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IMPLEMENTATION OF SAFETY MANAGEMENT USING MACHINE LEARNING APPROACH

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Abstract: Construction projects are found to suffer various problems and complex factors such as cost, duration, quality safety, management etc. Construction industry has been growing remarkably during the past several years. However, the most hazardous worksites in the country may be found in this industry. Construction is a high hazard industry that usually comprises of a wide range of activities that may even involve construction, alteration, and repair too. Construction workers engage in many activities that would make them exposed to very serious hazards, such as falling from rooftops, unguarded machinery, being struck by heavy construction equipment, electrocutions, silica dust, asbestos, fire, trench collapse etc. Each project shall have a safety management system in place that outlines the policies, processes, instruction, and documentation that will serve to establish the culture of safety and understanding for all tiers involved on the project. It is thus necessary to find out the type of hazards that are common on site so as to suggest ways to minimize the same. Nowadays like most other countries in the world automation and digitalization is introduced in construction sector too that make construction activity much more faster and safer. The scope of a fully digitalized construction sector is to be analysed so as to implement safety at job site.

Keywords; Safety Management, RII, Influence factors, Building Construction, SPSS, OSHA

I.INTRODUCTION

The construction industry is considered to have a very strategic role to play in development, particularly in the provision of infrastructure and other facilities and it is the infrastructure that support the overall growth and development of a country. Construction industry is considered as one of the most hazardous industries in the world. There has been an increase in the number of overall buildings that are built for commercial, residential, office and other purposes every year and due to the same reason the construction market continues to expand day by day as there is an increase in need of infrastructure facilities, homes, office spaces etc. The construction industry is very complex compared to other industries and hence it is prone to numerous health hazards too. Therefore safety is a very vital concern in the construction industry to result in a hazardous free and safe environment. Safety professionals have analyzed and studied that the major workplace accidents were initiated the unsafe behaviors and that their control is one of the key solutions to successful accident prevention resulting in low accident rate in construction sector. The number of fatal accidents in construction sites is not easy to quantify as there is lack of information on this issue which is not available for most countries. The main concern is completing projects with the required quality and speed with minimum time and cost. Carelessness has been considered as the major reason for accidents and hazards happening in construction job sites often resulting in impairment and death. With the change in timings and scheduling along with the change of men themselves combined with the nature of the construction jobs makes the construction industry as one with accident risks and unpredictable. Construction is one of the areas of employment where in hazardous conditions are part of the everyday working environment. The construction industry is prone to many hazards and accident which may happen if safety is ignored. Construction materials, tools, machinery and handling techniques all come with their own dangers and hence have to be handled with care. In construction, workers perform a great diversity of activities each of which has a specific associated risk. The worker who carries out a task is directly exposed to its associated risks, dangerous environment and passively exposed to risks produced by nearby co-workers too. Building design, materials, dimensions and site conditions are often unique, which require adaptation, that may even take time to settle down and a learning curve from site to site. Injuries can occur in numerous ways and at every juncture of the process. As a result, this situation has high frequency of accidents in construction, which makes it an unsafe industry to work. Degree of safety in this selected sector of the economy is not indicated by a single accident but by a set of accidents that have occurred within a specified interval of time. Knowledge about the noticeable trends in accidents is required in order to assess the level of safety and also directions for changes required for the same. Construction industry is a very unique industry and more susceptible than other industries. Each construction site involves many human resources and they execute different types of work related to each other. The workplace safety is an essential component of competence and productivity. Safety is the process of being protected against physical, social, spiritual, economic, political, emotional, occupational, psychological, consequences of failure, injuries, accident, damage or any other event which could be considered non-desirable,

fatal with a room for uncertainty. This can take the form of being confined from the event or from exposure to something that causes injury or death risk. Thus, the safety is not a perception to be thought of as added to the work itself instead safety is to be considered an integral part of the work to achieve a target of the organizations. It becomes necessary to consider certain safety measures and other programs to prevent accidents and injuries at job site and that helps to shaping employees believes and attitudes that lead to safe behavior, acts and ultimately to a strong safety culture. A poorly planned and untidy site is the underlying cause of many accidents which results from fall of materials and conflict between workers and plant or equipment and affects the safety and health of workers and also the cost and productivity too.

The advancement of construction industry especially in the field of safety by the introduction of unconventional and progressive methods that considers the upcoming future development is very vital. By the introduction of digital tools into construction sector, it not only reduces the health and safety hazards among workers but can also pave way to the economic growth of the industry. This study implements techniques of machine learning into construction safety sector hoping that in near future unlike all other developed countries our country would also suggest the possibility of introducing automation in industry. Automation would prevent the accidents and dealth and make the workplace a better and positive environment to work peacefully without the fear of hazards and risks. By carrying out this study we will be able to understand the risk factors involved in the construction projects. The comprehension of such factors would aid the management team to implement proactive measure for prevention or reduction of risk occurrences limiting accidents and deaths. The factors identified would aid to create a structural equation model that would provide the relation between various factors so as to identify how a particular safety factor influence the others.

This study is conducted to achieve the following objectives: 1) To identify fatal and non fatal hindrances to safety 2) To analyse the critical risk factors in construction site and to rank them using RII method 3) To classify the risk factors for structural equation modelling 4) To develop a suggestive model using machine learning algorithms 5) To test the accuracy and performance of these algorithms in prediction model. 6) To suggest proper preventive safety mechanisms in construction projects.

II. LITERATURE REVIEW

Cao, Houchen, and Yang Miang Goh. "Analyzing construction safety through time series methods." Frontiers of Engineering Management 6.2 (2019): 262-274 describes how temporal analysis techniques can be applied to improve the safety management of construction data. Various time series (TS) methods were adopted for identifying the leading indicators or predictors of construction accidents. The data set used herein was obtained from a large construction company that is based in Singapore and contains safety inspection scores, accident cases, and project-related data collected from 2008 to 2015. Five projects with complete and sufficient data for temporal analysis were selected from the data set. The filtered data set contained 23 potential leading indicators,predictors or input variables of accidents. TS analyses were used to identify suitable accident predictors for each of the five projects. Subsequently, the selected input variables were used to develop three different TS models for predicting accident occurrences, and the vector error correction model was found to be the best model. It had the lowest root mean squared error value for three of the five projects analyzed. This study provides insights into how construction companies can utilize TS data analysis to identify projects with high risk of accidents.

Deng, Langni, et al. "Research on safety management application of dangerous sources in engineering construction based on BIM technology." Advances in Civil Engineering 2019 (2019) aims to create a construction hazard source safety management module through secondary development of the Revit platform. At the same time, the Navisworks software is used to simulate the emergency rescue of construction safety accidents and formulate the corresponding emergency management plan. Finally, an engineering example is used to verify the performance of the development management module. The results show that the security management module created in this paper is highly operational, easy to use, and real-time data update, which has important guiding significance for actual construction safety management, simulation of construction safety accidents through Navisworks software can provide emergency management plans for engineering projects. Visual port management was carried out, and the emergency rescue simulation of the construction site emergencies was carried out with Navisworks software.

Keng, Tan Chin, and Nadeera Abdul Razak. "Case studies on the safety management at construction site." (2014) concluded that generally the construction site has good and structured safety practices namely safety policy, education and training, site safety inspection, safety auditing, safety meeting, site safety organization, personal protective equipments, emergency support and safety measuring devices, fall protective systems, and safety promotions. Nevertheless, several major problems are encountered in the safety practices; the problems are ignorance of workers on work procedures, lack of financial allocation for safety management, lack of awareness among workers, and language barrier between supervisors and workers. Several strategies have been suggested to overcome the problems, such as to provide effective safety training, allocation of budget for safety management, full commitment from the top management, and to provide safety booklets in various languages as the strategies to reduce problems in safety practices. The suggestions cover three aspects for the implementation of safety practices, i.e. awareness of workers, commitment of top management and the allocation of resources.

Yiu, Nicole SN, et al. "Implementation of safety management system for improving construction safety performance: a structural equation modelling approach." Buildings 9.4 (2019): 89. attempted to evaluate the effectiveness of SMS implementation based on the proxies to operational and safety performance. Also, the moderating factors to the association between quality and level of achievement of SMS and the performance proxies were identified. Results indicated the relationship between SMS implementation and positive project outcomes, based on the empirical data. Since the SMS implementation and operational/safety proxies are latent, a structural model was set out. Results indicated that the five motivation factors of SMS implementation could contribute to the improvement in the operational and safety performance, as revealed by six outcome attributes. This suggested that the existing SMS framework could be enhanced by incorporating a number of relevant incentives. Also, institutional cooperation among clients, engineers, and contractors would be essential, given the constraints of financial budget, and legal and contractual obligation.

Findings also implied the optimal resource allocation could be established for sustained improvement in operational and safety performance of the construction sector, given the abovementioned constraints.

III. METHODOLOGY

Safety is the outcome of several factors and these factors may be inter-related. Depending on the Literature Review, the study takes into consideration various factors affecting safety management in construction industry. Some similar factors were included and some new factors were added to it. The construction industry is increasingly challenging in order to successfully innovate so as to satisfy better aspirations and needs of society and clients, and improve competitiveness there by making it necessary to find out various factors affecting safety and to suggest recommendation on the most dominating factors. For any company in the building industry to remain competitive, it is necessary to improve the productivity which is only possible by fostering adequate safety at workplace. The method adopted to study on the implementation of safety in construction industries are illustrated with the help of a flow chart.

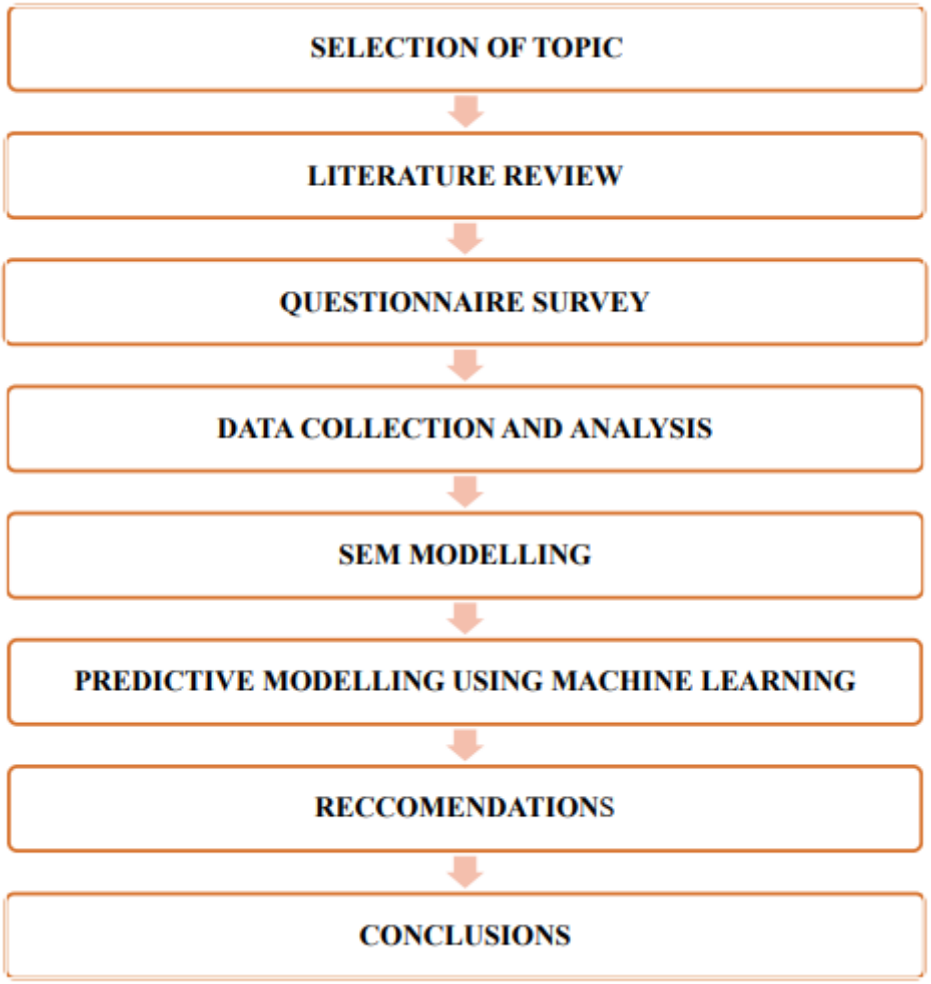


Fig.3.1 Schematic diagram showing methodology

SURVEY PLANNING

A survey can be defined as the process of collecting data from a group of people predefined inorder to gain information on various topics of interest. The people here can be termed as respondents. Questionnaire is often considered as the most common and a definite way of collecting datas in area selected. A questionnaire format would comparatively require less time duration and would also saves cost with the most discussed benefit that permits respondents to respond to the questionnaire at their personal ease. However, every coin has it's two sides. For this approach the major drawback is that the reply rate is usually lower as compared to face-to-face interviews. Data was collected from literature reviews from books, journals, articles, and websites which emphasize building construction's safety implementation. Factors affecting construction safety were identified from various literatures.

