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Empowering research for Sustainable Development Goals, ABC2: Architecture, Building, Construction, and Cities is a fundamental manifesto to address these pressing issues, fostering dialogue and knowledge exchange among researchers, practitioners, and policymakers. Exploring sustainable design, resilient infrastructure, advanced construction methods, and equitable urban development, ABC2 aims to empower the global community to create adaptive, inclusive, and sustainable environments. The ABC2 focus on cutting-edge research, technological advancements, and transformative strategies is essential for navigating the future of our cities and communities.

Editorial Article

Technology, Safety, and Regulatory Innovation in Built Environment Research

Farzad Rahimian[1*], Ashraf M. Salama[2]

[1*] School of Architecture, Building and Civil Engineering, Loughborough University, Loughborough, UK
[2] School of Architecture and Built Environment, Northumbria University, Newcastle upon Tyne, UK

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* Correspondence: f.rahimian@lboro.ac.uk

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Abstract

This editorial frames the second issue of *ABC2* around the convergence of technological innovation, safety management, and regulatory adaptation in the built environment. Despite the economic and social significance of the Architecture, Engineering, and Construction (AEC) sector, persistent fragmentation, declining workforce levels, and safety risks continue to challenge industry performance. Against this backdrop, the editorial situates Industry 4.0 and the emerging Industry 5.0 paradigm as transformative forces capable of reshaping construction processes, infrastructure resilience, and decision-making through human-centric, data-driven, and sustainable approaches. The contributions demonstrate how advanced technologies—such as Digital Twins, artificial intelligence, machine learning, extended reality, and data analytics—are being operationalised to address real-world challenges. Case studies span regulatory innovation in modular construction, global smart home typologies, predictive modelling for infrastructure failures, and proactive safety management for utility and highway workers. Together, they reveal how digital tools must be accompanied by regulatory evolution, organisational learning, and professional competence to realise their full potential. The editorial highlights several cross-cutting themes: the necessity of aligning technological advancement with regulatory frameworks; the growing centrality of data-driven methodologies; the influence of geographical and institutional contexts on implementation; and the enduring importance of human factors in safety and design. By synthesising these insights, the editorial positions Issue 2 as a significant step in ABC2's mission to cultivate evolving knowledge spaces at the intersection of technology, policy, and practice. It concludes by inviting further contributions that integrate analytical rigour with societal relevance to advance safer, smarter, and more resilient built environments.

Keywords: Digital innovation; Construction safety; Regulatory adaptation; Industry 4.0 and 5.0; Data-driven decision-making

Highlights

- Explores how advanced technologies reshape safety, regulation, and infrastructure resilience.
- Demonstrates the role of data-driven and AI-based methods in proactive risk management.
- Reinforces ABC2's mission to integrate technology, policy, and human-centred design

1 The AEC Industry at a Technological and Paradigmatic Turning Point

The Despite its significant impact on industrial employment (representing approximately 6% of total UK employment) and contribution of over £141 billion in gross value added to the economy in 2023 (ICAEW, 2025; ONS, 2024), the UK Architecture, Engineering and Construction (AEC) industry has been continuously criticised for its fragmentation for over six decades, resulting in numerous major industry reports. The industry currently employs approximately 2.05 million workers as of Q3 2025, though this represents a decline of 1.6% year-on-year and remains 12% lower than pre-pandemic levels (BCIS, 2025). The knowledge gap between design and construction continues to be identified as a major reason for this persistent discontinuity, with fragmentation, adversarial relationships, and ineffective integration across the project lifecycle remaining central issues highlighted in successive reports from Latham (1994) and Egan (1998) through to the Farmer (2016) and recent government construction strategies (HM Government, 2011; Strategic Forum for Construction, 2002).

The world has never been exposed to such a paradigm shift prior to the emerging industry 4.0 revolution – the governing foundations for shaping and delivering progressive changes for addressing issues embracing Society, Knowledge, Economy, and People (Rahimian *et al.*, 2021; Sheikhkhoshkar *et al.*, 2025a). Scientific advances and innovative technologies in architecture, engineering, and construction (AEC) are key factors in this process, the tenets of which can help countries move towards developing smarter and more sustainable communities (Najafi and Rahimian, 2025). The European Commission's Industry 5.0 framework extends this evolution by integrating human-centric innovation, resilience, and sustainability, to align technological advancements with societal and environmental needs (Najafi *et al.*, 2025). In this respect, the nine pillars supporting Industry 4.0 are widely accepted by the research and practice communities to include: the integration of extended Reality (XR=VR/AR/MR) (Potseluyko *et al.*, 2022; Rahimian *et al.*, 2019); where Digital Twins (Adu-Amankwa and Rahimian, 2025; Bakhshi *et al.*, 2024; Meng *et al.*, 2025) and mainstream Building Information Models (Bakhshi *et al.*, 2022) in particular are seen as a vehicle for addressing such issues as industry fragmentation, value-driven solutions, decision making, client engagement, and design/process flow to name but a few.

