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BIM approaches for enhancing safety and health Status in AECO sector: protocol for a systematic review

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Abstract

The construction industry is complex, dynamic, multicultural, and full of diverse activities and dangerous machinery. Many accidents occur because of limiting factors, such as safety and health culture, requirements, poor training of workers, and the restricted technologies implemented to prevent, plan, and monitor risks. Building Information Modelling (BIM) is recognised to enhance project management, planning, and inspection, reduce time and costs, strengthen collaboration, and decrease risks and accidents. A wide array of BIM-based tools and technologies with various functionalities are being investigated to enhance construction workers' health and safety. Among such technologies and methods are tracking devices, Augmented and Virtual Reality (AR/VR), automated rule checking, risk identification and Artificial Intelligence (AI). A systematic review following PRISMA Statement is proposed, aiming to investigate the current BIM-based technologies and evaluate effectiveness and usability within the Architecture, Engineering, Construction and Operations (AECO) industry to enhance occupational health and safety status. Consequently, this PRISMA Protocol (PRISMA-P) represents a complementary document to the systematic review that will be developed. Related articles will be gathered from top electronic databases in construction, safety, and health fields. Moreover, the literature review will focus on the BIM and associated technologies utilised in the AECO sector, exploring the construction fields, targeted groups and the system architectures developed. Likewise, examine the evaluation methods of the implemented tools to assess each technology's effectiveness. Finally, after stating the limitations of each study, the article will propose a safety and health framework involving the most efficient tools involving the whole project lifecycle.

1. INTRODUCTION

Construction projects are by nature long-lasting, complex, and dynamic. The construction process is recognised for having a strict and never halting schedule, overlapping tasks and objectives, various equipment and heavy machinery. Thus, leading to conflicts and disorganisation of the construction site and workspace (Zhang et al., 2011). Consequently, workers' safety and health are often compromised (Zhang, Teizer, Pradhananga, & Eastman, 2015).

Likewise, building construction projects are repeatedly exposed to natural factors, unpredictable environmental conditions, exhausting labours, and using resources for an extended time, making the Architecture, Engineering, Construction and operation (AECO) industry among the most hazardous industries (Ding & Zhou, 2013; Yuan et al., 2019).

Hence, construction accidents are considered global trouble, with countless injuries and fatalities taking place in construction sites worldwide (Shafique et al. , 2019). The United

States and the United Kingdom are considered leaders in construction safety management. They have identified safety accidents as the main issue for a reduced profit of the AECO sector (Ahn et al., 2020).

Furthermore, the construction worker has the most severe accident and death rates between other sectors, even though continual consideration for health and safety is trying to prevent accidents at the governmental level (Ahn et al., 2020).

In 2019, 199,200 injuries and illnesses in the AECO sector were recorded by the Occupational Safety and Health Administration (OSHA). Moreover, one in five worker fatalities were in construction. In addition, the AECO sector was responsible for 9.5 fatalities per hundred thousand full-time workers.

In 2020, the so-called "fatal four", struck-by-objects, Falls, stuck-in, and electrocution, were accountable for 58.6% of deaths of construction employees (U.S. Department of Labor; Bureau of Labor Statistics, 2019[1]).

Wang proposed a new theory for accident causes and prevention based on five accidents causation factors that are important to eliminate to prevent accidents. These factors are Environment and heredity, Management, Personal factors, Job factors, Unsafe actions, and conditions. Thus, the construction site demands consistent and enhanced inspection and supervision. Moreover, staff members must undergo unique and elaborate training prior to on-site construction activities to avoid dangerous behaviours (Wang, 2018).

Despite numerous attempts on job sites to enhance the AECO safety planning, the sector is still dangerous, and traditional safety methods are still far from achieving a zero-accident vision (Zhou et al., 2015). Indeed, old safety measures are error-prone due to manual monitoring and inspection. Subsequently, digitalised safety management, such as utilising Building Information Modelling (BIM), is being implemented (Eleftheriadis et al., 2017). BIM implementation is favourable and can also support continuous innovations in construction practices. BIM could offer fundamental decision-support means for architects throughout the pre-construction and design phases, assist in health and safety planning during the pre-construction phase, improve workers' performance and safety, and enrich site training (Wang & Chong, 2015).

Furthermore, the continuous improvement in the BIM technology has encouraged collaboration and made data communication faster, easier, and more efficient (Hongling et al., 2016; Hossain et al., 2018; Pham et al., 2020). Moreover, as BIM assists in visualising and organising digital data and ease its accessibility, BIM for safety planning is becoming established (Yuan et al., 2019).

BIM has been promptly recognised to modify how construction projects are delivered. Current studies on BIM and Safety cover a wide range of safety functions in construction(Sidani, et al., 2021; Sidani, et al., 2021). Moreover, BIM is able to support health and safety administration and blend safety with other construction planning procedures (Sidani et al., 2020).