Questionnaire structure:- The initial segment comprises of general data like the respondent profile, their experience in the relative fields, gender, common types of accidents occurring on site, their level of understanding on safety management, if they wanted construction industry to be automated and digitalized etc. A set of yes or no questions were also asked regarding job safety management. The second part consist of various safety elements for assessment which were further classified to two main factors being, implementation factors for safety achievement and project performance and outcome factors. The questionnaire was later converted to google form for the ease of response and was then sent to people working in different field. Guidelines were provided to the respondents to ensure that the procedure was followed properly to reduce errors. During the period of survey it was ensured

that the process was going smoothly and consistently. The data were stored in order to maintain confidentiality, and the output received from google form was then extracted in spreadsheets.

Consideration for Survey:- The main consideration for the survey was that it should be easy for respondents. If questions are too complicated, then there is a possibility of not responding. Care was also taken so that the initial questions did not negatively influence the later questions. Preliminary text was introduced for explaining the survey project to the respondents. Logic-based questions were avoided as they may cause respondents frustration, impatient and increase the drop-out.

Questionnaire Distribution:- The target groups in this study were professionals from the construction sectors. They included site engineers, project engineers, main contractors, sub contractors, site supervisors and consultants too. A total of 230 questionnaires were sent via google forms to respondents in the various field working in different areas across Kerala. The responses were to be based on the understanding, knowledge and experience of the respondents alone and not related to any kind of project work. Respondents were further informed about the confidentiality of their responses.

Safety Rating:- A Likert scale of 1-5 was utilised in this questionnaire to rate the safety parameter, showing their agreement. A Likert scale can be defined as a type of psychometric response scale often used in questionnaires, and it is considered as the most widely used and accepted scale in any survey research. When responding to a Likert questionnaire item, respondents specify their level of agreement to each statement. The scale is named after Rensis Likert, who published a report describing the use (Likert 1932). The American social psychologist Rensis Likert saw a need to be able to measure peoples' attitudes towards different issues. In 1932 as part of his Ph.D., he developed a way to identify a person's perceptions and their opinions and the factors that influence them. His research led him to develop a method of determining attitudes by presenting a statement and asking respondents to choose from a continuum of options to indicate the degree to which they agree to. The major advantage of using Likert scale is that is very easy and convenient to understand. The respondents have multiple choices without becoming overwhelmed. The five point likert scale is shown in Table3.1.

Table.3.1 Likert scale index

LIKERT SCALE INDEX	LEVEL OF SAFETY RATING
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly Agree

DATA COLLECTION

In successful achievement of the main objective of the study, one of the most important stage is collection of accurate and most relevant data. Data collection is the procedure of collecting important data records for the required sample of observations. To improve the questionnaire accuracy a pilot study was conducted. This phase of study contained identification of different causes, collection, and conclusions of the data. Pilot study section benefited in better formation of the questionnaires. This has helped embrace the more broad and expansive meaning of safety implementation in construction industry and also helped identify even more safety components from other literatures. Information obtained and recommendations provided from pilot study were very useful in identifying various factors affecting construction safety. A total of 230 questionnaires were sent to construction professional through mail, phones, social media platform etc in early January 2022. By the due date of early April 2022, a total of 216 questionnaires were received, resulting in a nearly 93.91% reply rate (Table 3.2). Missing data frequently occur after the respondent chooses not to respond to a question or when the respondent rejects to answer the question but here since every questions were marked mandatory there was merely no missing data.

Table.3.2 Statistical Data of Questionnaire sent and received

Total questionnaire sent	**230**
Total questionnaire received	**216**

ANALYSIS METHOD

Four different methods were used to analysing and modelling:
1) Statistical Descriptive Frequency Analysis using SPSS software
2) Calculating the Relative Importance Index (RII), and ranking the factors according to their significance
3) Carrying out a Structural Equation Modelling to find out various relations between different factors using Amos Software
4) Providing a suggestive PPE detection model that would detect both helmet and vest using Machine learning approach

A questionnaire survey was conducted to identify the major factors which will impact the jobsite safety management. The collected data were analysed using SPSS software which is capable of handling large amounts of data and can perform all of the analyses out of which frequency was analysed. Then the various factors are ranked using RII methods to reach at a conclusion regarding most affecting and least affecting factors to construction safety. Furthermore these factors were then utilized for carrying out a structural equation modelling.

SEM MODELLING

The factors identified were categorised into following factors: 1) Implementation factors for SM Achievement 2) Project performance and outcome factors A relationship is to be established between both these factors and therefore a structural equation model is to be formed. It is one of the multivariate statistical analysis techniques. It analyse the structural relationship between measured variables and latent variables. The modelling can be carried out using IBM SPSS AMOS. Two CFA models were created initially which is the measurement model and then these measurement models were combined to get a structural model that relates between the two factor mentioned above ie implementation factors for safety achievement and project performance and safety outcome factors. It is possible to know how certain factors influence the other and also whether the factors are related to one another. IBM SPSS Amos is one of the powerful structural equation modeling (SEM) software helping support the research and theories by extending standard multivariate analysis methods, including regression, factor analysis, correlation and analysis of variance too. With the help of Amos software it is possible to build attitudinal and behavioral models reflecting complex relationships more accurately than with standard multivariate statistics techniques using either an intuitive graphical or programmatic user interface. Amos is included in the Premium edition of SPSS Statistics and is a very helpful package available to model social and economic data in data science.

PREDICTIVE MODELLING USING MACHINE LEARNING APPROACH

Even though machine learning in construction feels like a faraway concept, still it is not decades away from becoming a reality, the future of the technology is closer than we actually think. In fact, machine learning has been steadily gaining buzz in the building industry these days. While it may seem like a highly technical non-human approach, but it can actually make things more human in construction sector by means of certain models that help foster safety in workplace making work effective and improving the productivity. Instead of taking humans out of the equation, machine learning lets people do their real jobs more effectively. Accidents are very common to construction industry. Questionnaire survey conducted help identify common types of accidents to sites and hence by means of machine learning techniques a model would further be created to reduce accidents and injuries. A PPE detection model is one such. The model is further created by image processing techniques. A vision-based approaches use cameras to record images or videos of the job site, which are then analyzed to verify the PPE compliances. This approach provides richer information about the scene that can be utilized to understand complex construction sites more promptly, precisely and comprehensively and the method is widely used in many developed countries. A number of object detection algorithms are available such as YOLO, CNN, Har Cascade etc and here YOLO V3 is used for modelling. In the mere future there are chances that construction industry unlike any other industry would be automated. The larger site works can be carried out under the surveillance cameras and this would help to save time and also facilitate the managers or site in charge to supervise the work more effectively. A PPE is very important to carry out work safely but due to the discomfort of wearing the same workers tend to avoid them that causes injuries. It also become very difficult for the safety officers to supervise and control the workers and monitor the provision of PPE. The model would therefore be more helpful.

IV. CONTRIBUTING FACTORS TO SAFETY IMPLEMENTATION

Safety management is considered as one of the important techniques used by managers in construction industry and construction projects to implement construction safety. A good project management can be those where in the construction vigorously pursue the efficient utilization of labour force with least or no injuries. There are some factors which affects the jobsite safety management at a greater level and have to be highly taken into account. The construction industry has a high number of fatalities and long-term injuries which are reported every year. This is unacceptable in a modern society and it also makes the industry inefficient as here the workers work with considerable fear. The construction industry has some special features which have a direct bearing on the accident potential with a direct proportion to it. In this trade the pattern of work is ever changing with time. Here the operations and physical circumstances change instantly unlike in the factories where the process, method and operations are generally respective. Timings and schedules vary considerably from place to place according to the requirement. The most important changing factor is the change of men themselves. Safety can be defined as a disciplined framework for managing the integrity of operating systems and processes handling hazardous substances by applying good design principles, engineering and operating practices. It deals with the prevention and control of incidents that have the potential to release hazardous materials or energy to nature and environment that has a damaging impact widely. Such incidents can cause toxic effects, fire, or explosion and could ultimately result in serious injuries, property damage, lost production, and environmental impact an the construction sector may also eventually fall.

UNSAFE ACT AND UNSAFE CONDITIONS

Workers are the most important asset in any organization and they have to be protected at any cost. The health and safety of individuals not only affects the quality of life while at work, but also the lives, and standard of living of the family and community on a whole. There is thus a need to safeguard the health and safety of the individual in respect of possible exposure to any occupational hazards that they may get exposed to. Unsafe conditions can be defined as the hazards that have the potential to cause injury or death to an employee. Some of these hazards include important safety procedures, malfunctioning equipment or tools or even failure to utilize necessary safety equipment such as goggles, helmets, vests or masks. Unsafe conditions can be found in a variety of workplaces, but they pose a special hazard to workers in industrial, manufacturing, or manual labor positions but more seriously they are mainly referred to construction sector. At the time of hiring, companies should provide workers with the information and training they need in order to avoid unsafe conditions at workplace. If a single employee engages in unsafe acts, other employees who work in the same environment will be exposed to unsafe conditions since they not only cause danger to themselves but the others too being dragged. Unsafe conditions are majorly attributed to owners of the workplaces. It can be avoided by following all necessary safety regulations and standards, making workers adhere to strict safe practices, providing protective environment for all the workers, maintaining machines and safety gadgets and above all, providing safe and secure work environments where workers feel safe and happy to work. Unsafe Act can be defined as any activity by workers which are not as per the prescribed safety standard or practice set by the organization or by the management themself and which may or likely cause

accidents or risk for self or others at workplace, damage equipments and bring losses in terms of reputations and revenue to employer leading to a fall of profit. Such human acts can be due to careless attitude of workers or lack of awareness on safety measures or not following safe work practices while at work. The most effective way to protect the people who work for a company is by reducing the work related accidents that is likely to occur over their. The first area to look at should be the elimination of all unsafe conditions in the construction workplace. Regular audits need to be conducted to identify the unsafe conditions and must be prioritised and then implemented which will show the employees that the company is serious about their well-being while they are at work boosting their confidence. Unsafe acts account for approximately 80% of all industrial accidents according to many recent studies carried out. This is always dealt with after unsafe conditions such as planning to train the employees on how to act safely when necessary. However, this is not the end as people all make mistakes and accidents will continue to occur how much ever plannings are done. Thus, the full health and safety program is an on-going one with continuous improvement taking place with the full on involvement and co-operation from workers.

