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# Integrating 4D and 5D BIM into occupational risk prevention in construction sites

## Integração do BIM 4D e 5D à prevenção de riscos ocupacionais em canteiros de obras

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**Abstract**

Occupational risk prevention in construction requires methods capable of anticipating hazards before workers are exposed to them on site. This article analyzes how Building Information Modeling, particularly 4D and 5D BIM, can support preventive safety planning by connecting geometric information, construction sequencing, temporary facilities, regulatory requirements, and cost-related safety decisions. The discussion is based on scientific literature addressing BIM-enabled safety management, fall hazard prevention, workspace planning, virtual reality training, automated rule checking, and smart construction site monitoring. The central argument is that BIM does not replace professional safety judgment, but strengthens it by making hazards visible, schedulable, measurable, and easier to coordinate before execution begins. BIM 4D supports the identification of spatial-temporal exposure, while BIM 5D may improve the visibility of prevention-related costs, including collective protective systems and temporary safety facilities. Although the direct reduction of occupational accident costs depends on implementation maturity and cannot be assumed without project-specific evidence, BIM-based planning may contribute to safer construction processes and more rational allocation of preventive resources.

**Keywords:** Building Information Modeling; 4D BIM; 5D BIM; occupational risk prevention; construction safety.

**Resumo**

A prevenção de riscos ocupacionais na construção civil exige métodos capazes de antecipar os perigos antes que os trabalhadores sejam expostos a eles no canteiro de obras. Este artigo analisa como a Modelagem da Informação da Construção (*Building Information Modeling* – BIM), especialmente o BIM 4D e o BIM 5D, pode apoiar o planejamento preventivo da segurança ao integrar informações geométricas, sequenciamento da construção, instalações temporárias, requisitos regulatórios e decisões de segurança relacionadas aos custos. A discussão fundamenta-se na literatura científica sobre gestão da segurança baseada em BIM, prevenção de riscos de queda, planejamento de espaços de trabalho, treinamento por realidade virtual, verificação automatizada de normas e monitoramento inteligente de canteiros de obras. O argumento central é que o BIM não substitui o julgamento profissional em segurança, mas o fortalece ao tornar os perigos visíveis, programáveis, mensuráveis e mais fáceis de coordenar antes do início da execução. O BIM 4D favorece a identificação da exposição espaço-temporal aos riscos, enquanto o BIM 5D pode ampliar a visibilidade dos custos relacionados à prevenção, incluindo sistemas de proteção coletiva e instalações temporárias de segurança. Embora a redução direta dos custos decorrentes de acidentes de trabalho dependa do grau de maturidade da implementação e não possa ser presumida sem evidências específicas de cada projeto, o planejamento baseado em BIM pode contribuir para processos construtivos mais seguros e para uma alocação mais racional dos recursos destinados à prevenção.

**Palavras-chave:** Modelagem da Informação da Construção (BIM); BIM 4D; BIM 5D; prevenção de riscos ocupacionais; segurança na construção civil.

## Introduction

Construction sites are characterized by temporary configurations, changing work fronts, interaction between multiple contractors, equipment circulation, material storage, height-related activities, and continuous transformation of the built environment. These characteristics make occupational safety management especially complex, because hazards are not static. A workplace condition that is safe in one phase of construction may become hazardous when a new activity, crew, access route, opening, scaffold, or temporary facility is introduced. Therefore, occupational risk prevention in construction requires tools that can anticipate risk conditions before workers are exposed to them physically. Within this context, Building Information Modeling (BIM) has become an important approach for integrating design, planning, construction sequencing, and safety information into a coordinated digital environment [1,2].

The scientific literature on BIM and safety management indicates that BIM can support hazard identification, preventive planning, visualization of risk conditions, and integration of safety requirements into construction processes [1,2]. However, its value depends on how it is implemented. If BIM is limited to three-dimensional visualization or clash detection, its contribution to occupational safety remains restricted. Its preventive potential becomes more relevant when the model is connected to time, logistics, temporary works, safety rules, and cost information. In this sense, 4D and 5D BIM should be understood as complementary layers for risk prevention rather than as isolated technologies.

4D BIM connects the three-dimensional model to the construction schedule, allowing project teams to analyze how site conditions evolve over time. This temporal dimension is critical for occupational safety because many hazards emerge from the sequence of activities rather than from the final design alone. Jin et al. showed that 4D BIM can support construction risk assessment during the design phase, helping designers and project teams evaluate hazards before construction starts [3]. Similarly, Lu et al. proposed a BIM-integrated safety risk assessment approach at the design stage, reinforcing the relevance of early risk analysis in building projects [4]. These contributions are aligned with the principle that occupational safety should be incorporated into planning and design decisions, rather than treated only as a site-level corrective activity.

