Construction Safety Knowledge for Practitioners in the Construction Industry

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***Abstract*- The construction industry involves risky and unhealthy operations which result in many human tragedies, discourage workers, disrupt construction, delay progress, and adversely affect cost, productivity, and reputation. Construction managers focus mainly on productivity in terms of cost, quality, and time. Construction project can never achieve its objectives unless construction professionals become aware of the safety-related issues. The main objective behind this paper was to create awareness among practitioners about various safety-related practices in the construction industry. Paper discusses the possible construction site hazards along with their root causes. The significance of safety culture and climate in the mitigation of site hazards has also been discussed. Paper highlights the role of owners and designers to ensure safe construction process. Applications of information technology (IT) based tools in ensuring safety during construction have also been reviewed. Beside this, attention has been drawn towards the importance of safe site layout in ensuring safety. The concepts of prevention through design (PtD) and safety into sustainability have also been elaborated.**

Keywords- Construction Safety; Safe Practices; IT

I. INTRODUCTION

The Indian construction industry is of significant economic importance. It accounts for about 11% of gross domestic product and employs approximately 33 million people, making it second biggest industry of the country after agriculture [1]. It is an essential contributor to infrastructural developments like: roads, dams, irrigation works, schools, houses, and hospitals. These construction works are the physical foundation on which development and improving standards of the country are established. The amount of money invested and jobs provided by the construction industry are larger than any other industry in India. About 50% of all expenditure incurred in five year plans is directly traced to the Indian construction industry [1].

The work force in the Indian construction industry comprises of 55% unskilled labour, 27% skilled labour, and rest are technical and supporting staff [2]. About 16% of the nation's working population depends on constructional works for its livelihood. Construction in the developing countries such as India is more labour-intensive than that of the developed countries, involving 2.5-10 times more workers per activity [3]. The labour in the construction industry is most vulnerable because employment is generally temporary in nature, employer-employee relationship is very weak and most of the time short-lived. The work has inherent risk to life and limb due to lack of safety, health, and welfare facilities linked with uncertain working environment [2]. Generally, workers are unskilled which migrate in groups with or without their families, throughout the country in search of employment. Communication problem among these workers due to differences in their language, religion, and culture reduce safety on the work sites [4].

The Indian construction labour is 7.5% of the world labour force but it contributes to 16.4% of fatal global occupational accidents [2]. It accounts approximately 11% of occupational injuries and 20% of deaths resulting from occupational accidents [1]. In the construction industry the possibility of a fatality is five times more likely than in a manufacturing industry, whereas the risk of a major injury is two and a half times higher. Each year, up to 120 people are killed at work place in the developed countries like UK and there are about 3000 workers who suffer from major injuries in construction-related accidents [5]. Unfortunately, not only construction workers suffer from accidents but, one member of the public, including children is killed each month [5]. This tarnishes the image of the construction industry, and making it more difficult to attract skilled labour [6].

In the past decade, need for safety awareness among construction companies has greatly increased [7]. This is due to the high cost associated with work-related injuries, workers' compensation, insurance premium, indirect costs of injuries, and litigation. Every year, a considerable amount of time is lost due to work-related health problems and site accidents [8]. There are several factors responsible for health problems and construction site accidents. The Occupational Safety and Health Administration (OSHA) examined the causes of construction fatalities, result showed that 33% of fatalities in construction were caused by falls, 22% were struck by incidents, 18% were caught in/between incidents, 17% were electrocutions, and 10% were caused by other reasons [9].

Safety and quality are vital in the construction industry. The industry desires good quality while ensuring a safe working environment at workplace. Pheng and Shiua [10] emphasized that quality and safety should be integrated to achieve better co-ordination and utilization of resources. Koehn and Datta [11] revealed that issues like poor quality work, unsafe working conditions, and lack of environmental control can be improved by adopting safety rules and regulations. Study, further stressed

that the implementation of an effective quality, environment, and safety program not only assures a quality work but also reduces cost and enhances productivity. Ahmed et al. [12] explored that a safe and organized site with good safety rules results in a better adherence to schedules, lower cost, and higher quality.

