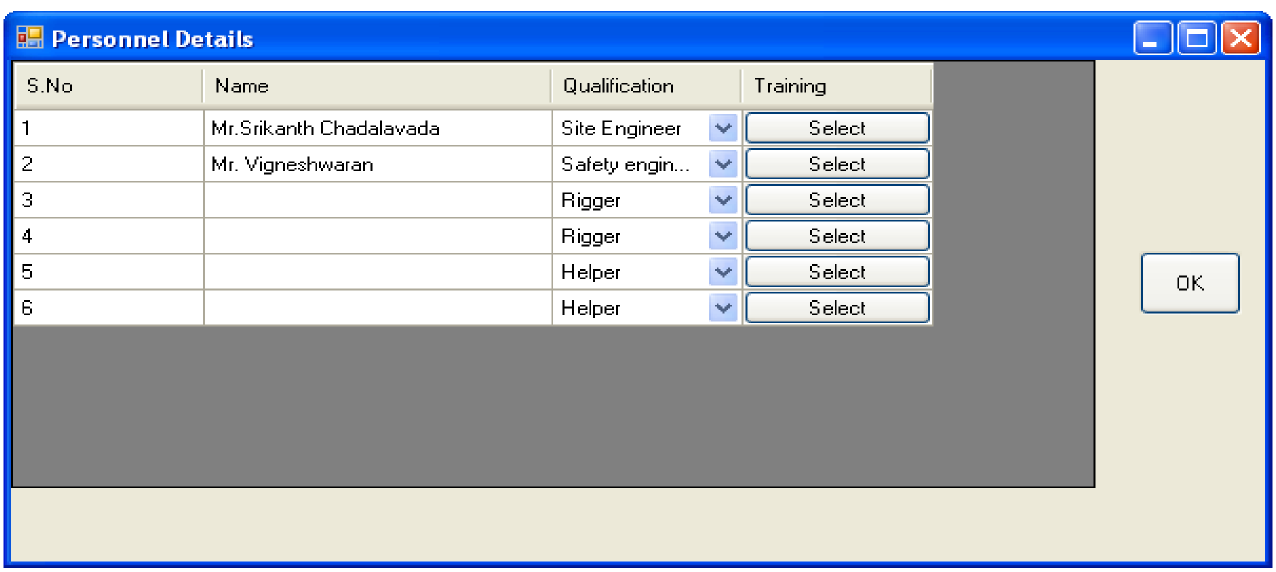

Figure 16. Finishing the Editing

8. The application interface is closed automatically and a new file is created in the “C:” drive; the file automatically opens when clicking the “Continue” button. The Excel file is generated from a macro-enabled template located in the system (Figure 17). Hence, the formatting and all other time-consuming jobs are eliminated. All the details entered in the application appear in the Excel file under their respective headings. The files that were added under Scheme and MSDS also appear as hyperlinks. In order to open these files, the file names should be clicked.

