

SAFETY MANAGEMENT IN CONSTRUCTION: NEW APPLICATIONS AND INNOVATIONS INVOLVED IN THE CONSTRUCTION FIELD

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ABSTRACT

This paper synthesizes a wealth of literature to elucidate the pivotal role of Building Information Modeling (BIM) technology in advancing safety management within the construction industry. Employing a range of methodologies, including systematic reviews, bibliometric analyses, and empirical studies, the research investigates the impact of BIM on hazard identification, safety training, and overall safety planning. The study extends its focus to other technological interventions, such as IoT and machine learning, in conjunction with BIM, to create a holistic safety management system. Insights from diverse geographical contexts, including China and Egypt, contribute to a global understanding of safety practices. The findings underscore BIM's efficacy in integrating safety measures from design to construction, with a potential for widespread adoption in both developed and developing countries.

Keywords: Construction Safety Management, Machine Learning, Systematic Review Bibliometric Analysis , Safety Leadership

1. INTRODUCTION

The construction industry is inherently complex, involving numerous stakeholders, dynamic environments, and inherent safety risks. In recent years, Building Information Modelling (BIM) technology has emerged as a transformative tool in enhancing construction safety management. This paper presents a comprehensive exploration of the existing literature, focusing on the intersection of BIM, safety management, and technological advancements in the construction sector. The study adopts a multi-faceted approach, incorporating bibliometric analysis, systematic reviews, and empirical studies to provide a nuanced understanding of the role of BIM and related technologies in improving safety practices

2. LITERATURE REVIEW

Yang et al (2019) - The author adopted a three-step literature review approach. The review consisted of bibliometric analysis and scientometric analysis. A total of 35 scholars met the thresholds for citation analysis. Some articles were excluded if they did not focus on safety in construction. Establish a legal framework and regulations for BIM application. Provide government support and publish specific BIM standards and guides. Learn from the experiences of developed countries, such as the UK. Applying digital information technologies and data analytics in safety management. Studying how BIM affects design for safety, site monitoring, and workers' safety behavior. Developing an adaptable safety climate and safety culture model.

Yiu et al (2019) – The author conducted a comprehensive literature review on SMS development and implementation. Recommendations for policy review regarding mandatory enforcement of SMS and its continuous improvement. Delphi survey method Desktop literature review Structured interviews Empirical questionnaire survey Partial least square structural equation modelling. Recommendations proposed for policy review on mandatory enforcement of SMS Facilitated project management to tackle labor shortages, tight project durations, and OSH challenges.

Mark Swallow et al(2019) – The author identified cultural barriers as a factor in 4D adoption. Only 31.2% of organizations currently use 4D modeling. Directors/managers have less awareness of 4D compared to professionals. Questionnaires were used to collect data for the study. The study focused on the application of 4D modeling at a construction site management level. Further academic research into current and developing adoption of 4D modeling. Quantitative study across the UK to enrich data on 4D adoption. Conduct further studies to provide empirical evidence of the value of 4D modeling.

Mário et al (2019) – Author conducted review to explore useful findings in existing literature. Methodological approach used to identify and appraise relevant literature. PRISMA guidelines followed for the systematic review. Databases used: Web of Science, Science Direct, Scopus, and IEEE. Search period: 2008-2018. Search criteria: Construction, BIM, safety, scaffold/scaffolding. Lack of knowledge and solutions for identifying hazards on

scaffolding Need for further research on BIM for construction safety on scaffolding Limited number of proposals for construction safety on scaffolding Analysis of current situation and suggestions for future research on BIM

Serenay et al (2019) - Definition of occupational health and safety management system by Australian scientist Bottomley. Connection and arrangement of processes to achieve specific objectives. Corrective actions as the basis of a systematic approach. Consideration of social structure, technological level, and political and legal system. Consideration of behavior patterns and mentalities of Turkish people. Preparation and implementation of national and international occupational health and safety management system. Occupational health and safety system based on voluntary basis Support defined structure with customary behaviors instead of written rules Implementation of structure by European Union and developed countries Consider social structure, technological level, and political/legal system in Turkey Take into account behavior patterns and mentalities of Turkish people Avoid unrealistic, utopian, or infeasible plans Need for permanent practices and creating standards ISO's contribution to the formation of systematic order at international level Insufficient implementation due to social and organizational culture effects

Serenay et al (2020) - The author identified fifteen factors affecting health and safety management. The questionnaire used a Likert scale to measure the impact of these factors. Health and safety policy, work environment, and inspection were ranked as the top three factors. The study was conducted in Hengyang city, China, which has a growing construction industry. Factors affecting health and safety management in construction industry Health and safety policy, work environment, and health and safety inspection ranked as top factors - Stakeholders need to establish a valuable management system based on local conditions Majority of workers in construction industry have less experience

Mostafa et al (2020) - The paper discusses the elements of safety management systems in the construction industry. It presents different safety management systems from various organizations in different countries. The paper also discusses the importance of measuring safety performance. A field study was conducted to explore contractors' perception on safety management. The study collected and analyzed 200 responses from construction firms. The results showed positive answers, indicating that safety performance in Egypt is slightly above average. The paper discusses the elements of safety management systems in construction. It presents different systems and their elements, such as Oregon OSHA and OTAR. The paper discusses lagging and leading indicators for measuring safety performance. A field study was conducted to explore contractors' perception on safety management. 200 responses were collected and analyzed, showing positive answers. The study suggests that safety performance in Egypt is slightly above average.