This PRISMA Protocol (PRISMA-P) intends to clarify the steps to carry out the systematic review. This review will highlight the types of technologies associated with BIM used in the AECO sector addressing safety and health. In addition, investigate the targeted risks, regulations and standards, fields, user groups, the technologies' system architecture, and evaluate the systems' effectiveness. Finally, based on the limitation of the recent interventions, a BIM-based safety and health framework will be provided involving the whole project lifecycle, assisting the various construction stakeholders in providing a safe construction process.

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[1] www.bls.gov/iif (accessed April 19, 2022)

Objectives

This research protocol aims to investigate BIM-based technologies for safety and health in the AECO sector. Thus, the proposed review will solely provide answers to the formulated questions:

1. Which are the safety approaches that are implemented in the AECO sector?
2. What are the objectives of implementing BIM-based health and safety tools in construction projects?
3. Which phases of the project lifecycle are the health and safety methods implemented?
4. Are the current systems improving traditional methods?
5. What are the common risks being targeted?
6. Are these approaches being implemented on-site or Off-site?
7. Which standards and regulations are being followed in implementing the safety measures?
8. What are the significant limitations of BIM for health and safety, and are the authors tackling these issues?
9. Which target groups are being involved?
10. How is the usability of the tools being assessed? (e.g., quantitative and qualitative approaches, case studies, comparative assessments, user-based evaluations)?
11. What are the main relevant BIM uses and Level of Information Needs specified for BIM-based safety?
12. What are the primary tools used to assist BIM in safety and health methods?

2. METHODS

This protocol follows the elements listed in the checklist of PRISMA-P. The methodology is elaborated in the upcoming sections. The PRISMA-P checklist encompasses 17 points to assist in planning and reporting a robust systematic review protocol (Page et al., 2021).

2.1 Eligibility criteria

The authors plan to follow The Preferred Reporting Items for Systematic Review and Meta-Analysis PRISMA-P as a Systematic Review Protocol. PRISMA checklist will be implemented to handle the collection and synthesis of the articles (Page et al., 2021).

2.2 Type of studies

The study might involve case studies, proof of concepts, and any paper providing information to evaluate the efficiency, identify the system architecture, techniques and methodology of the designed tools, implementation, and the assessment methods to validate the tools will be considered. Other research papers providing information about the BIM-based health and safety solutions will also be utilised.

2.3 Participants

Although PRISMA and PRISMA-P were developed in the health field and any participants are considered for clinical trials, the authors, and since the current systematic review is targeting engineering, the participants mean any person who took part in testing or evaluating the BIM-based tools. Thus, any stakeholder who has used technologies associated with BIM for health and safety or taken part in the implemented process will be considered. The main participants are site, safety and facility managers, architects, owners, students, engineers (surveying, mechanical, electrical, civil), and workers. The study will not have any gender discrimination and age restrictions. These participants will be essential to identify the target groups.

2.4 Interventions

The methods focusing on BIM for safety and health implemented in the AECO sector are of interest to the systematic review. The research might include automated rule checking, construction site planning, training practices, site monitoring, model visualisation and inspections, risk assessment and data management.

2.5 Timing

There will be no time restrictions. The investigation will include any applied intervention related to BIM for safety and health in any phase of the construction process.

2.6 Setting

No setting restriction will be considered.

2.7 Language

Only English publications will be included.

2.8 Exclusion Criteria

The review will reject conference articles, review articles, discussion papers, and unpublished papers. No time restrictions will be considered at first. Studies not related to the AECO sector will be rejected.

2.9 Information sources

The investigated approach will include the top multidisciplinary electronic databases for scientific literature in the field of construction. A previous test was performed to confirm they provide the most relevant and least duplicates, such as: *"SCOPUS, ScienceDirect, Academic Search Ultimate and Web of Science"*. The study will also follow the snowballing technique looking through the articles' references to see relevant studies from any other database that were not collected during the search (Wohlin, 2014), targeting new BIM-based tools and techniques for the AECO sector's health and safety.

2.10 Search strategy

To search as specific as possible but at the same time include all the possible fields of studies, four keywords are considered for the search strategy: ("Building Information Modelling, Construction, Health and Safety"). The second step is to consider the synonyms for the keywords to avoid missing any terms, in this case, ("BIM"). A combination of keywords was formulated to initiate the search. The keywords are in the fields of BIM for health and safety in construction. The combination considered is:

"Building Information modelling" OR BIM AND Construction AND Safety OR Health

Two independent authors will conduct the search. The research will initiate by inserting every keyword combination in one of the electronic databases; no language date or study type will be limited. The total number of articles will be logged in a pre-defined table to keep track of the number of articles for qualitative and quantitative studies. Keeping track of the rejected articles with each limitation will begin with the date, source, subject area, and language.

The final search approach will examine the collected articles' references to check for any relevant study included in the review.

3. STUDY RECORDS

3.1 Data management

When all the possible articles are collected and recorded, the studies will be transferred to (Mendeley), a software to manage references and assist in the screening phase, allowing another check for duplication and managing the data. Titles and abstracts of the gathered papers will be screened. After filtering the results, the full text of the papers will be collected and analysed. Two authors will perform all the mentioned steps independently.