Wilson and Koehn [7] suggested that safety practices vary with construction sites. All construction sites have unique aspects of safety to be considered. Larger construction projects are better organized to manage safety aspects. The larger construction firms have one person responsible for keeping the team members informed about possible safety problems. Small to medium firms do not have an adequate safety program or person to oversee safety criteria. Implementation of their safety management is with project superintendent. Wilson and Koehn [7] stressed that good management practices have a positive impact on overall project safety. Safety management analyses the reasons in which people fail to do what is expected from them and/or what is safe for them. It refers to the management of occupational safety, health, and the working environment. It concerns with influencing human behaviour to decrease mistakes which result in unsafe conditions.

Construction safety in India is still in its early years because safety laws are not strictly enforced. The contractors ignore basic safety rules and regulations. Although, to improve working conditions, the government has enacted specific legislation like the *Minimum Wages Act*, the *Workmen's Compensation Act of 1923* (modified in 1962), and the *Contract Labour* (Regulation and abolition) Act of 1970, very little of these are put into practice. *National Building Code of India 2005* provides guidelines for regulating construction activities across the country NBC [13]. Even then, workers' safety in the Indian construction industry is frequently pushed to the bottom stage of priorities by builders, contractors, and engineers.

In developing countries, safety rules usually do not exist, if exist; regulatory authorities are unable to implement such rules effectively. Therefore, effective safety knowledge among construction professionals can reduce accidents that directly or indirectly reduce project cost. Especially in developing countries like India, efforts should be made to raise the level of awareness among the workers and the employers about the importance of health and safety-related issues. Therefore, objective behind this paper was to create awareness among construction practitioners about the safety-related practices in the construction industry. The safety knowledge available on the subject has been categorised and discussed in subsequent sections.

II. CONSTRUCTION SITE HAZARDS

Hazard means inherent property or ability of something to cause harm and potential to interrupt with a process or person. The construction industry has a poor reputation because of high construction site hazards [14]. Hamid et al. [15] defined hazard as anything that can cause harm such as scaffold, excavation, roof work, ladders, etc. Twelve major groups of hazards in relation to works at construction sites (scaffolds, power access equipment, ladder, roof work, manual handling, plant and machinery, excavation, fire and emergency, hazardous substances, noise, protective clothing, and protection to public) have been divided into two major categories: physical injury hazard (associated with process of works or equipment use and climatic conditions such as scaffolds, power access equipment, manual handling, ladder, roof work, plant and machinery, and excavation) and health hazard (chemical, physical, and biological) [15].

Hazards which have risk of physical injury can cause direct injury to workers at site and if severe can cause death. However, hazards which have risk of ill health can only be notified after long time and shall cause sickness or death after certain time period [15]. Work hazards at workplace are either not perceived at all, or considered to be less hazardous than what they actually are [16-17]. In practice, every construction work is full of hazards; every hazard is full of risk, so awareness about safety is essential to prevent accidents on construction sites. Workers should be given information that accidents are not inevitable but are caused. They should be given training to develop skills to recognise the unsafe systems and to report and correct unsafe conditions and practices [18].

III. CONSTRUCTION ACCIDENTS

Accidents in the construction industry are costly in human and financial terms. The economic cost is not the only basis on which a contractor should consider construction safety. The reasons for considering safety are humanitarian concerns, economic reasons, laws and regulations, and organisational image [1]. Cost of safety is paid by the organization either through the uncontrolled cost of accidents or through the controlled cost of safety program [4]. The uncontrolled cost of accidents includes the loss of productivity, administrative time for investigations, disruption of schedules, wages paid to the injured workers, adverse publicity, liability claims, and equipment damage. The controlled cost of safety program consists of salaries of safety, medical, and clinical personnel, expenses for safety meetings, inspections of tools and equipment, orientation sessions, site inspections, personal protective equipment, and health programs [6]. The identification of root causes of accidents is a complex process. Accident mitigation requires a comprehensive understanding of construction process [18].

