"A Framework for Developing Safety Performance Management at Construction Sites."

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ABSTRACT

To provide a safe construction project environment, safety management in construction is essential. Due to the introduction of safety as one of the criteria in measuring the overall performance of a site on a worldwide level, it has recently acquired popularity in emerging countries like India. There will be an effort made to create a standardized and clearly defined safety performance evaluation framework for use on construction sites. In this case, a three-stage process was used. Three steps are involved in quantifying safety: Establishing what factors influence safety performance; Creating indicators that correspond to those elements; Arriving at a single measurable parameter, the Construction Safety Index (CSI). In order to determine safety, researchers have narrowed it down to various primary and secondary factors based on previous research, case studies and current safety regulations. Principal component analysis will be used to statistically extract the independent elements influencing safety from a questionnaire-based survey based on these considerations. Indicators at both the employee and management levels will be developed based on the identified independent factors. By conducting a second survey to ascertain relative relevance and analyzing the data using the analytical hierarchy approach, we may determine appropriate relative weights for the selected independent elements. To aggregate the safety performance into a single quantifiable metric, an index based on the indicators and their respective weights will be developed; this index can be named as the "Construction safety index." After the indicators is obtained and calculated, their performance in evaluating safety performance will be tested by on-site measurements or simulation models, and the results will be utilized to determine the modified safety index. For construction sites in India in particular, this technique may prove to be an essential element in boosting overall safety. It can serve as an international standard by which other countries measure their own construction safety measures.

Keywords - Safety Management System, Construction Safety, Hazard Identification, Incident Reporting, Safety Performance Metrics.

1.INTRODUCTION

There are many kinds of construction accidents, including falls from great heights, being stuck in or between machines, being struck by things, being run over by automobiles, being electrocuted, having one's clothing ripped off, and the collapse of buildings and other structures. Global When the rotary's location is looked up on Google Earth's position finding system and double-checked on other sites, the following issues arise, excavation, drowning, fire, lift failure, etc. Workers' carelessness and poor site conditions are at blame for these incidents. (Jha, 2012) Accidents can be explained by a number of different variables. The site's security is usually proportional to the scope of the work being done there. The largest construction firms, who handle most of the nation's building projects, are the ones most likely to invest in worker safety by providing them with training and protective equipment. There is a high danger of death or serious injury and a high number of deaths in the Indian construction sector since small contractors dominate the market (they account for 95% of the industry). Annual Report of Ministry of Labour, India, records the following data on the number of fatal and major accidents from 2015 to 2020: (Table 2). First, there has been no decline in fatal accidents between 2015 and 2019; second, this figure is quite low compared to those working in non-coal mines in India; nonetheless, the inefficiency of data collecting makes this statistic a bit dubious. India's non-coal mine fatality rate is disproportionately high compared to that of other nations. This is mostly attributable to the fact that the country's vast majority of employees (83%) are unskilled labourer who have not received enough training.

2.LITERATURE REVIEW

M. *Zhang* et al. (2020*)* -This paper aims to use bibliometric and content-based analysis methods to review the previous attempts in related fields and present the current research status in this field. The results clarify the major limitations and challenges of the current research from both technical and practical perspectives, in turn suggesting the direction of future research.

Umair Khalid et.al (2021) - This paper adopts an empirical research methodology based on literature review and secondary data gathered systematically from peer-reviewed journals. There are around sixty H&S factors and these have been assigned to cluster leadings forming six groups namely: ‘organisational’, ‘managerial’, ‘legislative’, ‘social’, ‘environmental’ and ‘personnel’ factors. In developing the rationale for the safety management system (SMS)

framework it has become apparent that the effective safety performance can only be achieved through effective (1) implementation of safety regulations, (2) leadership, (3) safety planning, (4) safety compliance, (5) performance measurement, (6) risk assessment, (7) safety inspection, and (8) Safety Culture.

***H. Wu* et.al (2022) -**This research, guided by the design science approach, aimed to develop a blockchain-enabled framework for assuring the effectiveness of on-site safety inspection of tower cranes (OSITC). First, a literature review was conducted to identify OSITC challenges and blockchain potential. Then, a blockchain-based conceptual framework was provided, with two major components: smart contracts and the consensus process, being discussed. Finally, using the Hyperledger Fabric architecture, a prototype system was developed to instantiate and test the proposed framework. The findings suggest that the blockchain can protect the OSITC's effectiveness by allowing safety inspections to be automatically executed via smart contracts and providing relevant stakeholders with trustworthy inspection records via consensus algorithms. This study provides a novel solution for tower crane safety management to construction researchers and practitioners, inspiring more discussions about blockchain technology.