One of the most technically relevant applications of BIM-based safety planning is the prevention of falls from height. Falls may be associated with unprotected edges, slab openings, temporary access deficiencies, incomplete guardrails, unsafe work platforms, or inadequate sequencing of collective protection systems. Zhang et al. demonstrated that BIM can be used to identify fall hazards and support prevention during construction safety planning [5]. Rodrigues et al. also applied BIM to construction safety in a case study focused on preventing falls from height, showing that digital modeling can assist in identifying hazardous situations and planning safety measures [6]. These studies support the use of BIM as a preventive planning environment for guardrails, safety nets, temporary platforms, protected circulation routes, and closure of openings.

BIM 4D is also relevant for workspace planning. Construction activities often compete for limited space, and unsafe conditions may result from overlapping work fronts, material storage conflicts, equipment movement, and inadequate separation between workers and hazardous zones. Pham et al. proposed a 4D BIM-based approach for planning temporary safety facilities in construction small and medium-sized enterprises, indicating that temporary safety systems should be coordinated with the construction schedule [7]. Getuli et al. further demonstrated that BIM-based immersive virtual reality can support construction workspace planning from a safety-oriented perspective [8]. These findings are important because they show that prevention is not limited to identifying isolated hazards; it also involves designing the spatial organization of the construction site.

Communication and training are additional dimensions in which BIM can strengthen occupational risk prevention. Safety information is often communicated through written procedures, drawings, toolbox meetings, or generic training sessions. These formats may be insufficient when workers need to understand dynamic and site-specific risks. Afzal and Shafiq evaluated 4D BIM and virtual reality for safety communication and training among a multilingual construction crew, showing the potential of visual and immersive methods to improve comprehension of safety information [9]. This evidence is consistent with broader literature on virtual and augmented reality in construction safety, which indicates that immersive environments may improve hazard recognition and risk awareness when properly integrated into training strategies [10].

The integration of accident knowledge, regulatory requirements, and automated rule checking represents another important development. Tran et al. proposed a hazard identification approach combining 4D BIM with accident case analysis of spatial-temporal exposure, linking historical accident information to project-specific construction sequences [11]. Kim et al. developed an automated safety risk assessment framework integrating safety regulations and 4D BIM-based rule modeling, indicating that regulatory criteria can be translated into computational rules for dynamic risk assessment [12]. These approaches are relevant because they reduce exclusive dependence on manual interpretation and enable more systematic identification of unsafe conditions.

The role of 5D BIM should be interpreted with conceptual precision. While 4D BIM emphasizes time and sequencing, 5D BIM connects model elements and activities to cost information. In occupational risk prevention, this dimension may improve the visibility of resources required for safety measures, including collective protection systems, temporary facilities, access equipment, inspections, signage, and preventive planning. Hire et al. proposed a conceptual framework for BIM-based site safety practice, emphasizing the need to structure safety processes within BIM workflows [13]. Alaloul et al. also reported positive perceptions regarding BIM for health and safety in building construction projects, while highlighting implementation challenges [14]. Therefore, BIM 5D should not be presented as a direct guarantee of cost reduction, but as a means of incorporating prevention-related costs into project planning and decision-making.

The integration of BIM with cyber-physical systems, computer vision, and simulation expands the preventive potential of digital safety management. Jiang et al. discussed a cyber-physical system for safety management in smart construction sites, showing how digital models may interact with monitoring and site control technologies [15]. Kulinan et al. advanced this discussion by integrating BIM and computer vision for workforce safety monitoring [16]. Sorbi et al. proposed an agent-based simulation framework for enhanced construction site risk estimation and safety management, indicating that simulation may support more dynamic understanding of risk distribution on site [17]. These technologies should be considered complementary to 4D and 5D planning because they can compare planned safety conditions with actual site behavior.

Despite these advances, BIM-based occupational risk prevention faces limitations. Effective use requires reliable models, accurate schedules, explicit modeling of temporary works, adequate safety rules, and collaboration between designers, engineers, safety professionals, contractors, and site managers. Tender and Couto emphasized the use of BIM for occupational risk prevention in construction sites, but such application depends on organizational capacity and integration with safety management practices [18]. Case-based evidence, such as the study by De Cet et al. on safety support in a water reservoir project, illustrates practical potential but should not be generalized without attention to project context [19]. Recent discussions on BIM's digital potential for construction safety also reinforce the need to address implementation barriers, interoperability, professional training, and integration with regulatory frameworks [20].