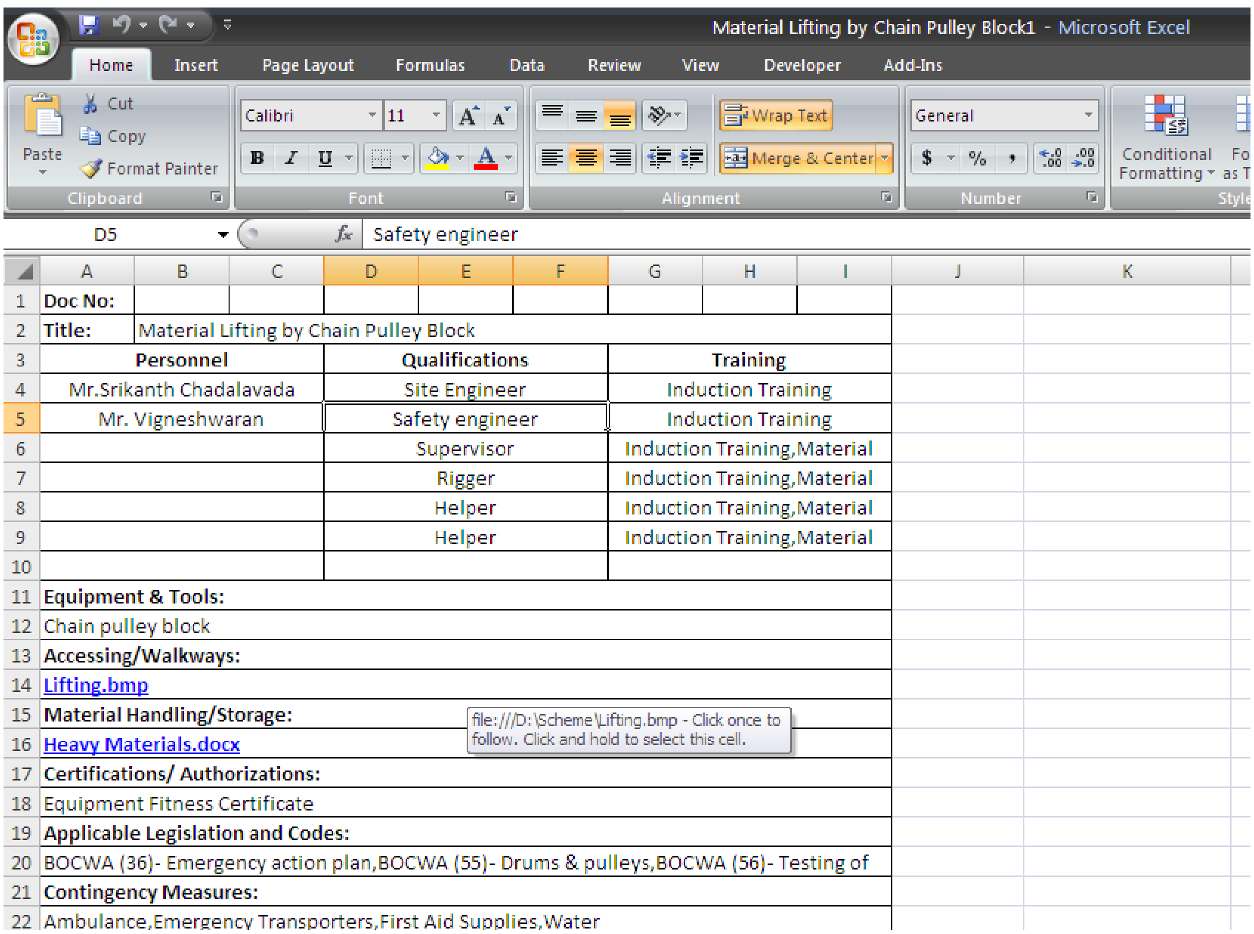

Figure 17. Excel Window Opened for Editing

9. Then, the document number, execution procedure, and the clean-up or restoration procedures can be filled up manually. After writing each point under the execution procedure and contingency procedures, with the row in which the point is written still selected, the green button shown near the headings can be clicked to insert a new row to write the next point. This macro feature was created to save time when inserting new rows, drawing borders, and merging cells. Because it is a macro feature, the "undo" (Ctrl+Z) option does not undo the row created by pressing the green button. Hence, a red button is provided to delete a row which was created accidentally (Figure 18).

