

ARTIFICIAL INTELLIGENCE IN CONSTRUCTION: CONTEMPORARY TRENDS AND EMERGING DIRECTIONS

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Abstract

This study examines current research on artificial intelligence (AI) in construction by combining key international studies with the available Bulgarian scholarly literature. The research shows that recent work has moved from general discussions of AI to integrated applications involving BIM, digital twins, computer vision, structural health monitoring (SHM), robotics, large language models (LLMs), and intelligent energy management. Although smaller in volume and only partly visible internationally, the Bulgarian literature indicates emerging directions related to AI in construction, BIM with AI elements, digital transformation, diagnostics of hydraulic structures, and energy-related applications. On this basis, the paper identifies the main contemporary trends, persistent research gaps, and priorities for future work.

Key words: artificial intelligence, construction, building information modelling, digital twin, computer vision, structural health monitoring, energy efficiency

Introduction. Artificial intelligence (AI) is increasingly evolving from a stand-alone digital tool into a structural driver of transformation in the construction sector. Because construction remains one of the least digitalised industries, AI is increasingly viewed as a means of addressing persistent problems such as low productivity, delays, cost overruns, safety risks, and limited process predictability [1, 2].

The earlier review literature focused on machine learning, expert systems, neural networks, and genetic algorithms, whereas later studies expanded the discussion to deep learning, computer vision, natural language processing, robotics, and digital management platforms [1–3]. The most recent publications from 2025–2026 show a higher level of integration: AI is analysed together with BIM, the Internet of Things (IoT), digital twins, sensor networks, cloud systems, and LLMs [4–11].

This paper adopts a systematic review perspective focused on scientific rather than popular literature. It combines international review studies, thematically central papers, and accessible Bulgarian academic sources in order to compare global developments with the emerging national research agenda. Because part of the Bulgarian output is not fully indexed in major international databases, these sources are treated cautiously as evidence of emerging local research activity rather than as a fully consolidated and globally visible research corpus.

Methodological and terminological framework. Examining artificial intelligence (AI) in construction requires both technological and civil-engineering perspectives. In this paper, AI is understood as an umbrella term covering machine learning, deep learning, natural language processing, large language models, computer vision, optimisation algorithms, and data-driven decision-support systems. Building Information Modelling (BIM) is treated as a coordinated digital environment for the planning, design, construction, and operation of built assets; Structural Health Monitoring (SHM) as the assessment of structural condition through measurements, sensors, and analytical models; Digital Twin as a dynamic data-linked digital counterpart of a physical asset; and Common Data Environment (CDE) as the shared platform in which project information is collected, exchanged, and updated.

Recent literature suggests that AI should not be assessed solely by model accuracy, but also by its capacity to be embedded in real construction processes. For this reason, current review papers classify applications not only by algorithm type, but also by stages of the asset life cycle: design, construction management, monitoring, operation and maintenance, and sustainability and energy efficiency [3–9].

Global scientific literature: from general reviews to integrated systems. General evolution of research. The reviews by DARKO et al. [1] and ABIOYE et al. [2] are foundational for understanding the field because they document the transition from fragmented applications toward a recognisable research area in architecture, engineering, and construction (AEC). Later reviews broadened the perspective to the full construction value chain, from pre-investment and design to construction, operation, and maintenance [3].

AI in construction project management. One of the strongest lines in recent literature concerns AI in construction project management. GAO et al. [4] show that cost, time, and safety management remain the leading domains, with AI used for estimation, delay-risk prediction, scheduling, hazard identification,

PPE detection, and accident prediction [4]. This confirms that AI is adopted first where repetitive project data are abundant and where better forecasting can directly improve project success.

Integration between AI and BIM. The integration of AI and BIM is one of the most important structural shifts in recent literature. BIM is no longer treated only as an information model of the asset, but as a central data environment on which AI adds analysis, prediction, coordination, and automation. The main areas of overlap include Building Information Modelling, 4D/5D BIM, clash detection, CDEs, digital twins, and automated control processes [5].