Fig.4.1 Unsafe act and unsafe condition

INFLUENCING FACTORS

OSHA standards fall into four categories which can be classified into general industry, construction, maritime and agriculture. OSHA issues standards for a wide variety of workplace hazards including the toxic substances, electrical hazards, fall hazards, hazardous waste, machine hazards, infectious diseases, fire and explosion hazards, occupational hazard and dangerous atmospheres. Employers must comply with the OSH Act's as mentioned in the general duty clause. The General Duty Clause, Section 5(a)(1) requires that every employer must furnish a place of employment which is free from recognized hazards that are causing or are more likely to cause death or serious physical harm to the employees employed in an organisation. Some of the factors identified to contribute in better safety performances are , 1) Material safety data sheet 2) Personal protective equipment 3) Safety training 4) Warning system 5) Record keeping 6) Housekeeping 7) Safety commitment.

V SAFETY MANAGEMENT

Safety management is an important techniques used by managers in construction industry and construction projects. A good project management can be those where in the construction vigorously pursue the efficient utilization of effective safety techniques. This would help save time and also the associated cost loses can be minimized reducing accidents and injuries. Whenever it comes to construction, it's always important to have safety management techniques to help foster safety at workplace. Often this requires some experience and skill sets from the managers. There are techniques and strategy that the safety management in construction sector can undertake to get the projects done efficiently and on time reducing mortality and morbidity and these techniques often aim to improve productivity. It is essential to check into factors affecting safety.

In recent years, the construction industry has taken many steps to ensure safe working conditions and work practices, yet the occupation remains hazardous after all the efforts taken. Prevention of accidents is a significant aim of construction management, both for human and financial consideration. The importance of safety management in construction and safety management system in the building is paramount and measures have to be taken. Effective safety management in construction projects ensures the proper administration of the safety precautions to be carried out at the construction site leading to reduced morbidity and mortality hence improving productivity and profitability.

SAFETY MANAGEMENT PRACTISES

1) Safety environment: A safe work environment is about more than just preventing injuries or the spread of disease, it is about making employee well-being a priority. A safe workplace is one where employees feel secure and enjoy a safe space, company values, and a positive co-working environment that encourages respect for everyone. In a good work environment, the workspaces and working and production methods have been designed and implemented in such a way that workers can work and move about safely. Workers are familiar with the hazards and risks related to the raw materials used in the work and the substances produced in the work processes, and they have been trained how to control them. The machines and tools used in the work suit their purpose. When planning and scaling the work, the employees' physical and mental preconditions are taken into account. Structural aspects of the work environment include the safety of passageways, workplace lighting, sound environment and indoor air quality. Functional factors include the organization of transportation and traffic and keeping workspaces and offices organized and tidy. Special attention must be paid to the identification and management of physical, chemical and biological health hazards in the workplace. Work machinery, equipment and tools must be in good working order, and they may be used only for the intended work and under the intended conditions. The necessary personal protective equipment and assistive devices must also be in good working order and used only for the intended situation.

2) Recruitment: It is a human resource management function, and it consist of activities that impact most critically on the performance of any company. It may be described as the set of activities and processes used to obtain a sufficient number of qualified people at the right place and time.

3) Selection: Selection is defined as the process of choosing the best labour from all construction labour and process of putting right men on right job. It is the procedure of matching company requirements with the skills and qualifications of to the employees. Selection is mainly used to attract and hire new employees who have abilities, skills, and experience that will help an organization achieve its goals and the entire process works by filtering. Here the in fit are rejected and only the right kind of people are accepted.

4) Training and development: Training and development is defined as a process of developing workrelated knowledge and skills in employees for the purpose of improving the safety systematically. Training is used effectively for developing technical and problem-solving skills among the workforce. Workplace impairment due to substances like alcohol, opioids or cannabis, or physical and mental factors, like fatigue and stress, can negatively affect workplace safety, employee wellbeing and the bottom line. Workplace safety training is as vital as workplace safety itself as it enables the management to ensure a safe and healthy work environment and also helps the employees to recognize safety hazards and correct them. It enables them to understand best safety practices and expectations.

5) Safety awareness: Building safety awareness is the first step in implementing a safety program as it shows that the management team cares about the wellbeing of the employees. If the management team is expressing that safety is important, then the employees will think that as well and when safe work practices are prioritized, the results are reduced injuries and increased production. In addition, awareness is part of the overall implementation of any policy or procedure an help attain better profitability and quality work.

6) Safe working conditions: People always prefer to work in good work environment. Safety behaviour is reflected by good attitude. Many accidents and incidents that occurred in the workplace especially in the building construction sites were due to inadequate sticking of workers to work procedures. Health of the workers are to be given great importance by providing all necessary and basic facilities as much as possible.

BARRIERS TO SAFETY

1) Demolition accidents: Demolition frequently occurs on construction sites and often involves using explosives to blast damaged buildings and other materials which can place workers in imminent danger. Although demolition accidents are sometimes unavoidable still the construction workers should be provided with safety equipment and proper training to lessen the risk of hazards. Depending on the circumstances, demolition injuries can include burns, lacerations, traumatic brain injury, broken bones, paralysis and most critically death too.

2) Slip, trips and falls: According to OSHA convention slip, trip and fall are among the most common causes of injury on construction sites. Debris, defects and holes in flooring, unsafe or broken stairs, poor lighting, and grease or oil on floors are all factors that can contribute to injury. These kinds of conditions can cause broken legs, sprained ankles, soft tissue injuries, lacerations, traumatic brain injury and even paralysis or death in extreme cases so care must be taken and work must be done only with proper shoes with enough traction.

3) Fire and explosion: There are numerous conditions on construction sites that can lead to fires or explosions at job site. Chemical and gas leaks, equipment malfunctions, electrical issues, and improper handling of flammable materials can result in accidents. Fire and explosion accidents on construction sites can cause injuries such as first-degree, second-degree, and third-degree burns as well as disfigurement, illnesses related to smoke inhalation, lung problems, and death.

4) Equipment and Machineries related accidents: Cranes and forklifts are regularly used on construction sites and require special training to operate those. These pieces of machinery can hold and carry loads weighing tons and must be operated with extreme caution. Still no matter how much care is used, lack of training, machinery defects, and equipment failures can cause horrific crane or forklift accidents that result in severe injuries or fatalities.

5) Struck by objects: Up to 11.1% of fatalities on construction sites are when objects strike workers. The leading cause of these accidents includes falling objects and vehicle hitting.

6) Caught between objects: Around 5.5% of fatalities on construction job sites involve accidents being caught between objects. Factors leading to their accidents include failure to inspect protective systems or trenches, unsafe egress or access, or unsafe spoil pile placement.

7) Trench or ground collapses: Trenches and other excavations are often necessary for building sites. However, this causes the ground and surrounding areas to be unstable and can collapse on workers who may be in or around the trench causing death.

8) Getting hit by a vehicle: This is a common accident on highway construction sites, when speeding or distracted drivers hit workers with their vehicles as the work is always very near to highways

9) Overexertion: Construction crews often work long hours without adequate rest pause , including extreme heat and humidity. This can cause injury from dehydration, fainting, or even strokes.

10) Falling Debris: Tools, building materials, pieces of scaffolding, or other supplies can do serious damage if they fall from significant heights over a worker standing below.

Fig.5.1 Construction site accident

VI. MACHINE LEARNING IN CONSTRUCTION INDUSTRY

The construction industry has not made as many technological advances as many other industries especially in countries like India which is still on way to reach developement and this has made things even more harder for the labour to work. It is even more difficult to find the resources to implement new technologies as it requires more of investment and skills. Machine learning could help the industry skyrocket forward thereby improving things on a daily basis for workers, contracting companies and end clients. Machine learning is nothing but a subset of artificial intelligence (AI). Even though it sounds like science fiction, but its applications are more technical and highly practical in day to day life. Basically these machines can learn and predict outcomes on their own especially without any human efforts. Rather than a person programming them the machine learning use software with algorithms that allow them to create predictions based on their analysis of data. Apart from the classic methods of prediction, even more advanced and complex methods are employed which has broadened the area of application of machine learning. Risk mitigation, Risk identification, analysis of information from Building Information Modelling, productivity improvement, injury prediction, equipment identification, project planning and cost assessment are some of the examples involved with respect to construction. The introduction of machine learning into construction project management has increased the efficiency of project in terms of productivity, economy, quality and reduction of time as well and also served well in ensuring construction safety. The performance of construction projects could also be predicted using the machine learning. Existing methods could not perform well, when compared to machine learning techniques, when several factors were involved. Recent study ensures that conventional estimating method used in the steel fabrication industry was outperformed by the machine learning methods, which estimated the steel fabrication duration much efficiently.

APPLICATION OF MACHINE LEARNING IN CONSTRUCTION SAFETY

1) Risk reduction : One of the most amazing things about machine learning is that it can figure out risks before they happen so as to prevent accidents, injuries etc. This helps humans identify risks and figure out how to prevent problems from arising before they turn to risk. Machine learning can identify risks, measure their impact and use predictive analytics to help reduce those identified risks. Tools like Construction IQ looks at the challenges of leaders in the construction field to understand how AI could help with these challenges. It found that the AI algorithms were able to prioritize problems and understand risk, such as potential consequences if a concern was not handled properly. This has the potential to help construction managers streamline their workflow and prevent problems.

2) Injury prediction: ML models can be created such as the Random Forest (RF) and Stochastic Gradient Tree Boosting (SGTB) to a data set of carefully featured attributes and categorical safety outcomes, extracted from a large pool of textual construction injury reports .The models can predict injury type, energy type, and body part with high skill outperforming the parametric models and even they can predict the severity of injury and the body part being effected.

3) Improve design quality: Machine learning can improve designs overall to make work spaces better for its ultimate human end users. The workspace used machine learning to help understand and predict the frequency of use for these meeting rooms, and the company would be able to design the space to best fit the needs of the people before starting construction on it. The benefits of machine learning in design is not limited there. Machine learning can also help workers figure out mistakes and omissions that might possibly be present in the design before going forward with building. Instead one can leave that to machine learning which ultimately saves teams critical times that can be used for more productive tasks then. With machine learning one can even test various environmental conditions and situations in the model. The technology can help to determine if a particular element of the design is optimal with life or can predict if it could create an issue down after application.

4) Create a safer job site: The potential applications of machine learning and artificial intelligence in construction are vast. Requests for information, open issues, and change orders are standard in the industry these days. Machine learning is like a smart assistant that can scrutinize this mountain of data so quickly within no time. It then alerts project managers about the critical things that need their attention so that it can be easily analysed. Several applications already use AI in this way to improve project safety. Its benefits range filtering of spam emails to advanced safety monitoring. Models can be created such as injury prediction, fire protection, equipment selection, dangerous area identification etc that would benefit the safe working of the construction industry preventing accidents.