Advanced Simulation (Seyedzadeh *et al.*, 2020), Computer Vision (Pour Rahimian *et al.*, 2020), Internet of Things (IoT) (Okonta *et al.*, 2025), Blockchain (Basheer *et al.*, 2024), Machine Learning (Seyedzadeh *et al.*, 2020), Deep Learning (Lee *et al.*, 2021), and Linked Data (Matarneh *et al.*, 2022) all provide immense opportunities for dealing with these challenges; more importantly, perhaps, provide real tangible (evidenced-based) innovative solutions that until now, have never been possible before. These technologies, alongside Large Language Models (LLMs) (Zhou and Xue, 2025) and Natural Language Processing (NLP) (Salimi *et al.*, 2025), provide unprecedented opportunities to tackle challenges and drive tangible, evidence-based innovations in the built environment (Sheikhkhoshkar *et al.*, 2025b). They are perceived as the 'true' enablers of future practice. Examples from other industries such as automotive, aerospace, and oil and gas have provided a showcase of solutions using advanced technologies. However, until relatively recently, AEC has only started to recognise terms such as "golden key" and "golden thread" as part of Digital Twins processes and workflows, recognising their potential in creating interconnected, transparent, and resilient systems.

As the journey of ABC2 evolves beyond the inaugural issue, we are pleased to present the second collection of research that exemplifies our commitment to cultivating diverse knowledge spaces across architecture, building, construction, and cities. The five articles in this issue demonstrate a convincing convergence around two interconnected themes. The first is technological innovation in construction processes, and the second is safety and risk management in infrastructure systems. The contributions within these themes advance both established and evolving knowledge spaces while addressing critical challenges facing the built environment today.

The inaugural issue established ABC2's foundational mission to bridge disciplinary boundaries and foster knowledge production that is methodologically rigorous and diverse, geographically distinct and inclusive, and epistemologically plural. Issue 2 capitalises on this foundation by demonstrating how

digital transformation, data-driven methodologies, and innovative analytical frameworks are reshaping our understanding of infrastructure resilience, occupational safety, and regulatory adaptation. From Hong Kong's regulatory responses to modular construction to global patterns in smart home implementation to advanced predictive modelling for infrastructure failures and worker safety, the contributions reveal how contemporary built environment research increasingly relies on complex computational methods while remaining firmly anchored in real-world challenges and practical applications.

2 Digital Innovation Transforming Construction and Regulatory Practices

The connection between construction innovation and regulatory adaptation emerges as a critical knowledge space in this issue. Fauth et al. (2025) investigate whether Modular Integrated Construction can contribute to the rationalisation of building permit processes in Hong Kong through a comprehensive SWOT analysis. Their findings uncover that MiC's prefabrication and standardisation facilitate rapid regulatory approvals through mechanisms such as In-Principle Approval and pre-approved component libraries. However, challenges persist, including regulatory misalignment, interdepartmental coordination complexities, and the need for clearer integration guidelines. This research addresses a fundamental challenge in the construction industry, which can be expressed as a key question: How can regulatory frameworks designed for conventional cast-in-situ methods adapt to accommodate innovative offsite construction approaches? The Hong Kong case offers valuable lessons for authorities worldwide seeking to modernise permission systems while maintaining safety and quality standards.

Aligning with this regulatory perspective, Ehteshami et al. (2025) provide a comprehensive typological analysis of global smart home implementations, demonstrating how residential buildings are being transformed through digital integration. Through systematic examination of diverse applications across multiple continents, the authors develop a framework that categorises smart homes as Integrated, Supportive, Defensive, Lifestyle, Efficient, and Intelligent. Their findings reveal significant geographical patterns, with European implementations accentuating healthcare applications while North American cases focus on lifestyle enhancements. This study advances the ***Building*** knowledge space by demonstrating how smart technologies adapt to specific user needs and local priorities, from security systems for vulnerable households to health monitoring for elderly residents and efficiency features for environmentally conscious users. The emphasis of the study on user-centric design and the non-monolithic nature of smart home implementations provides relevant insights for architects, technology developers, and policymakers.

3 Data-Driven Approaches to Infrastructure Resilience and Safety

A distinctive characteristic of this issue is the prominent role of advanced analytical methods in addressing infrastructure challenges, thus contributing to the ***Construction*** knowledge space. Mohandes et al. (2025) introduce a novel integration of Picture Fuzzy Set Theory with the Delphi Technique and System Dynamic Modelling to analyse factors contributing to sewer pipeline failures. Their study identifies eleven critical sub-factors, with pipe age, materials, third-party damages, internal corrosion, and various crack types emerging as primary culprits. Capturing the uncertainty inherent in expert judgments through Picture Fuzzy Sets while simultaneously modelling the complex interrelationships among deterioration factors through System Dynamics, this work represents how computational approaches can enhance infrastructure asset management. The findings provide important guidance for identifying maintenance interventions and reducing environmental impacts associated with sewer system failures, proving how advanced modelling techniques translate into strategies for infrastructure resilience.