A. Root Causes

Accidents are the direct results of unsafe activities and conditions, both of which can be controlled by management [18]. Abdelhamid and Everett [19] indicated three main root causes of accidents: failure to identify an unsafe condition that exists before or after the start of an activity, carry on a work in unsafe condition, and decide to perform regardless unsafe site conditions. Ali et al. [20] reveals that construction accidents happen due to unsafe acts and conditions. According to Tam et al.

[21] accidents are caused due to poor safety awareness, lack of training, lack of organizational commitment, poor technical supervision, uncontrolled operation, unwillingness to input resources for safety, shortage of skilled labour, unsafe equipment, lack of first aid facilities, lack of safety regulations, lack of personal protective equipment, lack of innovative technology, and poor information system.

Unsafe conditions (missing guardrails, defective tools, hazardous conditions, excessive noise, and lack of sufficient light) and unsafe behaviours (smoking at workplace, improper use of equipment, work without safety appliances, not to use protective equipment, and being in an unsafe place) are the immediate or the primary causes of accidents [18]. Unsafe conditions and unsafe behaviours are the responsibility of management as these are developed due to the failure of management to anticipate issues like training, maintenance, instruction, and not having safe systems at workplace.

The response of workers to the events which are developing unsafe conditions or unsafe acts is a logical route to accurately determine the root causes of accidents on construction sites [19]. Abdelhamid and Everett [19] stated that:

• Workers who do not have sufficient knowledge about their jobs fail to identify possible unsafe conditions,

• Workers with training and knowledge about their job but with negative attitude towards safety will never be accident free, and

• Management procedures which fail to identify and remove unsafe conditions in a proactive manner cause accidents.

The accident causation theories are tools for accident prevention programs [19]. Several theories like *Domino theory*, *Multiple Causation theory*, and *Human Factor theory* explain the occurrence of accidents. The *Domino theory* stated that an accident results from sequence of five dominoes (factors) standing on an edge in a line close to one another, when the first domino falls it strikes second which in turn knocks down third and so on. Removal of any one of first four will break the sequence and avoid the accident. *Multi Causation theory* stated that the contributing causes together in a random fashion result an accident. The *Human Factors theory* attributes accidents to a series of events caused by human error [20].

Management is responsible for the creation of the working environment, into which workers fit and interact. Proper site management reduce hazards and accidents [8]. Many accidents can be prevented if appropriate information is available at right time and place [22].

B. Factors Affecting

In general, accidents at work place occur due to the lack of knowledge, training, supervision, means to carry out the task safely or due to an error of judgment or carelessness. Sawacha, et al. [5] suggested that historical, economical, psychological, technical, procedural, organization, and working environment are seven groups of factors that influence the performance of safety at work place. The construction safety factors influence a project to larger extent and result in human suffering, delay in project duration, and cost overruns. De-chun et al. [23] suggested that unsafe behaviour of workers is the most significant factor causing site accidents, out of 90% of all construction accidents leading to death, 70% can be prevented by positive management action.

Aksorn and Hadikusumo [24] identified sixteen critical success factors (CSFs) which affect the implementation of any safety program. CSFs were grouped into four dimensions: workers' involvement, safety prevention and control system, safety arrangement, and management commitment. CSFs were defined as areas in which if results are satisfactory, will ensure success. CSFs were considered essential to the success of any program. A safety program can be assessed in terms of no injury to people, no damage to equipment, machines and tools, no damage to environment, no loss of market competition, no damage to company image, and increased productivity. Study revealed that CSFs can contribute to a marked improvement of safety performance. Garza et al. [25] analyzed four leading indicators of safety (*Experience Modification Rate*, *Recordable Incident Rate*, *Lost Time Incident Rate*, and *Workers Compensation Claims Frequency Indicator*) to give the overall picture of the safety performance of a construction project.