SUGGESTIVE MODEL FOR PPE DETECTION

While governing laws and safety regulations set by OSHA almost all company always hold employers responsible for enforcing, monitoring, and maintaining appropriate PPE on the job site and these employees often do not comply with the regulation provided by OSHA due to the lack of safety awareness, discomfort of wearing PPE, and the feeling that PPE interferes with their work not permitting ton work free. According to OSHA, not using proper PPE was one of the most violated regulations identified. To incentivize compliance, OSHA fines the employer by imposing a penalty for each employee who fails to comply with PPE requirements The burden of full compensation falls onto employers or employees since insurance companies do not cover any damages caused by improper PPE practice. At the same time the OSHA regulation also encourages employers to train workers about the necessity of proper PPE . However from a practical perspective, manual monitoring of large number of workers for PPE compliance is expensive, time-consuming and resource-intensive. Hence there is a need to implement machine learning method of PPE detection model. The model can be created in two different ways. Current techniques of automated monitoring of PPE compliance can be broadly categorized into two types which are sensor-based and vision-based. Sensor-based techniques often comprise of installing a sensor and analyzing its signals an example of which includes using Radio Frequency Identification (RFID) tags installed on each PPE component, and checking the tags with a scanner at the entrance of a job site to control if workers are wearing proper PPE provided to them. Another example includes using a local area network (LAN) to check RFIDs, installed on PPE components that continuously monitor PPE compliance while the employees are working on site so as to ensure safe working but still the major drawback is that the sensor-based approach requires a significant investment in purchasing, installing, and maintaining complicated sensor networks that might deter its implementation in practice, making vision based approach more frequent due to the reduced investment. Vision-based approaches use cameras to record images or videos of the job site, which are then analyzed to verify PPE compliance if the workers are wearing it or not. This approach provides richer information about the scene that can be utilized to understand complex construction sites more promptly, precisely, and comprehensively compared to other techniques that can be adopted for image detection. The ultimate aim is to detect the PPE compliances worn by the workers at site especially hat and vest and then the model works by providing the messages to the manager or the site supervisor with the help of an application that is already logged in his phone as admin type. Here the major advantage being there is no requirement that the supervisor or the manager need to be present on site throughout the day monitoring if the workers have worn PPE. The manager can login to the application any time and he can identify the workers not wearing the helmet or vest by image processing including the date and time being mentioned onto it. The manager can then penalize the worker for the same.

Object detection approach

PyCharm is an integrated development environment (IDE) used in computer programming, specifically for the Python language. It is developed by the Czech company JetBrains. It provides code analysis, a graphical debugger, an integrated unit tester, integration with version control systems (VCSes), and supports web development with Django as well as Data Science with Anaconda. PyCharm is crossplatform, with Windows, macOS and Linux versions. The Community Edition is released under the Apache License, and there is also Professional Edition with extra features – released under a proprietary license. Python is one of the widely used general-purpose, high level programming language. It was initially designed by Guido van Rossum in 1991 and developed by Python Software Foundation. It was mainly developed for emphasis on code readability, and its syntax allows programmers toexpress concepts in fewer lines of code. Python is a programming language that lets you work quickly and integrate systems more efficiently. The model creation is done by adopting the python language and then an android application is created. YOLO V3 algorithm was used for object detection. YOLO (You Only Look Once) is a method or a way to do object detection. It is the algorithm or a strategy behind how the code is going to detect objects in the image. The official implementation of this idea is available through Dark Net . It is available on github for people to use. Earlier detection frameworks, looked at different parts of the image multiple times at different scales and repurposed image classification technique to detect objects. This approach is slow and inefficient. YOLO takes entirely different approach. It looks at the entire image only once and goes through the network once and detects objects. Hence the name. It is very fast. That's the reason it has got so popular. There are other popular object detection frameworks like Faster R-CNN and SSD that are also widely used. Unlike the R-CNN-based approaches, YOLO reduces the computational burden and, thus, allows much faster detection of objects, by combining the classification and localization tasks into a single CNN framework. Particularly, a variant of YOLO model, YOLO-v3, takes a 416 × 416 RGB image as input and contains three output layers, each dividing the input image into 13 × 13 grids (Output-1), 26 × 26 grids (Output2), and 52 × 52 grids (Output-3). The architecture of the pre-trained YOLO-v3 models are modified based on the number of considered classes in each approach. Here in Approach-1, the YOLO-v3 model detects worker and n number of different PPE types. This is used as the input in modelling which represent a 100 % complete attire. The YOLO-v3 model directly detects worker's different combinations of PPE attire once the input is provided. Here the PPE to be detected are hat and vest which are very primary.

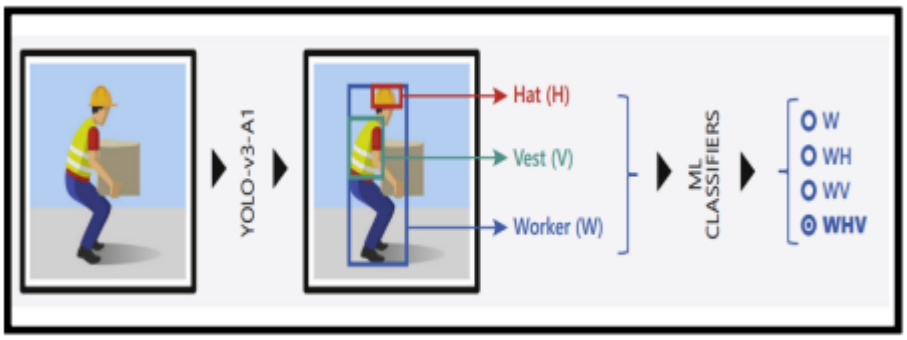


Fig.6.1 Input model for YOLO V3 detection[7]

Fig.6.2 Detection model for YOLO V3

LIMITATION OF DIGITALISED CONSTRUCTION

1) Our country do not have adequate financial security to get into a complete digitalized mode. Even though a PPE detection model is of at most privilege and importance there are a number of limitations to introducing the same to construction sector of our country.
2) Unlike other countries where there are surveillance cameras in job site our country lacks the same in normal small scale construction activities.
3) The safety of the workers are the matter of discussion here since is it never possible to enforce the protective equipment to workers nor it is possible to have a whole day monitoring.
4) Hoping that there are chances that one day our country would also move to betterment and digitalization the model would always be resourceful and effective.
5) The major reason behind not completely implementing digitalization is lack of useful resources and investment.

VII. RESULTS AND DISCUSSION

There are a number of factors affecting safety in construction industry. It is very necessary to identify the factors affecting safety so as to work on the same to improve and take measures to implement a safe work environment of the company. On basis of previous projects done by experts the influencing factor to safety is extracted. There were 10 major factors identified which were classified under two different titles. They are:
1) Implementation factors for SM Achievement :- • Safety commitment • Safety environment • Management roles • Faculty abilities and competence • Safety fundamentals and motives
2) Project performance and outcome factors :- • Safe working conditions • Quality work • Safety awareness • Safety Conformance • Secured and Content worker

Based on these factors a questionnaire was prepared to study on the agreement of different professionals regarding the influencing factors that contribute to construction safety. The questionnaire mainly focused on the opinions of main contractor, sub-contractor, site engineers, project engineers, supervisors and consultant and the target area being Kerala.

DEMOGRAPHIC ANALYSIS

A total of 230 questionnaires were sent, out of which 216 responses were received from different categories. The response percentage of each personnel working in their relative field is represented using a pie chart (Fig.7.1). Here it shows that about 24.1% of the total respondents were site engineers, 21.3% were supervisor, 15.7% were main contractors, about 8.3% were subcontractors, 22.7% were project engineers, and the remaining small percentage represents the sub-contractors(7.9%). The respondents designation would play an important role in their response together with the year of experience. So the experience of the personnel in their relative field were also collected. The experience and skill level of the person would facilitate giving an accurate response as they may already be familiar with such situation prevailing in their construction period. The responses from emergent to construction field are also equally important as they may have fresh ideas. The experience of the respondents in their filed of interest is shown (Fig.7.2) represented in percentage of people who have responded from less than a year of experience to more that five years expertise.

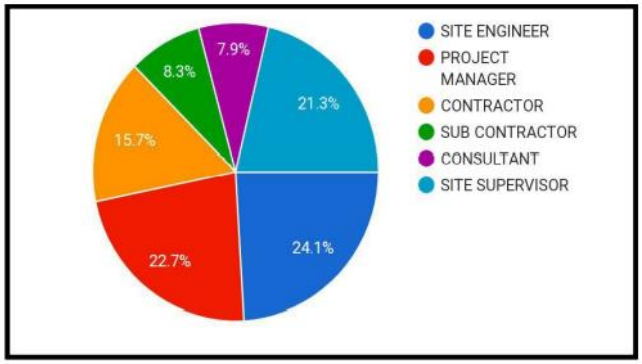


Fig.7.1 Respondents designation

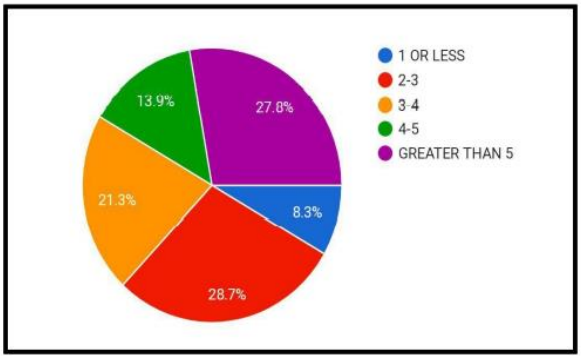


Fig.7.2 Respondents experience

Out of the total respondents it can be seen that approximately 82% were male and the remaining were female. Question was asked regarding the most common type of accidents that is likely to occur on site and a larger fraction of them agree that slip trip and fall was very common on site however hit by moving vehicles and machinery accidents were least occurring on site.

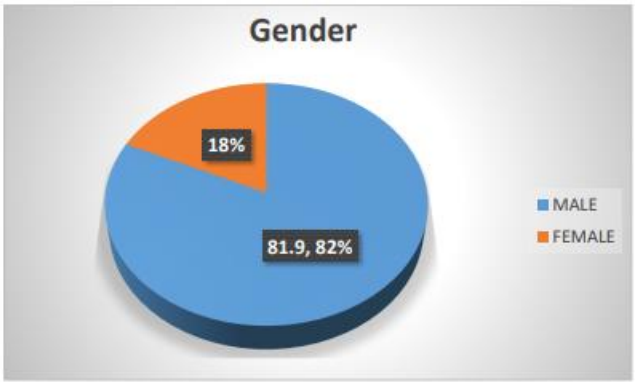


Fig.7.3 Respondents Gender

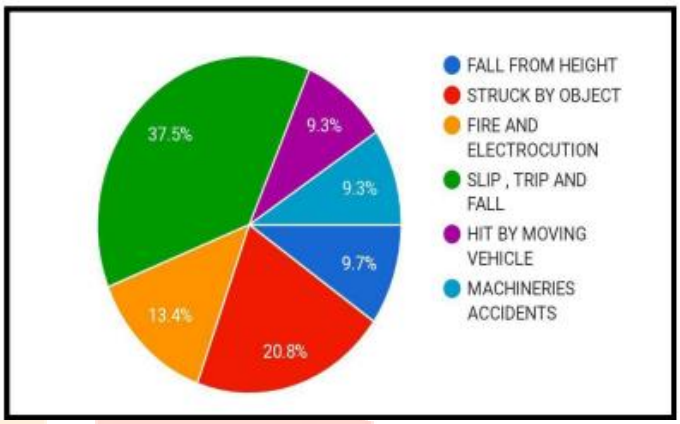


Fig.7.4 Major cause of accidents and injuries

The questionnaire also focused on the respondents level of understanding on safety management and the result is represented in Fig.7.5. Most of them had very low level understanding on safety management and therefore it is very essential that they need to be trained on construction safety. Survey analyzed whether the professionals are interested in automated and digitalized construction and 67% wanted the construction sector to be automated.