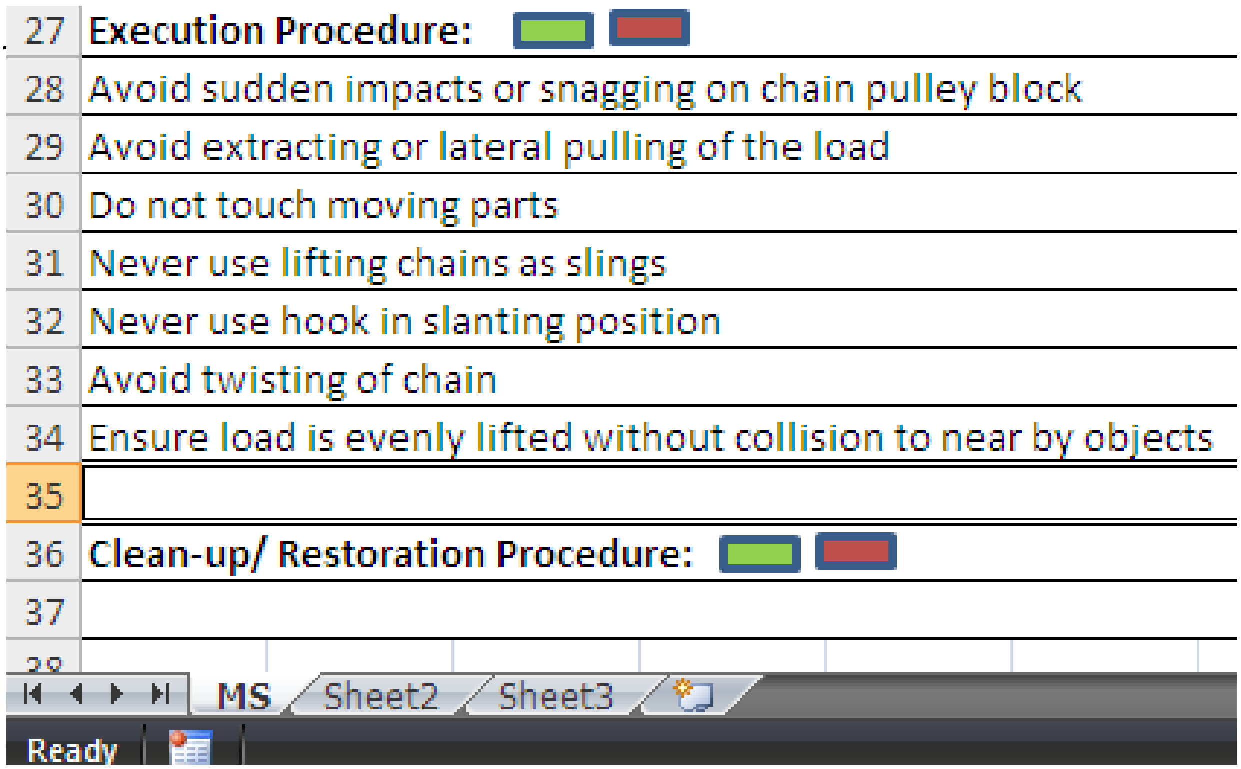

Figure 18. Entering Execution Procedure

10. After all the points in the procedures are written, the added Scheme drawing and MSDS files are opened. All the files are printed one by one and filed together, along with the risk-assessment documents. The final, printable document is shown in Figure 19.

Doc No:	MS 006	
Title:	Material Lifting by Chain Pulley Block	
Personnel	**Qualifications**	**Training**
Mr.Srikanth Chadalavada	Site Engineer	Induction Training
Mr. Vigneshwaran	Safety engineer	Induction Training
	Supervisor	Induction Training,Material Handling training
	Rigger	Induction Training,Material Handling training,Rigging training,Signalling training
	Helper	Induction Training,Material Handling training,Signalling training
	Helper	Induction Training,Material Handling training,Signalling training
Equipment & Tools:		
Chain Pulley Block		
Accessing/Walkways:		
Lifting.bmp		
Material Handling/Storage:		
Heavy Materials.docx		
Certifications/ Authorizations:		
Equipment Fitness Certificate,Operator Certificates		
Applicable Legislation and Codes:		
BOCWA (36)- Emergency action plan,BOCWA (41)- Overhead protection,BOCWA (55)- Drums & pulleys,BOCWA (56)- Testing of lifting appliances,BOCWA (61)- Identification and marking of safe lifting loads		
Contingency Measures:		
Ambulance,Emergency Transporters,First Aid Supplies,Water		
Precaution Measures:		
Barricades,Controls, Remote, Crane Operation,Cordon off area,Inspection of the working		
PPE:		
Helmet,Safety shoes,Coveralls,Goggles		
Execution Procedure:		
Avoid sudden Impact or snagging on chain pulley block		
Avoid extracting or lateral pulling of the load		
Do not touch moving parts		
Never use lifting chains as slings		

Figure 19. Final Method Statement

Thus, a safe work method for an activity is created in a fraction of the time. Most items are lists, hence the need for writing long, complex sentences and the difficulty of comprehending it are eliminated.

4.2. Limitations

This software is not without limitations. First, the tool requires that risk assessment is done separately from making the method statements. The hazard identification and risk assessment need to be done manually by the user because an interface is not provided This software does not perform the task of writing method statements intuitively. It only facilitates the process to save time. The checklists provided in the software tend to be too long and it will be confusing and annoying to pick from the lists. The applicability of this software for all activities is not certain. The additions made to the checklists if an item is not available do not remain, and they disappear once the application is closed. New items need to be added programmatically to keep them in the checkboxes.