C. Risk Estimation and Planning for Safety

Yi and Langford [26] considered the issue of safety risks at work place. Study suggested that safety managers should be well aware of direct causes of accidents along with indirect factors which adversely affect site safety. In order to predict when and where risks will reach its highest level, analysis should be performed based up on the information available. Study analysed accident history and provided the information about vulnerable situations. Study presented a method to estimate risks which help safety managers in safety planning.

IV. SAFETY CULTURE AND CLIMATE

The concepts of safety culture and safety climate were originated from organizational culture [27]. Generally, safety culture is a set of prevailing indicators, beliefs, and values that the organization owns in safety while safety climate is a summary concept describing the employee's beliefs about all the safety issues [28]. Safety climate is usually considered as more superficial than safety culture as it involves the current position of a company [29]. Researchers described safety climate as an

indicator of the overall safety culture of an organisation [30]. Mohamed [31] suggested that safety culture is concerned with the ability to manage the safety whereas; safety climate is concerned with the workers perception. The safety climate is largely a product of safety culture and the two terms should not be viewed as alternatives. Safety culture is crucially important due to the characteristics of decentralization and mobility in the construction industry [27]. Dejoy [32] compared two prominent safety management rubrics: behaviour change and culture change approaches in terms of their conceptual and theoretical foundations.

Choudhry et al. [33] reviewed literature on safety culture focusing on researches undertaken from 1998 onwards. Safety culture is responsible in influencing workers' attitude and behaviour. Some clarifications in terms of positive safety culture, safety culture models, levels of aggregation, and safety performance were provided. Although, the concept of safety culture is relatively new within the construction industry; it is gaining popularity due to its ability to embrace all perception, psychological, behavioural, and managerial factors. Fang et al. [27] established that exceptional relationships exist among safety climate and personal characteristics, including gender, marital status, educational level, and number of family members to support, safety knowledge, drinking habits, direct employer, and individual safety behaviour.

V. ROLE OF OWNERS AND DESIGNERS

Owner's involvement favourably influences a safety performance by setting safety objectives, selecting safe contractors and participating in safety management programme during construction [34]. The facility designers positively influence construction site safety by integrating safety consideration into design process. Gambatese and Hinze [35] developed a design tool to assist designers in identifying project specific safety hazards and their elimination. Study suggested that by considering construction workers safety, designers can eliminate common safety hazards and reduce workers injuries which reduce cost and liability. Also, under Section 15(1) and (2) of OSHA 1994, employers have duty to ensure that employees are not exposed to any hazard at workplace.

A. Owner's Role

Huang and Hinze [34] developed a model to evaluate impacts of owners' practices on project safety performance. Study established four indices (project, selection, contract, and owner) which quantitatively describe the project characteristics, the selection of safe contractors, the contractual safety requirements, and owner's participation in safety management. Literatures [36-38] elaborate that owner improves construction safety in similar ways as that of contractors. The contractor acts as a link between owner and subcontractor. The owner's role in construction safety is to supervise and facilitate safety management on project during construction. Owner may not be a leader in project safety management, but his attitude and physical involvement improve safety performance of general contractor and subcontractors. Owner should input adequate resources for making project safe, instead of relying on contractors.

B. Role of Designers

Prevention through design (PtD) focuses on the decisions made during the design process which create risks for contractors and workers. PtD focuses on what the design professional could or should do to mitigate these risks. The decisions from inception through completion of a construction project, taken by the owner and the designers, affect risks that workers come across. Gangolells et al. [39] stressed that the potential risks to the construction workers have to be identified and mitigated throughout the system to provide a safe work environment.