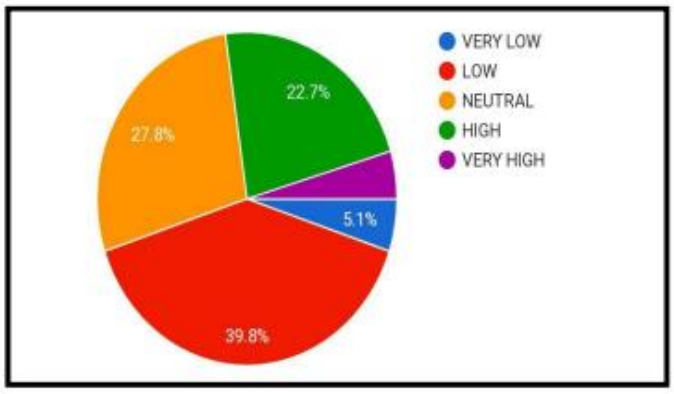


Fig.7.5 Respondent level of understanding on safety management

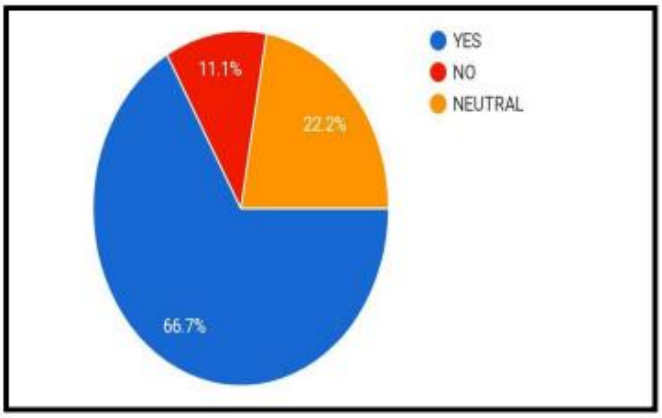


Fig.7.6 Respondents wanting construction industry to be automated and digitalized

The questionnaire also contained yes or no questions to be marked to show the agreement of the professionals to various questions asked. Fig.7.7 represent the bar graph which shows that they were not satisfied with present safety management. Here we can see that most of them agree to the fact that PPE is not made compulsory on site. Furthermore they add that health and safety training is also not conducted but safety posters were prominent on site and hazardous site inspection is also carried out.

The respondents also agree that unsafe act was more dangerous compared to unsafe condition because unsafe act is more difficult to recognize and correct because they involve human factors. Unsafe Act can be defined as any activity by workers which are not as per the prescribed safety standard or practice and which can cause or likely to cause accidents or risk for self or others at workplace, damage equipment and bring losses in terms of reputations and revenue to employer. Unsafe condition is the prevailing work or environmental condition which may be dangerous but can be avoided by identification.

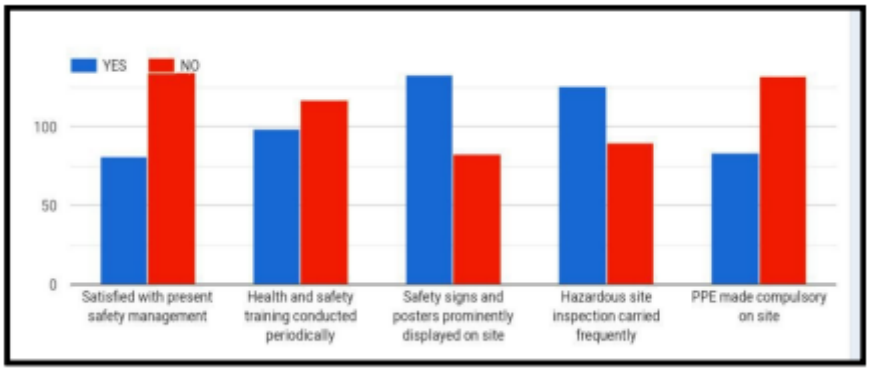


Fig.7.7 Work place safety

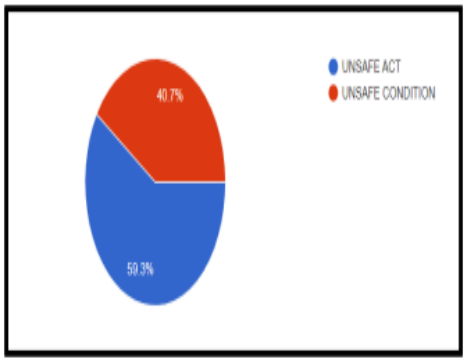


Fig.7.8 Unsafe act and unsafe condition

ANALYSIS OF INFLUENCING FACTORS

The responses collected were analyzed using SPSS software. SPSS stands for Statistical Package for Social Sciences and is used for various kind of statistical analysis. The project is intended to find out the frequencies of responses measured using Likert scale one to five. Here the survey responses collected via google forms are converted to spread sheets and then are imported to SPSS. Before importing to SPSS care was taken to put the variable name to first row and to avoid special characters when naming variables. After the data were fully incorporated it was analyzed. The statistical frequency analysis was performed to find the frequencies of each response. Then the output is extracted.

The frequency analysis method was then carried out for descriptive statistical analysis. The frequency analysis is mainly based on the number of occurrences chosen by the respondents. It is then followed by measure of relative importance by RII method. The Frequencies procedure provides statistics and graphical displays that are very useful for describing different types of variables. To create a table of frequencies which implies number of occurrences of given categories, analysis by means of descriptive Statistics is required for which the frequency in the required variables would be calculated. Here the selection of variables to be depicted in the frequency table by moving them from the left- to the righthand box. SPSS is a vast software which provides the user additional options, including statistics, charts, and format. The frequencies obtained after the analysis is further used for ranking the influencing factors by RII after which the factors most influencing and least are determined so as to work for improvement.

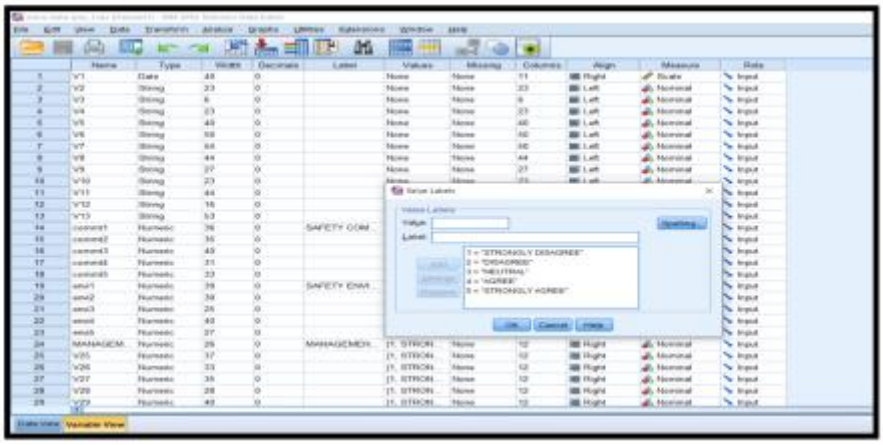


Fig.7.9 Analysis using IBM SPSS Statistics

A reliability test is to be carried out in order to check the internal consistency of the questionnaire. This can be done using the cronbachs alpha test by the SPSS software. Cronbach's alpha is the most common measure of internal consistency. It is most commonly used when you have multiple Likert questions in a survey questionnaire that form a scale and wish to determine if the scale is reliable. A reliability check ensures the stability of the questions asked and factors included.

Table7.1 Strength of association Check

Cronbachs alpha,a	Association strength
≥0.9	Excellent
0.8 to< 0.9	Very good
0.7 to< 0.8	Good
0.6 to <0.7	Acceptable
0.5 to <0.6	Poor
<0.5	Unacceptable

Table 7.2 Reliability test using SPSS

FACTORS	Cronbach alpha, a value
Safety Commitment	0.819
Safety Environment	0.790
Management Roles	0.864
Faculty ability and Competence	0.757
Safety fundamentals and Motives	0.727
Safe Working Condition	0.849
Quality Work	0.760
Safety Awareness	0.781
Safety Conformance	0.813
Secured and content Worker	0.757

Here in the above table we can see that all the factors are having the alpha value greater that 0.7 which implies that all the factors are acceptable and are having great internal consistency.

RII ANALYSIS AND RANKING OF INFLUENCING FACTORS

The Relative Importance Index (RII) was used to decide various personnel opinions on the influencing factor to safety in construction projects. RII can be be calculated as stated below: RELATIVE IMPORTANCE INDEX = $\frac{[5n_5+4n_4+3n_3+2n_2+1n_1]}{A*N}$ (7.1)

Where, n_5 = Number of Responses for Strongly Agree n_4 = Number of Responses for Agree n_3 = Number of Responses for Neutral n_2 = Number of Responses for Disagree n_1 = Number of Responses for Strongly Disagree A (Highest Weight) = 5 N (Total Number of Respondents) = 216

Based on the equation the importance of each influencing factors are determined and are ranked.

Safety commitment

Safety is very important to work peaceful in any environment and there are several factors that influence the implementation of safety at workplace. Strict measures have to be taken to implement safety and this is possible only by means of safety commitment. Safety commitment include various factors affecting it such as safety leadership, adequate machineries, safety inspection, accident prevention, and safety meetings. Out of the all, adequate machinery available to work is the most contributing factor to safety commitment by respondents.

Table.7.3 Safety commitment

Problem Statement	Code	RII	Rank
Regular safety inspection conducted	A	0.506	5
Regular safety inspection conducted	B	0.565	3
Adequate machineries available to work	C	0.588	1
Demonstrated safety leadership	D	0.567	2
Demonstrated safety leadership	E	0.547	4

Safety Environment

A safe and healthy environment will lead to a pleasant work place. This is only possible if adequate safety measures are taken and implemented wisely. Effective communication have to be ensured and workers issue have to be given attention. A safe environment is one where workers feel free to work. The respondents agree that safe environment can be achieved only when the workers are not pressurized to work. They also have responded that awareness class alone cannot contribute to safe work environment unless made to practice.