Large language models (LLMs) and generative AI. The newest wave in the literature is associated with large language models (LLMs) and generative AI. Recent reviews show that LLMs are entering construction as tools for knowledge synthesis, document interpretation, regulatory support, contract processing, and question answering over BIM/IFC content, while also raising concerns about hallucinations, domain-specific inaccuracies, verification, and data protection [11].

Computer vision, safety, and monitoring. Computer vision is among the most practically mature AI domains in construction. Current reviews describe integrated monitoring systems using fixed and mobile cameras, UAVs, wearable devices, and multi-sensor configurations for progress tracking, object recognition, hazard detection, PPE control, and comparison between planned and executed work [4, 6]. The field is moving from reactive safety analysis toward proactive, explainable, and user-centred monitoring solutions.

Structural health monitoring (SHM). Structural health monitoring (SHM) is another area in which AI already has substantial engineering value. The literature shows a transition from traditional vibration-based approaches to vision-based techniques, multi-sensor data fusion, and automated damage diagnosis, enabling earlier defect detection and better maintenance planning for bridges, dams, transport infrastructure, and buildings with high reliability requirements [7].

Digital twins, IoT, and real-time data. Digital twins are now discussed as AI-enhanced systems rather than merely as dynamic digital representations of physical assets. In combination with IoT, sensors, and cloud platforms, AI-driven digital twins support real-time monitoring, predictive maintenance, quality control, dynamic scheduling, and stronger links between design, execution, and operation [5, 9].

Robotics and automation. Robotics in construction is increasingly associated with AI-driven autonomy rather than simple mechanisation. Recent reviews frame the field through the Sense-Think-Act logic and highlight object recognition, action planning, human-robot interaction, robotic assembly, inspection, and autonomous site operations, especially in dangerous, repetitive, labour-intensive, or highly standardised tasks [10].

AI, sustainability, and energy efficiency. AI is also becoming important for sustainability and energy efficiency. The current literature links AI to

predictive control, pattern recognition, adaptive operation, and smart-building management, connecting optimisation not only with construction processes but also with long-term building performance, HVAC operation, indoor environmental quality, and low-carbon operation [8].

Bulgarian scientific literature: emerging directions and publication contexts. Bulgarian scholarly output on artificial intelligence in construction remains considerably smaller than the international body of literature and is not fully visible through major indexing systems. Nevertheless, the accessible national publications, including journal articles and university annals, make it possible to identify several emerging thematic directions rather than a fully consolidated field. A first direction is the general conceptual discussion of AI in construction, represented by the contribution of ZDRAVKOV and NEDYALKOV [12].

A second direction concerns BIM, digitalisation, and more intelligent design and management environments. In this respect, the contribution of MAVROVA-GIRGINOVA [13] on digital transformation in hydraulic engineering and the development of BIM with elements of artificial intelligence is particularly indicative.

Closely related to this is the application of AI to diagnostics and monitoring in civil-engineering contexts. MAVROVA-GIRGINOVA's work [14] on the technical diagnostics of dams points to the use of neural-network-based and data-driven approaches in the assessment of hydraulic structures.

The Bulgarian context should also include publications dealing with digital transformation in a broader sectoral sense. The contribution of ANTONOVA and CHAPAROV [15] is relevant because it discusses the advantages and barriers of digital transformation in Bulgaria, including digital competences, technological uptake, and institutional constraints in the construction sector.

A further recent line is associated with intelligent systems, Industry 5.0, and energy-related applications in buildings. The article by SIMONOV et al. [16], indicates that Bulgarian authors are increasingly connecting AI with intelligent systems and energy-oriented solutions in the built environment.

Taken together, these Bulgarian sources do not constitute a fully consolidated and internationally visible research corpus, but they do indicate several promising directions of local academic activity: conceptual framing of AI in construction, BIM-linked digitalisation, diagnostics and monitoring of engineering structures, digital transformation, and energy-related applications. The Bulgarian case should therefore be understood as an emerging research landscape documenting the early formation of a national scholarly agenda in this field.