Hinze and Wiegand [40] suggested that designers should not only consider users of a facility after project completion but must consider facility users as the project is being constructed. The safety of construction workers cannot be granted by legislation alone but should be extended beyond legislation. Contractors and Designers play a strong role in reducing incidents of injuries and fatalities among construction workers. Decisions taken by designers will not only ensure workers safety but also reduce compensation, loss of working days, project cost, and unnecessary delay in project duration. Hinze and Wiegand [40] suggested that the construction workers safety depends on decisions made by the designers during design phase. Toole [41] explored how a designer plays an important role in observing site conditions that poses a hazard and in choosing a component that is less risky to the construction workers.

VI. APPLICATIONS OF INFORMATION TECHNOLOGY

The construction industry is highly labour-intensive, unskilled and semi-skilled labours are cheap, unorganised, being unaware of their rights, builders find it convenient and profitable to use such manpower. While implementing safety regulations and laws many construction companies do not adhere to the safety codes. In such situations, it is very important to introduce virtual environment or IT advancements for the demonstration of construction process, hazards identifications, and safety planning.

Kartam [42] explored a prototype integrated with critical path method for safety and health knowledge-intensive system. It identifies safety and health concerns for those who modify the design and construction methods to make a project less hazardous to construct. Saurin et al. [43] developed an integrated planning and control model for production safety. It

integrates safety into three hierarchical levels: production, planning, and control. Navon and Kolton [44] developed an automated model of monitoring fall hazards in building construction. It identifies locations in building where fall-from-height hazards appear and proposes protective activities to be integrated into the schedule. It monitors the existence of guardrails and warns when something goes wrong. Wang et al. [45] developed an innovative simulation-based model that assesses the hazards for each activity in the construction schedule. The model is an approach to manage safety and schedule simultaneously.

IT technologies enable contractors to share their understanding with designers [46]. IT applications helpful in resolving safety issues are discussed below:

A. Web-Based

Cheung et al. [47] developed a web-based safety and health monitoring system for construction management. Safety performance on site was measured through integration with database, web, and expert systems. Online database was created to evaluate the impact of various hazards at workplace. An online prototype system developed by Yu [48] helps in capacity assessment of various construction professionals. Web-based tool using artificial intelligence (AI) support professionals in their decision-making process on competence basis and perform hazard identification and safety regulation checking [46].

B. Virtual Reality

Virtual reality (VR) is an advanced human-computer interface to simulate a realistic environment [49]. Hadikusumo and Rowlinson [50] developed a VR model for integrating design and construction processes during pre-construction planning stage for improved constructability. The model proposes user-interactive virtual construction sessions that allow designers or builders to construct and criticize the proposed facility using a 3D virtual environment to capture the safety knowledge in terms of experience in safety hazards at workplace and accident precautions. By performing virtual construction during the project's pre-construction planning stage, the designers or builders are able to undertake rehearsals of the construction process, allowing them to analyse and criticize designs as well as performing what-if scenarios for the selection of a safe construction method [51]. A knowledge-based VR enables planners to perform virtual experiments on the construction processes, dynamically visualize the site environment, and identify all possible health and safety problems 52].

C. Four-Dimensional Computer Aided Design

Four-dimensional computer aided design (4D CAD) model is an innovative integration tool which combines two separated information sources, a construction schedule and a 3D CAD model [53]. The construction schedule and 3D model integration allows users to run a visualization of the planned construction process of a project. 4D CAD-safety research integrates 4D CAD and site safety for assisting the designers or builders in analysing and utilizing safety plans in terms of what, when, where, and why a safety measure is needed.

Chantawit et al. [54] and Hadikusumo and Rowlinson [50] removed variations in sequence interpretation in safety planning by using 4D CAD and VR for hazards identifications. 4D CAD facilitates 3D visualisation of construction process on a computer screen and safety engineers to interpret construction sequence. Benjaoran and Bhokha [14] described 4D CAD application that analyses the design information to detect construction hazards and recommend necessary safety requirements. These measures are then inserted into the construction schedule and visualized in 4D CAD together with construction sequences. It helps in creating explicit visual perceptions of the construction process and making it an effective collaboration media for construction team [53].