Table.7.4 Safety Environment

Problem Statement	Code	RII	Rank
Recruited workers with high awareness	A	0.592	4
Worker's issue given attention	B	0.630	2
Workers feel free to work	C	0.635	1
Appointed safety managers with high morale	D	0.622	3
Awareness classes provided	E	0.562	5

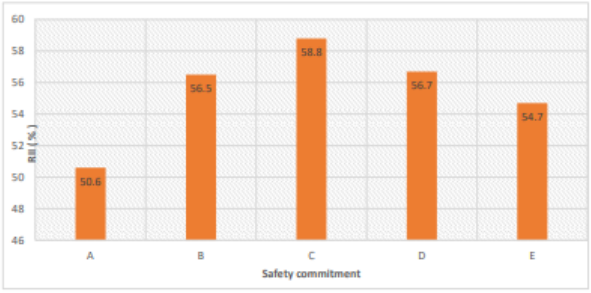


Fig.7.10 Safety Commitment

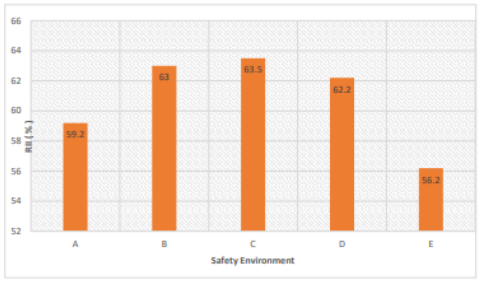


Fig.7.11 Safety environment 7.4.3

Management Roles

The management team of every organization has an important role to play in establishing and implementing safety in that organization. There are certain well-defined roles that the management play in implementing safety and the management roles involve the following roles as listed in the Table 7.5. The professionals agreed that sub-contractor supervise the work effectively by ranking them the most contributing management roles and they also agree that workers are not involved in meeting by ranking them the least.

Table.7.5 Management roles

Problem Statement	Code	RII %	Rank
Well cordinated teamwork	A	53	5
Proper communication system provided	B	64.5	2
Sub-contractor supervise the work	C	64.6	1
Accident investigation carried out	D	55.7	3
Accident records maintained	E	53.1	4
Adopted safety organisation and meeting	F	51.6	6
Workers involved in meeting	G	50.9	7

Faculty abilities and competence

The overall performance of any industry lies on the abilities of the faculty present. The same is with construction industry too. The abilities and competence of the faculty help establish safety in work place. The professional agree that allocating adequate manpower is the best way to ensure safety so that work can be completed on time and on the same hand well communicated presentation is not happening in sector.

Table.7.6 Faculty abilities and competence

Problem Statement	Code	RII %	Rank
Qualified project manager appointed	A	62.8	3
Allocated adequate manpower for work completion	B	67.6	1
Allocated adequate manpower for work completion	C	62.7	4
Injury reduction strategy maintained	D	63.8	2

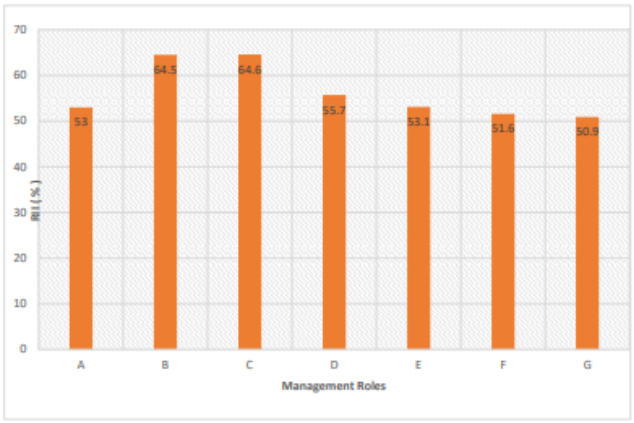


Fig.7.12 Management Roles

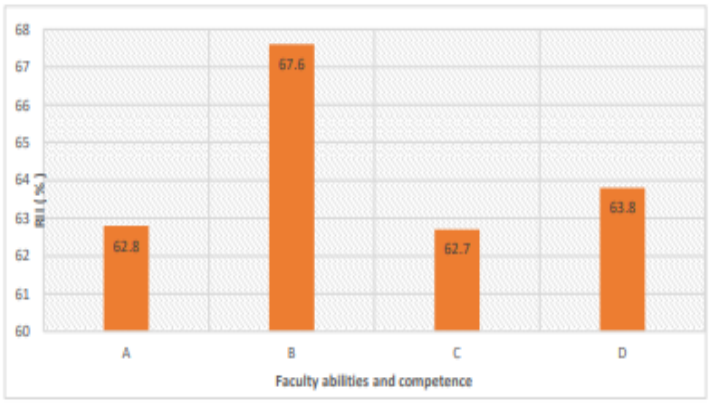


Fig.7.13 Faculty abilities and competence

Safety Fundamentals and motives

The safety fundamental mainly include completing work on time, providing compensation etc. The respondents were provided statements as shown in the Table7.6 and they replied that safety legislation was fulfilled on time by ranking them first. They also agree that no trainings on PPE were provided.

Table.7.7 Safety fundamentals and motives

Problem Statement	Code	RII %	Rank
Client requirement fulfilled on time	A	63.7	3
Compensation provided for injury and accident	B	63.8	2
Compensation provided for injury and accident	C	63.9	1
Media, society informed on accident	D	53.9	4
Training on PPE provided	E	53	5

Safe working condition

The Professionals agree that better housekeeping is the best way to reduce accidents and injuries and thereby they ranked housekeeping as the most contributing factor to safe working condition. At the same time, they also agree that sufficient rest pause is not provided to workers.

Table.7.8 Safe working condition

Problem Statement	Code	RII %	Rank
Better house keeping	A	65	1
Proper storage and transportation of site materials	B	57.1	4
Sufficient rest pause provided	C	57.1	4
Sufficient rest pause provide	D	60.9	3
Sufficient rest pause provided	E	62.3	2

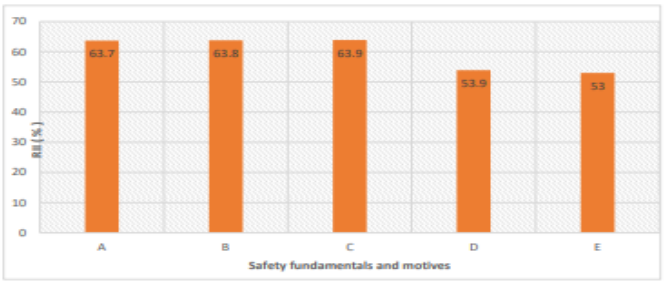


Fig.7.14 Safety Fundamentals and motives

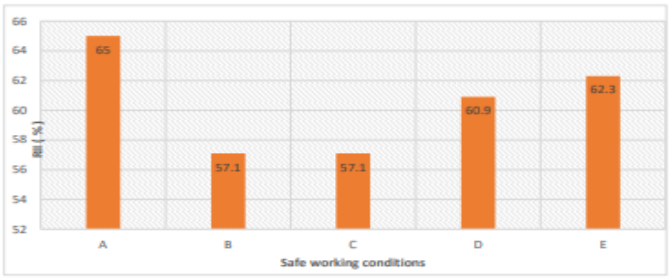


Fig.7.14 Safety Fundamentals and motives

Quality work

Good quality work adds to safety. It reduces accident rate as well as injuries. The questionnaire survey conducted states that concerned staff and workers improve the overall work quality. However controlled working reduces the work quality as the workers become overwhelmed and tired.

Table.7.9 Quality Work

Problem Statement	Code	RII %	Rank
Controlled work on site	A	56.4	4
Decreased trend in accident rate	B	59	3
High Team spirit	C	62.7	2
Concerned staff and worker	D	63	1

Safety awareness

Before entering into construction site, one must be thoroughly aware about the type of accidents, injury etc that is likely to occur. An ignorant worker not just risk themselves but also put the life of others at risk. Skilled workers are ranked the most by the professionals but still they agree that experienced worker need not be fully aware of safety.

Table.7.10 Safety awareness

Problem Statement	Code	RII %	Rank
Workers selected based on experience	A	58.3	5
Skilled workers prioritized	B	67.3	1
Workers educated on safety	C	59.1	4
Demonstrated sense of belongings	D	60.3	3
Well defined responsibilities given to workers	E	61.2	2

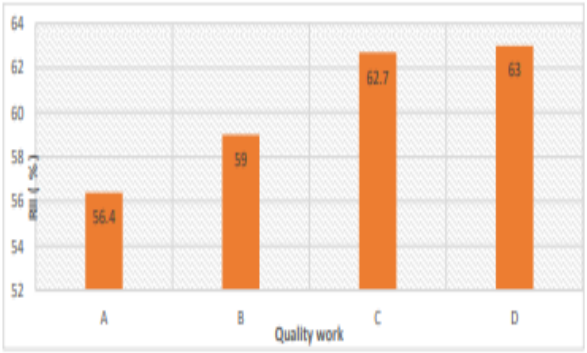


Fig.7.16 Quality work

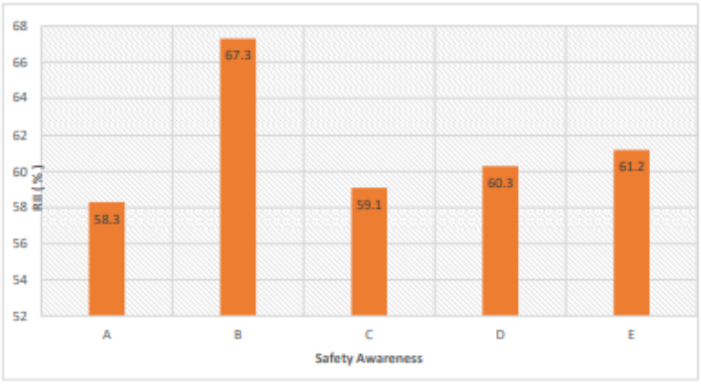


Fig.7.17 Safety awareness

Safety Conformance

Programmes have to be conducted in order to ensure safety in construction. This is only possible by taking strict action against violation of safety. Sufficient stock of PPE is to be maintained but this is not happening on construction industry according to the rankings provided by the professionals. High participation in safety activity is one of the best ways to ensure safety.

Table.7.11 Safety conformance

Problem Statement	Code	RII %	Rank
Safety regulations enforced strictly	A	56.4	3
High participation in safety activities	B	58.4	1
Incentives offered for participation in safety activity	C	56.4	3
Budget spent to implement safety	D	56.7	2
Sufficient stock of PPE maintained	E	55	5

Secured and content worker

The ultimate aim of safety is nothing but secured and satisfied worker. This is the final result of safety. The questionnaire survey confirms that safe home return of the worker is the fruit that safe workplace bear by ranking it the first. Alcohol or drug abuse is ranked the last as it is the least safety contributing factor.

Table.7.12 Secured and content worker

Problem Statement	Code	RII %	Rank
Satisfied working ultimately	A	54.9	4
Healthy environment achieved	B	61.5	2
Reduced death and accident rate	C	60.9	3
Safe home return for workers	D	62	1
Alcohol or drug abuse	E	53.2	5

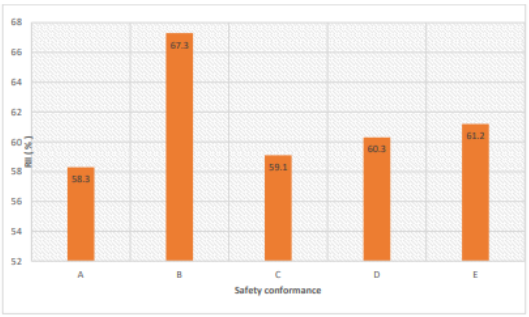


Fig.7.18 Safety Conformance

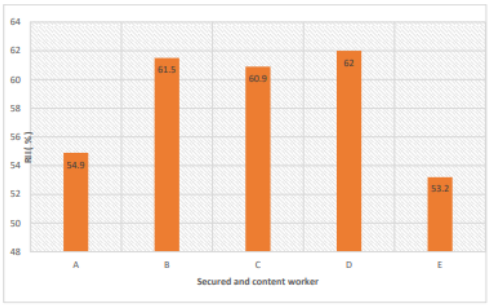


Fig.7.19 Secured and content worker

IDENTIFICATION OF INFLUENCING FACTORS

A number of factors influencing safety parameter in construction industry is studied and each factors were ranked. It is also very necessary to identify the factor which is most influencing as well as the factors which are least influencing so as to suggest suitable remedy measure for the same. Here in order to identify the most as well as the least contributing factor, the mean of the 10 factors are taken. If the mean happens to be similar then their standard deviation are considered and the one with lower standard deviation are valued.