Safety management in construction and infrastructure operations receives renewed attention through two complementary studies focusing on different aspects of occupational risk. Sarvari et al. (2025) conduct a qualitative analysis of utility strike incidents in the UK, identifying thirty-three causes categorised into worker-related and work-related issues. Through systematic coding of incident reports using NVivo software, the research uncovers that inadequate leadership, insufficient competence, and unskilled operators constitute primary antecedents to utility strikes. Most considerably, the study proposes an innovative three-phase framework (pre-event, event, and post-event) that operationalises both proactive and reactive safety measures. This framework synthesises Safety I and Safety II principles, offering practical guidance for organisations seeking to prevent utility strikes while building organisational learning capacity.

Extending this safety focus to highway operations, Bortey and Edwards (2025) developed a machine learning-based predictive model for classifying body parts most susceptible to injury among highway workers. Using a comprehensive dataset of over 72,000 incidents, the research demonstrates that Support Vector Machine algorithms achieve 99% classification accuracy when predicting anatomical injury risk. The study identifies region, site/project, event type, vehicle involvement, and location as key predictors, with legs/knees, lower arms, and heads emerging as the most frequently injured body parts. Suggesting a user interface concept that visualises vulnerable body regions based on modelled risk profiles, this study demonstrates how machine learning can transform safety management from reactive incident analysis to proactive risk prediction, enabling targeted interventions and resource allocation.

4 Technology, Data, and Decision-Making

The five articles selected for issue 2 of ABC2 validate the productive possibility of integrating advanced analytical methods with domain-specific expertise to address key built environment challenges. Several common threads emerge that warrant reflection.

- *First, technological innovation*, whether in construction methods (Fauth et al., 2025), residential systems (Ehteshami et al., 2025), or analytical techniques (Mohandes et al., 2025; Sarvari et al., 2025; Bortey & Edwards, 2025), technological innovation requires corresponding evolution in regulatory frameworks, organisational practices, and professional competencies. The Hong Kong MiC case shows how policy incentives and pre-approval mechanisms can facilitate innovation adoption, while the utility strike analysis reveals how inadequate leadership and training can undermine the strength of technological solutions.
- *Second, data-driven decision-making* emerges as a unifying methodological approach across ***Building*** and ***Construction*** knowledge spaces. From Picture Fuzzy Set Theory for infrastructure assessment to machine learning for injury prediction, these studies showcase how complex analytical methods can generate insights from comprehensive datasets. However, they also highlight the importance of domain expertise in interpreting computational outputs and translating them into interventions. The integration of qualitative expert judgment with quantitative modelling reflects a maturing understanding that neither purely technical nor purely experiential approaches suffice for addressing contemporary built environment challenges.
- *Third, geographical diversity* continues to enrich the understanding of how universal challenges manifest across different contexts. This issue spans Hong Kong's dense urban fabric and regulatory innovation, global smart home implementations across Europe, North America, and Asia, infrastructure management challenges, and UK highway safety concerns. This geographical breadth shows how local conditions, regulatory cultures, and market dynamics shape the implementation of technologies and methodologies, emphasising the need for context-sensitive approaches rather than one-size-fits-all solutions.

- *Fourth, user-centricity and human factors* receive sustained emphasis across multiple articles. Whether examining how smart homes adapt to diverse user needs (Ehteshami et al., 2025), how operator competency influences utility strike risks (Sarvari et al., 2025), or how worker characteristics relate to injury patterns (Bortey & Edwards, 2025), these contributions establish that technological and procedural innovations must account for human capabilities, limitations, and behaviours. This human-centred view supports broader trends toward inclusive, sustainable built environments.

5 Looking Forward

This Issue 2 advances ABC2's mission of cultivating knowledge spaces characterised by transparent borders and possibilities for growth and evolution. The articles demonstrate how established knowledge spaces, such as construction management, building performance assessment, and safety risk analysis, continue to evolve through the integration of emerging technologies, advanced analytical methods, and innovative regulatory approaches. Concurrently, they contribute to evolving knowledge spaces at the intersections of digital transformation, infrastructure resilience, and evidence-based policymaking.

The progression from Issue 1 to Issue 2 reveals encouraging patterns in the development of ABC2. While the inaugural issue established geographical and methodological diversity spanning Kazakhstan, New Zealand, the United Kingdom, South Korea, and South Africa, Issue 2 extends this global reach while extending the focus on computational and data-driven approaches to challenges in the built environment. This evolution suggests that ABC2 is positively attracting research that integrates theoretical rigour with practical insights.

As we continue building this platform for transformative scholarship in architecture and built environment research, we invite contributions that further explore the themes emerging across our first two issues, in addition to our standard themes across the four knowledge spaces: Architecture, Building, Construction, and Cities. The knowledge spaces cultivated within ABC2 remain spaces of possibilities and anticipation of growth, evolution and development. We look forward to continuing this journey with the international research community.

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