Safety integration into construction process using 4D CAD is useful in conceptualizing and comprehending the sequence and spatial constraints in a construction schedule. It is a proactive approach to improve construction safety and to relate safety with plans. Safety activities and requirements are identified earlier during the planning phase and inserted in the construction sequence. Safety awareness can be achieved through the visualisation of developed 4D model.

D. Building Information Modelling

Sulankivi et al. [55] explored application of four-dimensional building information modelling (4D-BIM) in construction site safety. It links safety issues to the construction planning and provides more illustrative site layout and safety plans. Koo and Fischer [53] suggested that the construction industry requires a tool that can generate, manipulate, and link the execution schedule with 3D components in single environment. Hence, after 4D CAD, building information modelling (BIM) enhanced the simulation of construction process by linking execution schedule with 3D model. The main idea behind BIM is a single repository where every item is described only once [56]. Sulankivi et al. [55] used 4D-BIM for construction site safety planning. Study illustrated that BIM-based safety planning improves occupational health and safety.

E. Geographic Information System

Cheng and Ko [57] developed a decision support system (DSS) for safety monitoring of hillsides. The system is based on fuzzy set theory to analyse collected data, slope stability, and locate areas of adverse conditions and their causes. The system increases precision and accuracy in decision making in prevention of possible disasters. It uses a geographic information

system (GIS) integrated with relational database management system to display and monitor conditions graphically.

Cheng et al. [58] developed GIS-based decision support system to assist construction engineers in monitoring and controlling the excavation. The layout of construction site and various instruments are represented in various data layers; each layer is integrated with GIS-based relational database management system.

Bansal [59] suggested the use of GIS for retrieving information from the safety database and linking it with the activities of the schedule or components of a building. The safety database along with 4D modelling and topographical conditions in single environment assists safety planners in examining of what safety measures are required when, where, and why. GIS-based navigable 3D animations in construction process facilitate easy understanding of the construction sequence and in prediction of the spots of adverse conditions. GIS-based safety planning along with geospatial analysis facilitates the perception of construction along with surroundings [60].

Manase et al. [61] explored utilisation of various analytical capabilities of GIS and suggested that accident prevention procedures can be positively enhanced by the application of GIS. GIS capabilities enhance the analysis of fragmented construction environment and ease the understanding of various factors in the construction industry to mitigate accidents. GIS-based system known as GIS for accident prevention (GISAP) integrates different datasets to give an overall picture of geographical changes to predict future accident trends along with visual identification of accident spots.

F. IT- Based Site Monitoring

In order to track workers at workplace to reduce rate of accidents, various IT-based safety monitoring systems are installed. Safety monitoring using video cameras helps in tracking multiple workers at workplace. Placements of cameras at workplace for surveillance purpose are becoming more common in reviewing workers productivity and analyse position, activity, and status of construction resources. Yang et al. [62] developed a robust multiple workers tracking system for the construction site surveillance. Teizer [63] utilized 3D range imaging cameras as sensing devices for detecting and tracking of construction resources (workers, equipment, and materials) to reduce the chances of accidents.

Lee et al. [64] developed mobile safety monitoring system to reduce the rate of fatal accidents at workplace. The system consists of four phases, acquiring data, transmitting data, identifying the situation, and managing workers safety. System is automatically informed when workers approach dangerous places by wireless communication. Consequently, safety managers come to know about hazardous situations and take appropriate actions to manage dangerous situations. The system works on mobile sensing device which has several sections such as sensing, alarming, broadcasting a voice message, and sending a message by wireless to the site office in order to keep watch and prevent workers from approaching hazardous situations.