Table.7.13 Influencing factors

Problem Statement	Code	RII %	Rank
Safety commitment	A	55.48	10
Safety environment	B	60.85	3
Management roles	C	56.23	9
Faculty abilities and competence	D	64.28	1
Safety fundamentals and motives	E	59.66	6
Safe working conditions	F	60.5	4
Quality work	G	60.32	5
Safety awareness	H	61.27	2
Safety conformance	I	56.62	8
Secured and content worker	J	58.53	7

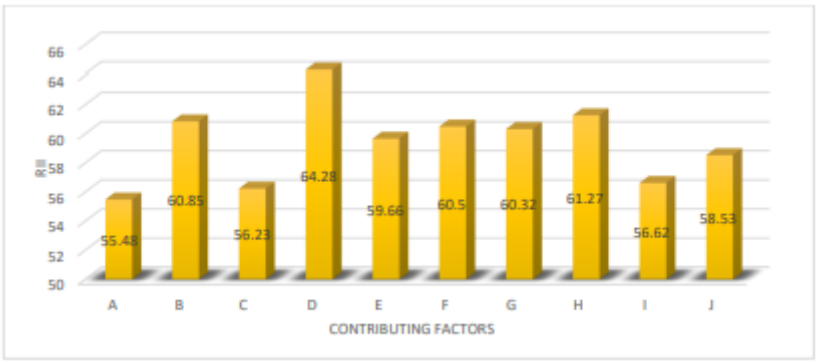


Fig.7.20 Contributing safety factors

It can be seen that through questionnaire survey the professionals responded that faculty abilities and competence is the most contributing factor to safety. Every organization would have skilled faculty and it applies to the construction industry too. The faculties are in charge of the safety implementing task and they have to ensure that there are safe environment to work. Construction industry being the most dangerous one all the workers have to be trained before entering to work. This is possible only if skilled and talented faculties are available. The respondent stated that safety commitment is not responsible to safety as always commitments are often a lie. The commitment lies only in the name and they are not applied to action. Measures have to be taken in order to put the safety commitment to action.

SEM MODELLING

Structural equation modeling (SEM) is considered to be a powerful and a multivariate technique found increasingly in scientific investigations in modern days to test and evaluate multivariate causal relationships between variables. SEMs differ from other modeling approaches as they test the direct and indirect effects on pre-assumed causal relationships between variables. SEM is a nearly 100-yearold statistical method developed and that has progressed over three generations. The first generation of SEM has developed the logic of causal modeling using path analysis. SEM was then morphed by the social sciences to include factor analysis too. By its second generation the SEM expanded its capacity. The third generation of SEM began in 2000 with Judea Pearl's development of the "structural causal model," followed by Bayesian modeling. SEM is a combination of two statistical methods that are confirmatory factor analysis and path analysis. The growing importance of SEM in data analysis is largely due to its ease of use. SEM opens the door for non-statisticians to solve estimation and hypothesis testing problems that once would have required the services of a specialist. The models that can be seen as types of Structural Equation Modelling would include

Confirmatory Factor Analysis, Confirmatory Composite Analysis, Path Analysis, Partial Least Squares Path modelling and Latent Growth modelling. Out of the various confirmatory factor analysis is used here.

CFA is also known within SEM as the the measurement model because is the step taken to determine how the unobserved variables are related to the latent variable as measured by the indicators. Latent variables are the observed variables and are also called endogenous variables while the unobserved variables are the exogenious variable. Here CFA models of both the factors are first analysed with is later combined to SEM model.

Software used

IBM SPSS Amos is mainly used to carry out the structural equation modelling. It is considered to be one of the powerful structural equations modeling (SEM) software helping support the research. IBM SPSS Amos implements the general approach to data analysis known as structural equation modeling also known as analysis of covariance structures or even the causal modeling. This approach includes special cases and many well-known conventional techniques, including the general linear model and common factor analysis. It can also be used to build attitudinal and behavioral models reflecting complex relationships more accurately than with standard multivariate statistics techniques using either an intuitive graphical or programmatic user interface. With Amos we can quickly specify, view, and modify the model graphically using simple drawing tools and then one can assess the model's fit, make any modifications, and print the graphic of the final model. Simply specify the mode graphically and then the Amos quickly performs the computations and displays the results. Inorder to carry out the work the factors were classified to implementation factor for SM achievement and Project performance and outcome factor and the work mainly aims to identify the relation between the two variables.

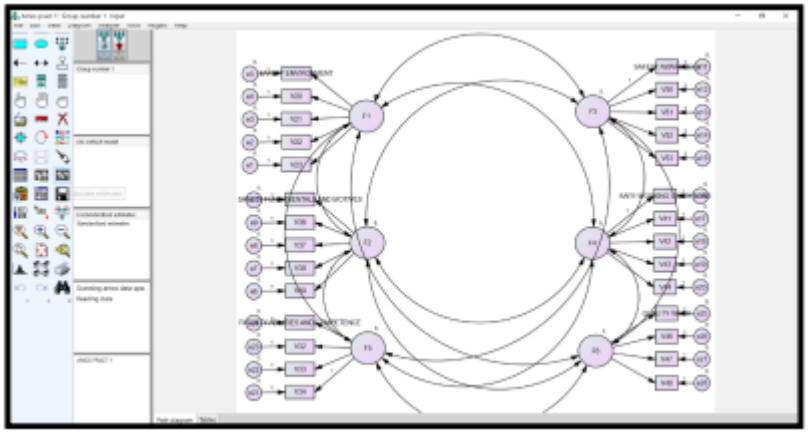


Fig.7.21 Analysis using SPSS Amos

CFA modelling CFA allows the researcher to establish whether a pool of observed variables, underlying broader theoretically derived concepts can be reduced into a smaller number of latent factors. As such the CFA is used for several purposes including scale development and as a foundation for latent regression analysis and structural equation modelling (SEM). Data should be continuous and include a sufficient number of observed variables to allow the model to be identified. The model can be classified as just identified, over identified and unidentified. A just identified model would have the degree of freedom as 0 while the over identified model would have the DOF mode than 0 while un identified model would have the DOF less than o. A good fit model should not be un identified. The fitness of model can be further classified as the following:

1) Absolute model fit
   • Chi square value and p value >0.05 • RMSEA 0.9

2) Incremental model fit • AGFI >0.9 • Comparative fit index CFI >0.9 • Normed fit index NFI >0.9 • Tuucker lewis index TLI >0.9

3) Parsimonious model fit • Chi sq/DOF

Table.7.14 Cim/DOF Check

Discrepancy	Fitness
≤3	Acceptable fit
≤5	Reasonable fit

Table.7.15 GFI check

GFI	Fitness
1	Perfect fit
>0.9	Reasonable fit
>0.95	Excellent fit

Table.7.16 NFI check

NFI	Fitness
0.85-1	Perfect fit
<0.85	Acceptable, can be improved substantially

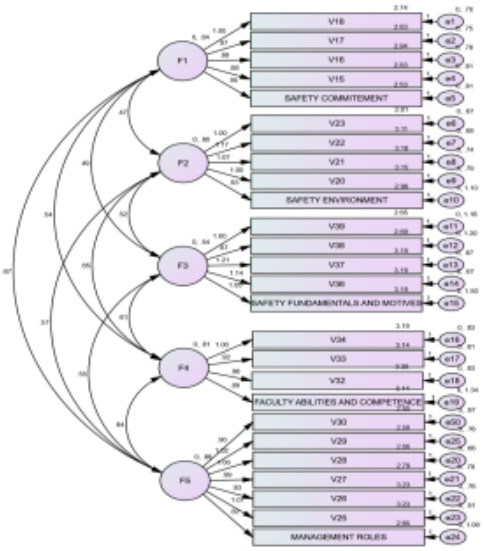
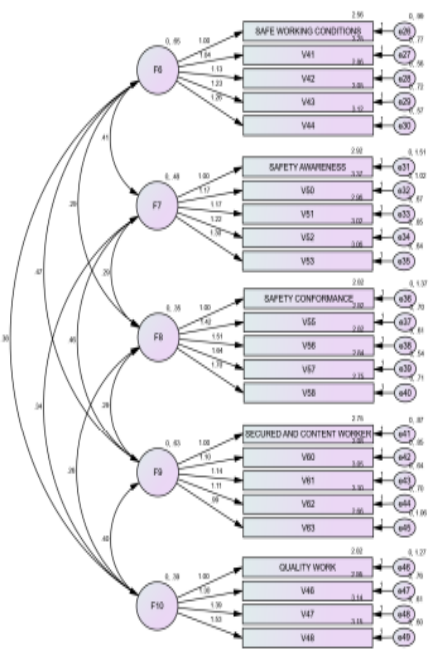


Fig.7.22 CFA Model for Implementation factor for SM achievement

Here the summary of the CFI model is:
• Chi-square = 933.708 • DOF = 289 • Probability level = .000 • Number of distinct sample moments: 377 • Number of distinct parameters to be estimated: 88 Degrees of freedom (377 - 88): 289 OVER IDENTIFIED hense safe • P value =0 significant • Chi sq>DOF • RMSEA =0.102>0.08 (Deviation less) • GFI=0.86 approx 0.9 ABSOLUTE FIT • Min discrepancy =3.231.