Salar Ahmadisheykhsarmast et.al (2023) -This paper presents a novel decentralized blockchain-based system for accident/incident information management of construction projects. The proposed system leverages the benefits and advantages of blockchain, smart contracts, and decentralized IPFS storage to address the security transparency, tampering, and trustworthiness issues of the conventional approaches. The proposed system is simulated by using real-world construction accident data to demonstrate how blockchain technology can provide a novel solution to assure security, transparency, authenticity, availability, and immutability of the accident/incident data for improving safety management.

Nelson Akindele et.al (2024) - This analysis reveals a marked increase in research interest and identifies central thematic connections within the body of literature. The systematic review assesses VR technologies, including immersive, desktop-based, BIM-based, 3D game-based, and augmented reality, addressing their roles in hazard identification and safety training. The study also underscores challenges like infrastructure, content modeling, and interoperability and proposes directions for future research. Recommendations include probing into VR's role in cognitive safety risks and the impact of users' prior safety knowledge on learning outcomes. This study suggests that developing tailored VR experiences for specific user groups could significantly advance safety practices in the construction industry.

3. METHODOLOGY

When developing and evaluating a safety management framework for construction sites, choosing the appropriate research approach is crucial to ensure comprehensive and reliable results. The three primary research approaches—qualitative, quantitative, and mixed methods—each offer distinct advantages depending on the objectives and scope of the study. Here's a detailed description of each approach and how they can be applied to this type of research:

Qualitative Approach
Description:

- **Focus:** The qualitative approach emphasizes understanding the underlying reasons, motivations, and perceptions related to safety practices. It aims to explore the complexity of safety management through detailed and subjective insights.
- **Methods:** Includes interviews, focus groups, observations, and content analysis.

Application in Safety Management Framework:

- **Understanding Experiences:** Conduct in-depth interviews with construction managers, safety officers, and workers to gain insights into their experiences with current safety practices and challenges.
- **Exploring Perceptions:** Use focus groups to explore the perceptions of different stakeholders regarding the effectiveness of existing safety measures and the need for improvements.
- **Case Studies:** Analyze specific case studies of construction sites to understand how safety practices are implemented and adapted in different contexts.

Quantitative Approach

Description:

- **Focus:** The quantitative approach emphasizes numerical data and statistical analysis to measure and quantify safety performance. It aims to provide objective and generalizable findings through structured data collection.
- **Methods:** Includes surveys, statistical analysis, and the use of existing safety performance metrics.

Application in Safety Management Framework:

- **Surveys and Questionnaires:** Develop and distribute surveys to gather quantitative data on safety practices, incidents, and compliance levels across various construction sites.
- **Performance Metrics:** Analyze safety performance metrics such as incident rates, near misses, and compliance rates to evaluate the effectiveness of current safety measures.
- **Statistical Analysis:** Use statistical methods to identify patterns, correlations, and trends in safety data.

Mixed Methods Approach

- **Focus:** The mixed methods approach combines both qualitative and quantitative techniques to provide a more comprehensive understanding of safety management. It integrates numerical data with contextual insights.
- **Methods:** Includes a combination of surveys, interviews, focus groups, and statistical analysis. The mixed methods approach is justified due to its ability to provide a comprehensive, balanced, and practical understanding of safety management practices. By integrating qualitative insights with quantitative data, the research design addresses the complexity of safety management in construction, ensuring the development of a framework that is both evidence-based and contextually relevant. This approach enhances the validity, reliability, and applicability of the research findings, ultimately leading to a more effective and robust safety management framework.

Data Collection-

In the data collection phase, a safety management survey and interviews were carried out. A questionnaire used for safety management survey was distributed by face-to-face meetings and through email to top management representatives of the construction companies including project directors, project managers, safety managers, safety officers, site engineers. While safety management interviews were conducted by face-to-face meetings of the above-mentioned company‟s top management representatives. Qualitative method was used for analysis of management interviews and quantitative method was used for analysis of safety management survey. For this purpose, literature review was carried out on existing safety framework in developed and developing countries. Based on this literature review and the results obtained from above phases, construction safety framework is proposed for implementation of safety on construction sites by local construction companies.