Nik et al (2020) - The study used a quantitative design and survey method. Cross-sectional survey was conducted to collect data from selected samples. Questionnaire was used as the instrument for data collection. Quantitative design Survey method (current survey or cross-sectional survey) Data collection through questionnaires Exploratory Factor Analysis (EFA) using Principal Component Analysis (PCA) method with Varimax Rotation. Improvement measurements are proposed for the identified critical factors. The framework of construction safety management based on system thinking can identify faults or failure reasons.

Karim et al (2020) - The paper begins with a review of existing literature and related ontologies. The methodology employed for ontology development is described. The SHE ontology was developed through seven different steps proposed by Noy and McGuinness (2001). Protege editor was used as the ontology editor for its open code, free access, and simplicity. Several ontologies have been proposed in the literature for safety information sharing and job hazards. Future work includes enhancing the developed ontology and evaluating it in real case studies. The research is moving into an industry piloting phase. Designers' active usage will improve the tool's utility and functionality. The aim is to enable risk treatments in a growing safety in design knowledge base.

Amin et al (2020) - Sensor-based systems for improving construction safety have gained momentum in literature. Vision-based monitoring systems are a mainstream research focus in construction. The study provides an overview of recent advancements in safety risk management. Opportunities for future work in the field have been identified. A dataset of 397 documents was analyzed and reviewed in a qualitative analysis. Insole pressure sensors have been used to detect and classify awkward working postures. Future research should focus on integrating sensor-based systems with BIM. Further research is needed to explore how sensor data can be turned into actionable insights. The possibility of developing end-to-end solutions should be investigated.

Nguyen et al (2021) - At the author point of view, BIM technology improves construction safety management. BIM can assist in hazard identification and safety training. 4D-BIM allows visualization of safety arrangements in construction projects. GIS technology connects construction schedule with 3D BIM model. Future studies should

focus on developing tools and working methods for BIM technology in construction safety management. Practical experience in safety planning using BIM needs to be gained. Advanced safety management methods and technologies are needed to address construction occupational accidents in Vietnam.

Narimah et al (2021) - literature review conducted on drivers and barriers of IR 4.0 technologies implementation. Focus on key elements and requirements of IR 4.0 technologies. Systematic literature review conducted to identify drivers and barriers of IR 4.0 in safety construction industry. Future study focuses on key elements and requirements of IR 4.0 technologies. Adoption of smart systems like cyber-physical systems and digital twins in safety management. Identification of drivers and barriers of IR 4.0 in the construction industry.

Fansong et al (2021) - Construction safety literature study conducted using bibliometrics approach. Analysis of construction safety articles published in the 21st century. Focus on construction safety in developed and developing countries. Major organizations and authors involved in construction safety research. Construction safety research in developed and developing countries Major contributors and contributing organizations in construction safety research Hot topics in the construction safety industry - Future directions for research development

Felipe et al (2021) - The authors study used the PRISMA methodology for systematic review. The study consisted of five stages: preliminary, identification, screening, eligibility, and inclusion. The PRISMA flow diagram was used to refine the selection of articles. Perform quantitative and statistical analysis of factors to establish relationships and weighting. Reduce risks and avoid accidents in construction projects. Use the Construction Accident Causation Framework (CACF) for classification. High accident rates in construction industry Safety problems affect workers, families, and social welfare Accidents impact performance, productivity, and project planning

Tomay et al (2021) - The authors review explores the relationship between personality traits and mindfulness. The impact of national culture on mindfulness is still unknown. This study investigates the association of mindfulness with personality traits and national culture.

Regression analysis is used to examine the influence of independent variables on mindfulness. Future studies should investigate the role of other personal characteristics on mindfulness of construction workers. Potential sources of common method bias may affect the results of the findings. This study contributes to the body of knowledge and has the potential to reduce the cost of safety programs.

Tiantian et al (2021) - The author proposes a safety management system for construction workers. The system integrates BIM and IoT technologies for improved safety management. It includes behavior recognition, vital signs monitoring, and safety training subsystems.

The system uses video surveillance, wearable sensors, and 3D models for training. It has automatic data collection, information update, and throughout the life cycle. No information provided about future studies Regression analysis used to examine the influence of independent variables on mindfulness .Data collection instruments, participant characteristics, and data analysis approach detailed Validation conducted through 10 -fold cross-validation.

Mwewa et al (2021) – The author contributes to the body of knowledge in OH&S management. The study recommends adopting compliance, workplace processes, policy, and human resource development.