4.3. Scope for Improvement

This software concept will be a very useful tool which will change the way method statements are perceived. With further software improvements, the quality of method statements can be improved greatly.

First, integrating hazard-identification and risk-assessment processes with the software using a similar interface will add benefits.

Second, this software could be developed in a higher programming-language platform to make it more user-friendly. In such a case, MS Excel will not necessarily be required for typing method statements and fewer clicks will be required to directly print the added reference files.

The currently provided checklists are of limited scope. The next versions need to have the ability to load the checklists from a database. This database can be created and maintained at the organization's central office and can be accessible to employees with varying degrees of permission levels, depending on the designations. Also, a keyword search bar could be used to avoid the unnecessary process of scrolling through long checklists. Integrating this software with a server will make it accessible from anywhere through the Internet. A web-based form, such as a PHP application, can be used so that a copy can be generated from anywhere while the database is still updated.

5. CONCLUSIONS

5.1. Conclusion

- Method-related causes existed more at the construction site, and they were the cause for a higher proportion of the incidents.
- The enforcement of methods is low because method trainings are not provided on a regular basis. Communicating the methods and the competence of the subcontractor's supervisors needs to be improved.
- Negligence of rules and procedures by the workers must be curbed.
- A part of the problem that needs to be addressed, improving the work methods followed at construction sites, involved giving guidelines and having a different approach for method statements.
- Proper designs for method statements and the subsequent enforcement will not only help avoid incidents by improving work methods, but will also improve job planning. The implication of this is that frequent work stoppages by safety authorities at construction sites for violating safety rules can be avoided by better planning and guidance offered by safe work-method statements.
- The developed VB software can be used to write method statements that account for all the requirements of the proposed model which, in turn, can be used to improve the work methods followed at site. This will help to avoid incidents which arise from non-inherent causes.

5.2. Limitations of the Research

- The collected data came from refinery and thermal power-plant construction projects, hence the findings may only apply to these kinds of projects.

- There may be other factors, such as geographical, socio-economic, or cultural factors, which could be attributed to method-related incidents. However, these factors were not explored in this research.
- The solution concept only focused on improving the design of method statements and did not address the issue of poor enforcement.
- As already known, the construction industry is dynamic. The popular belief is that using software for safety plans is dangerous because it might lead to missing some of the risks or precautionary measures that should be taken. This is the fundamental reason that this software is made so that it does not, say, identify the precautions or applicable codes automatically, but it is the user who has to pick or add what is required.

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APPENDIX: IRB CERTIFICATION

NDSU **NORTH DAKOTA STATE UNIVERSITY**

Institutional Review Board

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Fax 701.231.8098

Federalwide Assurance #FWA00002439
Expires April 24, 2011

Friday, April 05, 2013

FederalWide Assurance FWA00002439

Eric Asa
Construction Management & Engineering

Re: IRB Certification of Exempt Human Subjects Research:
Protocol #**EN13219**, **"Identification of the Root Causes of Methods-Related Constructions Accidents in India"**

Co-investigator(s) and research team: **Venkata Siva Ganesh Chintalapudi**

Certification Date: 04/05/2013 Expiration Date: 04/04/2016
Study site(s): **Varied**
Funding: n/a

The above referenced human subjects research project has been certified as exempt (category # 2,4) in accordance with federal regulations (Code of Federal Regulations, Title 45, Part 46, *Protection of Human Subjects*). This determination is based on IRB materials (received April 2, 2013).

Please also note the following:

- If you wish to continue the research after the expiration, submit a request for recertification several weeks prior to the expiration.
- Conduct the study as described in the approved protocol. If you wish to make changes, obtain approval from the IRB prior to initiating, unless the changes are necessary to eliminate an immediate hazard to subjects.
- Notify the IRB promptly of any adverse events, complaints, or unanticipated problems involving risks to subjects or others related to this project.
- Report any significant new findings that may affect the risks and benefits to the participants and the IRB.
- Research records may be subject to a random or directed audit at any time to verify compliance with IRB standard operating procedures.

Thank you for your cooperation with NDSU IRB procedures. Best wishes for a successful study.
Sincerely,

Kristy Shirley

Kristy Shirley, CIP, Research Compliance Administrator