3.2 Selection process

The first step will include screening the articles' titles and will be done independently by two authors to ensure that all articles related to the study are included, and the excluded articles are also similar. In the second step, any doubts or uncertainty that arises from screening the article's titles, abstracts will be screened to confirm the relation between the systematic review's and the article's objectives. Full texts will be gathered after the studies meet the inclusion criteria. Any doubts that arise in the first and second steps concerning the article's relevance, a full-text review will be done, and any further doubts will be included in the review. After merging the independent results, any disagreement between the two authors will be discussed. A third author will settle any arising differences. The elimination of any study following the screening of the entire text will be justified and documented.

3.3 Data collection process

Qualitative information will be obtained from the studies and recorded in the systematic review using a pre-designed table (The consumers and communication review groups data extraction template) (Montgomery & Shepard, n.d.)[2]. The evidence acquired will involve data related to the BIM and health and safety in construction, related technologies, target groups, system architecture, implementation methods, hardware and software used, results of the studies and problems they encountered with future recommendations. Two authors formulated the table to collect the data to answer the research question and objective. Two authors will fill the pre-defined table. Then, the results will be merged. Any issue will be resolved by discussion. A third author will resolve any further conflicts.

<u>Data items</u>

The information obtained in the review will take into consideration four main categories:

- Name and description of the BIM-based tools.
- The tool type includes tools, technologies, description, stakeholders targeted, system architecture, and implementation methods.
- The case studies will be analysed for targeted construction project phases (Design, Pre-construction, construction, operation and management), effectiveness in improving health and safety status, and system evaluation methods.
- The authors' future plans and study limitations.

3.4 Outcomes and prioritisation

Primary outcomes

The review's main outcome is identifying the new BIM tools for health and safety and evaluating the effectiveness and limitations implemented in building construction projects. Additionally, this research will examine the stakeholders, implementation stages (Design, Pre-Construction, Construction, Operation and Management) and fields, system architecture, and advantages of these technologies.

Secondary outcomes

The secondary outcomes are associated with readiness; the review will assess the intervention's effectiveness, hardware, and software. It will also state the intervention's time consumption, expressly:" If the system architecture took more time than allocated and if it impacted the project schedule positively or negatively". The stakeholders' contributions to the tools could be developing the models or assessing them.

[2]https://emptyreviews.files.wordpress.com/2011/11/madridmeetingpresentation-finalpostedits.pdf (accessed April 19, 2022)

3.5 Risk of bias in individual studies

Two separate authors will review the possibility of bias in eligible articles. The study's quality will be assessed utilising the Cochrane Collaboration tool to assess the possibility of bias (Higgins et al., 2019). The following elements of the articles will be evaluated: intervention implementation, stakeholders involved, tools and equipment utilised, and data analysis. In case of conflict, they will be determined by a discussion. Furthermore, a third author will be appointed to settle any further disagreements.

4. DATA

Toxic exposure is a known cause of SFN, and its association with a variety of toxins such as alcohol and chemotherapeutic agents has been well reported in the literature.[1] Emerging evidence suggests that exposure to volatile organic solvents may also cause SFN.[2] This case series discussed the presentation and management of three pathologists who developed SFN, likely due to toxic exposure to volatile organic solvents in their work.

4.1 Synthesis

It is unlikely that a meta-analysis would be possible to conduct since the given data of the studies are primarily qualitative and not quantitative. The authors would adopt a random effect model if the studies' given data were standardised (population, intervention, implementation methods and outcomes). The results might include numerous architectural frameworks or implementation methods. Thus, the results will be categorised into several groups, the project's life cycle phases, type of tools, targeted risks, among others.

In case of any missing data, the studies' authors will be contacted to retrieve this information. If missing data cannot be obtained, the authors will build up the discussion to assume it. For example, if a proposed tool is made to inspect the construction site for risks, but it was not mentioned which target group, construction phases, on-site or off-site, the authors will assume that safety managers will use it during the construction phase on-site.

4.2 Meta-aggregation

A Meta-Analysis would most probably not be applicable for this type of study. If the obtained studies indicated any possibility of developing a meta-analysis, a Meta-aggregation would be amended.

4.3 Meta-bias

A Meta-Analysis would most probably not be applicable for this type of study. If the obtained article showed the possibility of formulation a meta-analysis, a Meta-Bias would be amended.

4.4 Confidence in cumulative evidence

The systematic review is in the engineering field, and the expected findings will not be appropriate for a Meta-Analysis. Consequently, confidence in cumulative evidence will not be applicable as well.

In case the results of the studies showed relevance for a Meta-Analysis, the GRADE (Grading of Recommendations Assessment, Development and Evaluation) method would be used to assess the final evidence and recommendations' quality and strength (Gopalakrishna et al., 2014).

AUTHORS’ CONTRIBUTIONS

All authors took part in reading and approving the final version.

AMENDMENTS

Any further amendments related to this protocol will be illustrated, and the specific date will be mentioned.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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