VII. SIGNIFICANCE OF SAFE LAYOUT

Site layout planning involves identifying, sizing, and locating necessary temporary facilities (TFs) on a construction site. TFs range from simple lay down areas to ware-houses, fabrication shops, maintenance shops, batch plants, and residence facilities [65]. TFs are needed to support construction operations and to provide services for workers on site. The inclusion of all necessary TFs and properly positioning them on site can have a positive impact on safety. TFs that have an impact on health and safety include access roads, lay down areas, warehouses, and welfare facilities which consist of first aid station, toilet, rest area, washing facilities, and cafeteria [66]. Good site layout is significant to promote safe and efficient operations, minimize travel time, decrease material handling, and avoid obstruction during movements of materials and equipment [67].

The site layout planning should include safety aspects along with the smooth and low-cost flow of materials, labour, and equipment [68]. Health and safety issues were often ignored in the earlier studies on site layout planning [8]. Improper site layout causes number of injuries, accidents, and work-related illness and contributes additional cost and delays. Elbeltagi and Hegazy [66] suggested that to evolve a safe site and to increase productivity, three aspects namely, defining the necessary TFs needed for safety reason on construction sites, defining proper safety zones around the construction space, and considering safety in the process of determining the optimum placement of facilities must be considered during site layout planning.

VIII. SPATIAL AND TEMPORAL EXPOSURES

The risks and exposures change with time, as building and site topography change, as workers arrive at, move between, or leave certain locations. Sacks et al. [67] revealed that spatial and temporal exposures occur when a space hit by the loss-of-control event overlaps with the region where a victim is present concurrently. Sacks et al. [67] developed algorithm to predict fluctuating risk levels in construction projects which varies in space and time. The software implements the construction hazard assessment with spatial and temporal exposure (CHASTE) model for managing safety in construction. In CHASTE, construction plan and building geometry is used to calculate the extent of exposure. It resolves two issues; firstly extent of exposure on workers to danger posed by activities performed by other teams on site; secondly, it accounts risks and exposure that change through time as building and site topography change [69]. CHASTE helped construction managers in enhancing construction safety by making adjustments in schedules, avoiding risky exposures by providing information of where and when

high risk levels are expected.

IX. SAFETY AND SUSTAINABILITY

Construction workers' safety and health is vital for sustainability of the construction industry. The construction industry's perception of sustainability includes construction workers' safety and health in addition to the safety and health of the facility users. Rajendran and Gambatese [70] recognized safety and health of the workers as part of sustainability initiatives and considered the entire facility life cycle to sustain all resources. Study developed *sustainable construction safety and health rating system* to assist the construction industry in incorporating construction workers' safety and health into sustainability concepts and practice.

X. CONCLUSIONS

While completing high quality work within specified time and cost, safety of workers requires a significant attention. The paper sensitizes construction professionals regarding the importance of safety aspects and their consequences. The review suggests that there is a lack of responsive tools and resources to assist designers in addressing construction safety. Unsafe acts, unsafe conditions, and failure of management to anticipate hazardous situations are the main causes of accidents. Work hazards on project site are not perceived to the extent they can harm, hence, awareness is a safe way to prevent accidents at workplace.

Review suggests that advancements in IT not only facilitate the integration of construction and safety planning but also ensure the delivery of the project without accidents, litigation, and delays. Current growing IT tools such as 4D CAD, BIM, VR, and GIS suggest new ways and means to improve safety. IT tools help in performing virtual rehearsals prior to the commencement of actual construction and enable practitioners to perform what-if scenarios in the selection of a safe construction sequence. GIS assists practitioners in analyzing safety plans in terms of what, when, where, and why safety measures are required.

Literature suggests that owners and facility designers play a crucial role in the selection of a safe contractor and elimination of various safety hazards. PtD approach facilitates their decisions throughout the project and reduces project cost, liability potentials, and more importantly ensures project safety. The safety and health issues of workers and facility users ensure the sustainability of developed the facility. The paper shall act as a guiding instrument to construction professionals for addressing safety aspects during different stages of a construction project.

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