From a strategic perspective, integrating BIM into occupational risk prevention is aligned with technological innovation applied to the preservation of workers' physical integrity. It allows safety to be considered before execution, supports the planning of collective protective systems, improves communication among stakeholders, and may contribute to more rational allocation of preventive resources. Its possible contribution to reducing social, institutional, and insurance-related costs should be framed as an indirect and context-dependent implication of better accident prevention, not as a universally demonstrated outcome. This distinction is essential for academic credibility.

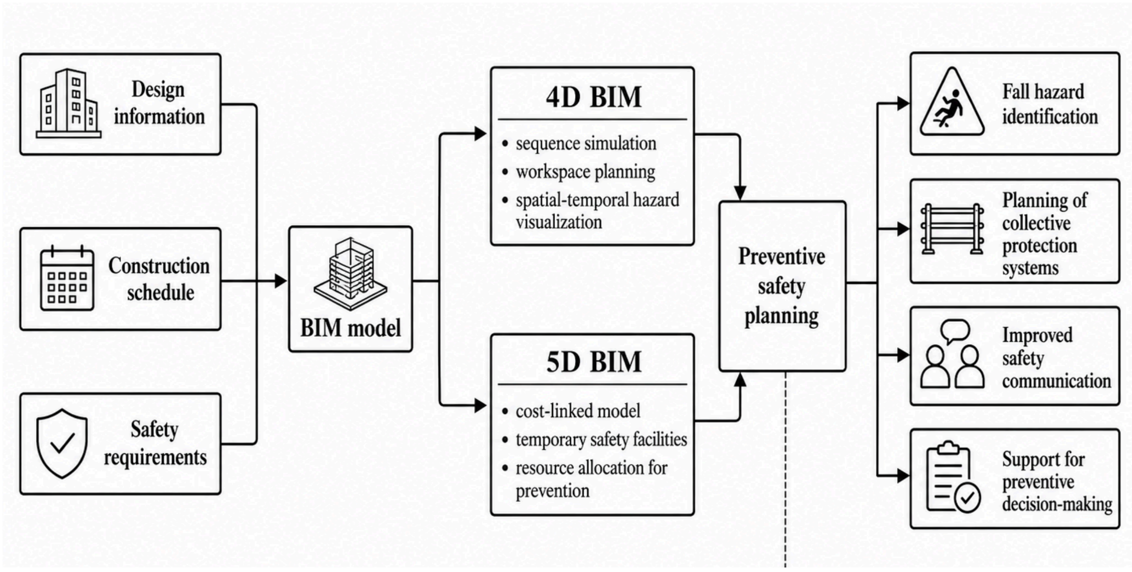


Figure 1. Conceptual integration of 4D and 5D BIM for occupational risk prevention
Source: Created by author.

In conclusion, 4D and 5D BIM can function as preventive layers in construction safety management when they are used to connect design, schedule, site logistics, temporary facilities, safety rules, and cost planning. BIM 4D supports anticipation of spatial-temporal hazards, while BIM 5D may strengthen the economic visibility of prevention measures. The strongest evidence supports applications in fall hazard identification, workspace planning, safety communication, rule-based assessment, and digital monitoring. For civil engineering practice, the integration of BIM into occupational risk prevention represents a shift from reactive control to model-based prevention, provided that the technology is supported by reliable data, professional expertise, and systematic safety governance.

**References**


1. Martínez-Aires MD, López-Alonso M, Martínez-Rojas M. Building information modeling and safety management: a systematic review. Saf Sci. 2018;101:11-18. doi:10.1016/j.ssci.2017.08.015.
2. Fargnoli M, Lombardi M. Building Information Modelling (BIM) to enhance occupational safety in construction activities: research trends

emerging from one decade of studies. Buildings. 2020;10(6):98. doi:10.3390/buildings10060098.