Development of Questionnaire

construction projects were selected for pilot testing of questionnaire, followed by the interviews. The respondents of the pilot study had an experience of more than five years in the construction safety management on sites. This exercise was conducted face to face, ensuring 100 per cent response. From their feedback, the questionnaire was amended and redistributed to same individuals, and a final questionnaire (See Appendix I) consisting of consists of 25 questions covering seven aspects of safety management was developed from the feedback of these experts to suit local environments.

S.No.	Statement	Yes	No
I	**Health and Safety Policy**		
1	Is there a written Health and Safety Policy for this project?		
2	Does the policy comply with local, regional, and national health and safety regulations?		
3	Has a risk assessment been conducted for this project?		
4	Are risk assessments regularly updated?		
5	Have all workers received Health and Safety training relevant to their roles?		
6	Is there a system in place to ensure ongoing training and certification?		
7	Is appropriate personal protective equipment (PPE) provided to all workers?		
II	**Safety Organization**		
1	Is there a designated Safety Officer or Safety Manager for the project?		
2	Is the Safety Officer's role clearly defined in the project's organizational structure?		
3	Are there designated safety roles for different levels of the organization (e.g., supervisors, foremen)?		
4	Are safety responsibilities and expectations clearly communicated to all employees?		
III	**Safety Training**		
1	Is there a structured safety training program for all workers?		
2	Is any training given to new employees?		
3	Is safety training a compulsory item within the budget?		
4	Are there specific training requirements for different roles (e.g., supervisors, equipment operators)?		
IV	**Safety Inspections**		
1	Is there a defined schedule for regular safety inspections?		
2	Is there a standardized checklist or form used during inspections?		
3	Do inspections cover all critical areas such as equipment, work practices, PPE, and emergency procedures?		
4	Are inspection findings documented clearly and promptly?		
5	Is there a system in place for tracking and addressing identified safety issues?		
V	**Safety Promotion**		
1	Are there regular safety communications or briefings conducted on-site?		
2	Are safety signs and posters prominently displayed on site?		
3	Are safety awards meted out on a regular basis with recognition given for good safety performance by individuals?		
4	Is there a structured safety training program for all employees?		

5	Are there safety incentive programs in place to reward safe behavior?		
VI	**Personal Protection Program**		
1	Have the requirements for the provision of personal protective equipment (PPE) been indicated in the contract agreement / safety plan?		
2	Has a sufficient stock of carefully selected and appropriate PPE been obtained?		
3	Have an effective system for the issuance, recording, and inspection of PPE and its replacement been established?		
VII	**Documentation and Accident Prevention**		
1	Has any arrangement made by your company to keep record of accidents occurring during execution of project activities?		
2	Is there a system for tracking and archiving safety documentation?		
3	Are all safety procedures, policies, and protocols documented and readily accessible to all relevant personnel?		
4	Is there a comprehensive safety documentation system in place for the project?		
5	Is there a mechanism for workers to provide feedback on safety practices and suggest improvements?		

4.CONCLUSION

Safety management survey explored seven aspects of construction site safety including (1) health and safety policy; (2) safety organization; (3) safety training; (4) safety inspections; (5) safety promotion; (6) personal protection program and (7) documentation and accident prevention. Conclusions made from the statistical analysis of safety management survey are shown as below:

- The construction company's top management needs to consider the development and implementation of safety, health and environmental management systems. Safety organizational chart needs to be displayed on site.
- Competent safety staff be appointed responsible for implementation of safety practices on site. The concept of submission of specific safety plan by the subcontractor needs to be introduced in the construction industry.
- Health and safety training plan, training to new employees and financial budget to safety are the issues that need attention by management of the company.
- Safety inspections need to be made at regular intervals from the client**.**

- Safety performance needs to be checked at regular intervals at management level by means of conducting safety audits.
- Safety bulletins need to be provided and different awards schemes need to be introduced to motivate and increase the safety performance level of workers at project site.
- The documentation of safety record and accident prevention policy/plan also requires top management attention.

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