What is new in the contemporary literature? The most novel feature of the contemporary literature is not any single AI algorithm, but the integrative character of recent developments. Global publications increasingly treat AI as part of a unified digital ecosystem in which BIM, digital twins, computer vision, IoT, cloud platforms, robotics, and text- and knowledge-analysis systems interact [3–11]. A second new feature is the move toward agentive and real-

time systems that support ongoing managerial decisions, interpret documents, feed digital twins, compare planned and executed work, and assist autonomous or semi-autonomous robots [5,9–11]. A third is the growing attention to the organisational preconditions of AI adoption: data governance, institutional capacity, skills, and implementation strategies [17]. In the Bulgarian case, novelty should be understood not as evidence of a mature field, but as an indication of expanding thematic scope and increasing local academic attention to AI-related topics in construction and the built environment.

Main challenges and research gaps. Despite visible progress, the literature outlines several persistent challenges. Data quality remains problematic because construction data are often unstructured, fragmented, and generated in incompatible formats [2, 5, 6]. Explainability is increasingly important because construction decisions are taken under regulatory constraints, contractual responsibilities, and high safety risks, which makes black-box models difficult to adopt without reservation [4, 6, 7]. Interoperability among BIM, CDE, IoT, and digital-twin environments is still insufficient [5, 9, 15]. Finally, successful implementation depends not only on technology, but also on organisational readiness, stakeholder coordination, and the availability of trained personnel [17].

Prospects for the Bulgarian context. For the Bulgarian construction-engineering community, several directions appear particularly promising. These include AI in energy-efficient and sustainable construction, especially for building-system management and operational optimisation [8]; the integration of AI with BIM and digital twins in buildings and infrastructure assets [5, 9, 13]; and AI for diagnostics, monitoring, and technical operation of hydraulic and other engineering structures [7, 14]. At the same time, terminological and methodological stabilisation remains necessary, given the rapid entry of English concepts into construction literature.

Practical implications for science and practice. From a practical point of view, the accumulated literature shows that AI has the highest readiness for implementation in automated site observation, safety analysis, forecasting of delays and costs, energy optimisation of building systems, and monitoring of the technical condition of structures [4, 6–10]. These are applications in which data availability, measurable effect, and relatively clear criteria for evaluation coincide.

For academia, this means that future Bulgarian studies should increasingly be organised around real pilot cases rather than general conceptual claims, for example AI-based energy diagnostics of buildings, AI and BIM analysis in reconstruction and renovation, AI in the monitoring of hydraulic structures, and risk assessment using multimodal data [7, 8, 13, 14, 16]. For practice, this implies phased implementation: instead of seeking a universal AI system for all tasks, the more realistic approach is the gradual accumulation of good practices in separate domains such as site safety, schedule management, building management, and energy efficiency.

Directions for future research. Future research at the international level is likely to converge around several themes: domain-specific models and benchmark environments for construction, explainable and trustworthy AI, and stronger evaluation in terms of engineering usefulness, reliability, and robustness rather than only generic machine-learning metrics [4, 6, 7, 11, 17].

Conclusions. Artificial intelligence is already one of the main drivers of digital transformation in the construction industry. International research shows an accelerated transition from fragmented applications to integrated systems in which AI operates together with BIM, digital twins, computer vision, SHM, robotics, and energy-optimisation systems [3–11].

The Bulgarian literature is smaller in volume and only partially visible through major international databases, yet the available publications indicate several emerging directions: AI in construction, BIM with AI elements, technical diagnostics, digital transformation, and energy-related applications [12–16]. These directions should be interpreted as signs of a developing national research agenda rather than as a fully established and internationally consolidated field. More generally, the future of AI in construction will depend not only on advances in algorithms, but also on the ability to build reliable data resources, interoperable environments, trained specialists, and a clear methodological framework.

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