The summary of the model is: • Number of distinct sample moments: 324 • Number of distinct parameters to be estimated: 82 • Degrees of freedom (324 - 82): 242 • Chi-square = 899.115 • Degrees of freedom = 242 • Probability level = .000 OVER IDENTIFIED • Parsimonious fit, Incremental fit check satisfied • RMSEA=0.11 considerable absolute fit GOOD FIT



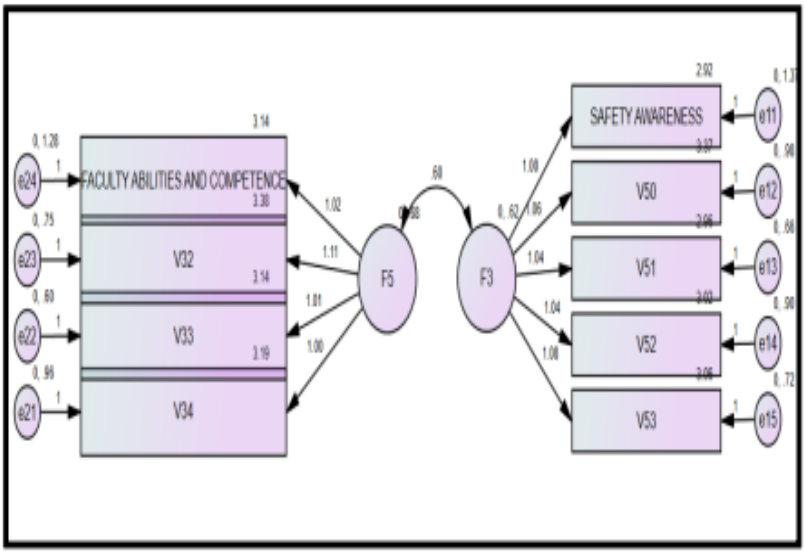


Fig.7.23 CFA model for project performance and outcome factor

Fig.7.24 SEM model

The summary of the SEM model is: • Number of distinct sample moments: 54 • Number of distinct parameters to be estimated: 28 • Degrees of freedom (54 - 28): 26 • Minimum was achieved Chi-square = 144.612 • Degrees of freedom = 26 Probability level = .000 , significant OVER IDENTIFIED, GOOD FIT • Regression weight, Critical value >±1.96, model fit

Table7.17 Model fitness check

	CFA 1	CFA 2	SEM	CHECK	FITNESS
P	0	0	0	0	PERFECT
TLI	0.71	0.71	0.73	0-1	PERFECT
NFI	0.71	0.71	0.82	<0.85 acceptable =0.85-1 perfect	ACCEPTABLE
CFI	0.77	0.77	0.85	0-1	PERFECT
RMSEA	0.102	0.112	0.145	<0.08 perfect 0.08-1 acceptable	ACCEPTABLE
Cmin/DOF	3.23	3.72	5.5	<5 or equal	PERFECT

Over all the model is a good fit model hence can be accepted. The detailed fitness analysis is provided in the annex. model fit in statistics measures the variance between observed and model-implied data using correlation and covariance matrices. Though calculating is a model that fits the data is not too complicated in AMOS, interpreting the results can be a bit challenging at times. All the models are tested in Amos and the basic checks are provided in the Table 7.15 .The values that are tested is represented below where

• TLI = Tucker-Lewis coefficient also known as Bentler-Bonett non-normed fit index ranges from 0 to 1 where a value closer to 1 represents a very good fit while 1 represents a perfect fit.

• P = the probability of getting a discrepancy as large as CMIN value if the respective model is correct. • CMIN/DF = discrepancy divided by degree of freedom. The value of interest here is the CMIN/DF for the default model and is interpreted as follows: If the CMIN/DF value is ≤ 3 it indicates an acceptable fit. If the value is ≤ 5 it indicates a reasonable fit

• RMSEA = Root Mean Square Error of Approximation where values higher than 0.1 are considered poor, values between 0.08 and 0.1 are considered borderline, values ranging from 0.05 to 0.08 are considered acceptable, and values ≤ 0.05 are considered excellent

• NFI = Normed Fit Index also referred to consists of values scaling between (terribly fitting) independence model and (perfectly fitting) saturated model. A value of 1 shows a perfect fit while models valued < 0.85 can be usually improved substantially

• CFI = Comparative Fit Index has value truncated between 0 and 1 where values closed to 1 show a very good fit while 1 represents the perfect fit

VALIDATING THE SUGGESTIVE PPE DETECTION MODEL

The transformation from theoretical designs to working system is done in this stage. Developed package of system is tested with simple data, accurate error identification and then through proposed change from the user. A rehearsal working of system is done so that the system is scrutinized, for pointing out errors and modifications required if any keeping in mind the expectations and specifications from the system. Awareness about the new system is made to the users through training, and with the underlying philosophy of the system. System performance v/s the expected requirements are evaluated. The implementation problems if any is taken seriously and taken care of along with admiring the achievements, failures etc. The security of the system is very must. The objective of system security includes protection of information and property from theft, corruption, or natural disaster, while allowing the information and property to remain accessible and productive to its intended users. The term system security, means the collective processes and mechanisms by which sensitive and valuable information and services are protected from publication, tempering or collapse by unauthorized activities or untrustworthy individuals and unplanned events respectively. The technologies of system security are based on logic. The android developed is an admin only type where the admin being the supervisor or the manager himself can log on to the application installed in his phone using the user id as well as the password allotted. Once the application is installed the next step is testing and validation. Testing determines the correctness, completeness, and quality of software being developed. Validation refers to the process of checking that the developed software meets the requirements specified by the user. The activities involved in the testing phase basically evaluate the capability of that system meets its requirements. The main objective of testing is to detect errors in the application. Errors occur if some part of the developed system is found to be incorrect, incomplete or inconsistent. Worker, hat, and vest defined as the three object classes were detected by YOLO-v3-A1 individually. This is provided as the input image to detect the PPE. Next ML classifiers were used to check if a detected hat or vest was in fact worn by a detected worker. Based on the worker's PPE attire, they will be classified as person , hard hat ,vest etc showing the degree to which they are perfectly worn. Then it would be compared with the input image provided. The trained YOLO-v3 models can be applied to construction images or even videos to generate results in real-time. These models have effectively learned the features of workers and the most common PPE components, i.e., hard hat and vest, and therefore, can be used in a transfer learning framework to build other solutions for detecting PPE too. Once the worker fail to wear the hard hat or vest then soon images of the person will be sent to the android application indicating the day and date that the helmet or vest was not worn. Here the surveillance camera that is assumed to be present on the worksite will detect the and visualise the image of the person.

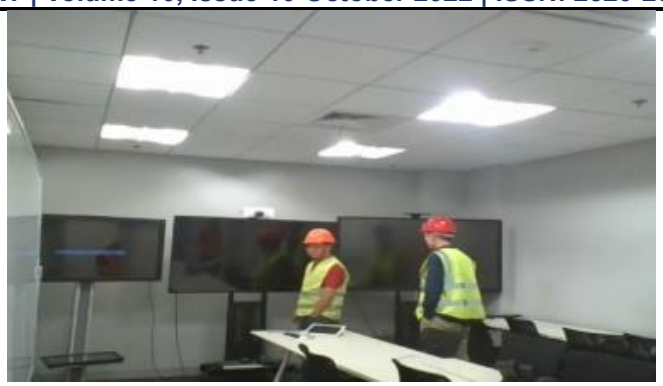


Fig.7.25 Input image for YOLO V3 model detection Fig.7.26 Surveillance camera supervision

Here we can see that the worker would pass the surveillance camera that present in the workplace. The worker may be strictly asked to wear hat ,vest but due to the discomfort caused they may remove the attire at the very first opportunity . The ML model will immediately assess the image and then YOLO V3 will detect the same and the output will be provided. The android application makes supervising more effective and reliable .This imposes a strict provision to compulsorily wear ppe on site as the workers may get punishes or penalised on not wearing one. There is also no need of a whole day invigilation required on site to monitor the PPE provision as the application is one the hand of the manager.

Fig.7.27 Object detection by YOLO V3 model Fig.7.28 PPE detection android application

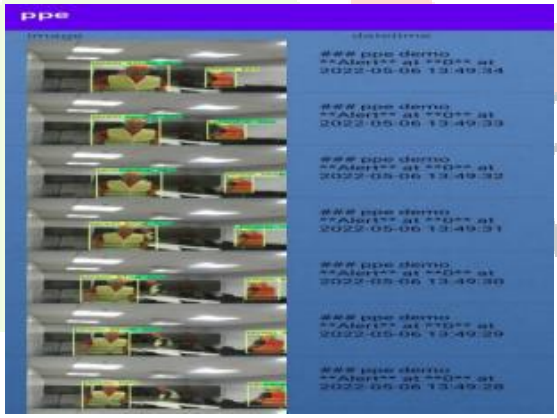


Fig.7.29 PPE detection details

One of the main limitations of vision-based detection methods is that they are susceptible to occlusion, poor illumination, and blurriness and the image may not be very clear. Moreover, the speed of the implementation may vary depending on the computer hardware used for testing. Furthermore, although the theoretical framework introduced in this study is designed to be scalable to any number and type of PPE, proposed methods were only tested on hat and vest classes, necessitating future experimentation with more data to draw conclusions about the generalizability of the results. Moreover, the proposed methods do not identify the colour of the PPE components, neither do they associate any personal identification with the output of the verification. At the same time, this latter limitation guarantees the privacy of individual workers on the job site.

MEASURES TO IMPROVE CONSTRUCTION SAFETY

Construction works are often expensive and frequently results in arguments and claims that might generally affects progress of construction projects. The environment of any construction organizations should be in a position to implement projects with successful completion. Some of the methods to improve construction industry safety include the following: 1) Everybody related to construction industry including the labourers prefer to work in healthy and positive environment therefore it is the duty of the company to provide an ambiance to work efficiently without any kind of difficulty 2) Organizations should make sure there is enough lighting present at the construction sites which can indirectly reduce the number of accidents on site. When accident rates are very low it would impart a confidence among workers to work with full energy, eradicating fear. 3) Continuous safety training and meetings should be arranged to achieve better performance and productivity and enable the labours to know their responsibilities on site and to wear all the safety gadgets provided and to take all instructions provided especially for the safety of

the workers 4) The survey analysis also shows that workers are addicted to drugs or alcohol and they were found using the same at site. 5) Strict drug and alcohol tests should be implemented on a surprise basis at the site or company and strict action should be taken with the employees who are tested positive. Such careless workers not only put them to risk but also the life of subordinates are endangered. 6) Adequate safety instrument and PPE equipment should be stocked on site so that there is no shortage to use. 7) The workers should be included in safety meetings and they must be given a chance to raise their issues so that the same can be cleared 8) Better housekeeping would reduce or prevent slip trip and fall or other kind of accidents on site and ensure sufficient cleanliness and tidy work place as there will not be accumulation of debris 9) All employers need to honour the basic rights of all their employees, including their safety at work. The employer is responsible to provide the required personal protective equipment and maintain their validity for use, as well as for the training of workers in their proper use. 10) The employer is required to enroll qualified and certified safety and health supervisors at his worksites, and assure that personnel is aware of his responsibilities and duties toward keeping the worksite safe, and also how to improve it to be healthier and safer for everyone. 11) The employer is also ultimately responsible for providing intact equipment and machines at the worksite. If any machine or piece of equipment is found to be faulty, a maintenance technician must be available on site or there should be a properly equipped and staffed workshop on site or close by to do all possible repairs and maintenance. 12) Equipment and machines also need to be replaced in a timely manner with new ones. All workers must be properly qualified and practically trained for every task they are required to perform. Moreover, continuous on-the-job training about safety and occupational hazards at their worksite also need to be a part of every worker's arsenal. 13) In case of any incident or injury, the safety and health supervisor should report and record that incident as accurately as possible. Periodic medical examination of workers shall be carried out

VIII CONCLUSION

1) Several factors influencing construction safety were identified and were further classified as implementation factors for SM achievement and project performance and outcome factors
2) Out of the various factors, faculty abilities and competence was the most ranked influencing factor and similarly safety commitment was the least ranked factor contributing to safety
3) The survey also revealed that slip trip and fall was the most commonly occurring accident on site contributing to 37.5% of the various other accidents.
4) The professionals also agree that PPE is not compulsory on site and hence strict action have to be taken 5) Unsafe act is was more dangerous compared to unsafe condition according to the respondents as it involve human factors which is unavoidable
6) SEM modelling was carried out to determine if the variables were related and the fitness was checked and it was a good fit model
7) Suggestive modelling of PPE detection was created using machine learning approach and the future scope was analyzed
8) The YOLO V3 model would detect the PPE attire and through android application the one not wearing hat and vest can be figured out immediately through image processing
9) The limitation of implementing the model in a developing country like India is also analysed
10) Barriers to a fully digitalized and automated construction industry is discussed among which financial instability is the major reason

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