The findings can be applied to other industries and developing countries, The findings of this study can be applied to other industries. The study contributes to the body of knowledge on management strategy success factors. The study recommends adopting specific factors for improving OH&S performance. The study suggests applying these factors in other countries with similar OH&S issues.

Wei et al (2021) - The author proposes a safety management system for construction workers. The system integrates BIM and IoT technologies for improved safety management. It includes behavior recognition, vital signs monitoring, and safety training subsystems.

The system uses video surveillance, wearable sensors, and 3D models for safety, Safety training subsystem provides 3D model-based training and clarifications. Early warning module alerts and informs personnel in dangerous areas. Violation statistics stop work and require safety training for non-compliant personnel.

Yuting et al (2021) - The author focuses on safety management of civil engineering construction. It uses artificial intelligence and machine vision technology for safety management. The study improves the safety management level of civil engineering structures.

The paper addresses the lack of consistency and insufficient basic research. Study the whole process of emergency management in civil engineering construction safety incidents. Improve construction safety incident management theory. Enhance the construction of emergency response capacity. Improve the level of safety management. Further research needed for harsher environments.

Siyeon et al (2022) - Safety in construction site is given equal importance as per the construction plan. Safety is followed. The results of this study can be applied in future studies. Future studies can investigate the relationship between human factors, SA, and safety performance at construction sites. Physical and physiological data collected using wearable wristband sensor SA measured using SAGAT (SA Global Assessment Technique) Goal-directed analysis used to determine Unsafe behavior is the main cause of accidents at construction sites. Workers have inadequate perception and response to risk factors. Construction industry exhibits a high proportion of work-related injuries and deaths. Causes of accidents include unsafe working methods and poor management.

Bjorn et al (2022) - BIM is a valuable tool for analyzing occupational safety issues. BIM can help avoid hazards and risks and increase safety. BIM integrates safety measures from design to construction and use phases. BIM enables integrated safety planning within construction planning.

The author emphasizes the importance of integrating safety issues in construction work planning. BIM methodology can be implemented in complex and common construction projects. Safety management should be integrated with project management for efficiency. BIM 4D allows for better control and communication among stakeholders.

Paul et al (2022) - The author briefly introduces the concept of leadership competency(ies) and leadership models. The paper explores a holistic view of safety leadership using the Systems Thinking approach. - The paper develops a personal leadership competency model for safety managers. Further investigation of the effect of the leadership competency model on safety outcomes. Testing the impact of the competencies on safety performance in complex environments. Developing a Personal Leadership Competency Model for Safety Managers. Personal leadership competency model Safety managers Systems Thinking approach Emotional, social, and cognitive competencies Nine leadership competencies Complex work environment

Anca Draghici et al (2022) - The author fills a gap in the safety-management literature. It contributes to the existing literature on workplace safety improvement. Limited studies have examined the relationships of safety-management practices in safety-sensitive organizations. Future studies should include measures of safety climate, culture, and safety compliance. Future studies should compare safety-management practices in different organizations. Future studies should consider both safety compliance and safety-management practices. Future studies should focus on workers' safety training and safety-promoting activities.

Floris et al (2022) - The study analyzed the literature on safety management systems. It focused on the design, implementation, effectiveness, and challenges of SMS. The research domain has seen a shift from North America and Europe to Asia and Australia. There are a limited number of institutions contributing to the field. Chinese institutions have been publishing more SMS-related research in recent years. The research is interdisciplinary, with industrial engineering being the most contributing category. The research has focused on various application domains, including occupational health and safety, process safety, patient safety, food safety, and construction safety. Assess impact of SMS research on industrial practices and its success. Explore research from America, Africa, and Central Asia. Incorporate research findings from basic science knowledge domains. Limit bureaucratic approaches in SMS and make them more efficient. Consider the role of SMS in different work settings and uncertainty management.

Muneerah et al (2023) - Numerous computer vision and machine learning approaches have been employed. - YOLO-v5 model outperformed all methods in the literature in terms of inference speed. - YOLO-v5 model showed promising results for detecting workers, PPE, and heavy equipment. - YOLO-v5 model had lower performance in detecting small objects like safety helmets.

YOLO-v5 model can handle imbalanced classes well. - Some objects, like workers behind rebars, were not detected by the model. Enhancements to improve small object detection in the system. Determining safety status of workers based on detected PPE and equipment.

3. CONCLUSION

In conclusion, the literature review reveals a robust body of evidence supporting the instrumental role of BIM and associated technologies in elevating safety standards in construction projects. From hazard identification to integrated safety planning, BIM emerges as a versatile tool that not only enhances safety but also streamlines construction processes.

The paper highlights the interdisciplinary nature of safety management research, incorporating elements of artificial intelligence, machine vision, and geographical information systems. As the construction industry continues to evolve, embracing BIM and technological innovations is imperative for ensuring not only efficiency and precision but, most crucially, the well-being of the workforce. The study provides valuable insights for practitioners, policymakers, and researchers, laying the groundwork for future advancements in construction safety management.

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