3. Jin Z, Gambatese J, Liu D, Dharmapalan V. Using 4D BIM to assess construction risks during the design phase. Eng Constr Archit Manag. 2019;26(11):2637-2654. doi:10.1108/ECAM-09-2018-0379.
4. Lu Y, Gong P, Tang Y, Sun S, Li Q. BIM-integrated construction safety risk assessment at the design stage of building projects. Autom Constr. 2021;124:103553. doi:10.1016/j.autcon.2021.103553.
5. Zhang S, Sulankivi K, Kiviniemi M, Romo I, Eastman CM, Teizer J. BIM-based fall hazard identification and prevention in construction safety planning. Saf Sci. 2015;72:31-45. doi:10.1016/j.ssci.2014.08.001.
6. Rodrigues F, Baptista JS, Pinto D. BIM approach in construction safety: a case study on preventing falls from height. Buildings. 2022;12(1):73. doi:10.3390/buildings12010073.
7. Pham KT, Vu DN, Hong PLH, Park C. 4D-BIM-based workspace planning for temporary safety facilities in construction SMEs. Int J Environ Res Public Health. 2020;17(10):3403. doi:10.3390/ijerph17103403.
8. Getuli V, Capone P, Bruttini A, Isaac S. BIM-based immersive Virtual Reality for construction workspace planning: a safety-oriented approach. Autom Constr. 2020;114:103160. doi:10.1016/j.autcon.2020.103160.
9. Afzal M, Shafiq MT. Evaluating 4D-BIM and VR for effective safety communication and training: a case study of multilingual construction job-site crew. Buildings. 2021;11(8):319. doi:10.3390/buildings11080319.
10. Li X, Yi W, Chi HL, Wang X, Chan APC. A critical review of virtual and augmented reality applications in construction safety. Autom Constr. 2018;86:150-162. doi:10.1016/j.autcon.2017.11.003.
11. Tran SVT, Khan N, Lee D, Park C. A hazard identification approach of integrating 4D BIM and accident case analysis of spatial-temporal exposure. Sustainability. 2021;13(4):2211. doi:10.3390/su13042211.
12. Kim D, Yoo T, Tran SVT, Lee D, Park C, Lee D. Automated safety risk assessment framework by integrating safety regulation and 4D BIM-based rule modeling. Buildings. 2024;14(8):2529. doi:10.3390/buildings14082529.

13. Hire S, Sandbhor S, Ruikar K. A conceptual framework for BIM-based site safety practice. Buildings. 2024;14(1):272. doi:10.3390/buildings14010272.
14. Alaloul WS, Qureshi AH, En YP, Khan SA, Musarat MA, Alzubi KM, et al. Survey evaluation of Building Information Modelling (BIM) for health and safety in building construction projects in Malaysia. Sustainability. 2023;15(6):4899. doi:10.3390/su15064899.
15. Jiang W, Ding L, Zhou C. Cyber physical system for safety management in smart construction site. Eng Constr Archit Manag. 2021;28(3):788-808. doi:10.1108/ECAM-10-2019-0578.
16. Kulinan AS, Park M, Aung PPW, Cha G, Park S. Advancing construction site workforce safety monitoring through BIM and computer vision integration. Autom Constr. 2024;158:105227. doi:10.1016/j.autcon.2023.105227.
17. Sorbi T, Getuli V, Capone P, Rahimian FP. Agent-based simulation framework for enhanced construction site risk estimation and safety management. J Inf Technol Constr. 2024;29:1219-1238. doi:10.36680/j.itcon.2024.054.
18. Tender M, Couto JP. Prevention of occupational risks in a construction site using BIM. In: Arezes PM, Baptista JS, Carneiro P, Branco JC, Costa N, Duarte J, et al., editors. Occupational and Environmental Safety and Health III. Cham: Springer; 2022. p. 63-73. doi:10.1007/978-3-030-89617-1_6.
19. De Cet G, Miazzi N, Paparella R, Boso DP. How Building Information Modeling technology supports safety on construction sites: the case study of a water reservoir in Italy. Buildings. 2025;15(3):403. doi:10.3390/buildings15030403.
20. Manzoor B, Charef R, Antwi-Afari MF, Alotaibi KS, Harirchian E. Revolutionizing construction safety: unveiling the digital potential of Building Information Modeling (BIM). Buildings. 2025;15(5):828. doi:10.3390/buildings15050828.

21. Sustainable solutions for urban infrastructure: The environmental and economic benefits of using recycled construction and demolition waste in

permeable pavements. (2025). *ITEGAM-JETIA*, *11*(53), 131-134. https://doi.org/10.5935/jetia.v11i53.1886

22. Analysis of the performance of helical piles under various load and geometry conditions. (2025). *ITEGAM-JETIA*, *11*(53), 135-140. https://doi.org/10.5935/jetia.v11i53.1887