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SPECIAL ISSUE EDITORIAL: MANAGING THE DIGITAL TRANSFORMATION OF CONSTRUCTION INDUSTRY (CONVR 2023)

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The 23rd International Conference on Construction Applications of Virtual Reality (CONVR 2023), held from November 13th to 16th at the University of Florence, Italy, served as a significant gathering for researchers and industry experts dedicated to exploring the intricacies of digital transformation within the architecture, engineering, construction, and operation (AECO) sector. This year's conference attracted over 150 participants from 32 countries, creating a dynamic environment for discussions on the latest advancements in Virtual and Augmented Reality (VR/AR), Building Information Modeling (BIM), Digital Twins, Internet of Things (IoT), Artificial Intelligence (AI), Linked Building Data, as well as simulation and automation in the construction industry. The overarching theme of "Managing the Digital Transformation of the Construction Industry" reflected the urgent necessity of digitalization into construction practices and processes and provided the foundation for rich exchanges of knowledge.

Given the rapid technological advancements and the evolving challenges faced by the construction industry, it is imperative to address the themes presented at CONVR 2023. The papers selected for this special issue encompass a diverse range of topics that highlight the critical importance of leveraging emerging technologies and digital processes in the AECO sector. Each contribution not only reflects the latest advancements in the field but also addresses the practical challenges faced by industry and academics. By delving into areas such as workforce safety training, energy efficiency in building retrofitting, risk assessment through advanced simulations, and the use of artificial intelligence for regulatory compliance, these studies collectively aim to create a foundation for improved practices in construction.

Engaging with these themes is essential for fostering a culture of continuous improvement and innovation within the industry. The insights derived from this collection of research not only offer valuable perspectives on current trends but also pave the way for future explorations that can lead to enhanced safety standards, more efficient resource management, and greater adaptability in the face of emerging challenges.

In this special issue, we present a collection of innovative research contributions that explore diverse aspects of digital transformation in the construction sector. One significant topic examined is the utilization of real-world data and BIM to enhance the realism and effectiveness of safety training programs. Speiser and Teizer (2024) presented the development of a Virtual Construction Safety Training (VCST) framework which aims to bridge the

gap between theoretical training and practical application by formalizing data modeling concepts and integrating real-time location tracking, ensuring that workers are better prepared for on-site hazards. Furthermore, the application of VR technology in road safety design is also a focus. Meocci et al. (2024) investigated the potential of driving simulators to accurately assess the effectiveness of road safety measures comparing between VR simulations and on-field tests. Their study validates the use of VR as a reliable tool for simulating real-world conditions, enhancing decision-making for in real-world road network design applications. However, a critical step in advancing the adoption of VR for safety training applications or real-world scenario assessment lies in establishing whether it constitutes a valid and effective method for replicating practical conditions and transferring knowledge. Addressing this need, Getuli et al. (2024a) proposed a two-fold evaluation method for VR safety training programs, combining spatial tracking and subjective trainee feedback. Their study demonstrates how integrating objective spatial data with user perceptions enhances the assessment and optimization of VR safety training protocols.

In line with advancing the adoption of emerging technologies to improve projects' safety performances, Tran et al. (2024) have leveraged Large Language Models (LLMs) to create a Construction Safety Query Assistant (CSQA) that streamlines the extraction of safety regulations. By enhancing the accessibility and comprehensibility of complex construction safety documents, this tool addresses significant compliance challenges faced by industry stakeholders. Similarly, Sheikhkhoshkar et al. (2024) utilized advanced text-mining techniques and semantic analysis to develop a taxonomy of functionality concepts in project planning and control systems. Their study not only clarifies critical functionalities but also enhances informed decision-making by offering a structured classification aligned with expert insights. In a distinct application of advanced AI techniques, Matarneh et al. (2024) employed convolutional neural networks (CNN) combined with transfer learning to achieve highly accurate detection and classification of asphalt pavement cracks. Their approach demonstrates how AI-driven solutions can optimize infrastructure maintenance strategies, reducing costs and extending service life through precise damage identification.

Moreover, prioritizing the human aspects of the construction process, Afalobi et al. (2024) designed a framework for assessing the ergonomic risks associated with exoskeleton use in construction tasks. Through a digital twin approach, the study aims to enhance worker safety by quantifying exertion levels and addressing the physical demands placed on workers. Additionally, Sorbi et al. (2024) propose an agent-based simulation framework integrated with 4D BIM to improve risk estimation and safety management on construction sites. By simulating agent behaviors and visualizing hazard interactions through heatmaps, their approach provides safety managers with actionable insights to optimize planning and reduce on-site risks.

Shifting the focus towards facility and asset management, Messi et al. (2024) sought to overcome the challenges related to the adoption of AR for Facility Management operations with regard to registration methodologies in both indoor and outdoor environments, promoting improved visualization and communication on construction sites. However, achieving effective facility management in large-scale and complex environments also requires robust systems capable of integrating diverse data sources for informed decision-making. In this context, Di Giuda et al. (2024) proposed an Asset Management System (AMS) that integrates BIM, GIS, and Business Intelligence (BI) tools. Their web-based application combines spatial, performance, and operational data with advanced analytics, offering a scalable solution for optimizing space and monitoring environmental quality in educational facilities.

Imani et al. (2024), discussed the sustainability of building operations, analyzing retrofit strategies through systematic literature reviews and artificial intelligence methodologies. This research not only identifies the gaps in current practices but also proposes a comprehensive roadmap for developing tailored energy-saving solutions based on building typology, which is crucial for meeting environmental targets in retrofitting projects.

Additionally, the importance of improving education and knowledge transfer in the AECO sector is highlighted in this issue with the contribution of Bragadin et al. (2024), which discussed the establishment of a BIM-enabled Learning Environment that facilitates the sharing of resources among students and practitioners. This initiative is designed to modernize construction education and equip future professionals with essential skills in BIM technologies.

Furthermore, contributions investigating the application of a linked data approach to improve data management and support complex processes have been included, highlighting their potential to shape the future of data management in construction. Particularly for seismic assessment of unreinforced masonry buildings, Leonardi et al. (2024) enhanced the methodologies for defining modeling assumptions, ultimately improving data interoperability and decision-making processes within the field. In the area of cost estimation, Cassandro et al.

(2024) addressed the challenges of unstructured cost data by proposing a new architecture for the AECO industry. Their study integrates structured cost data into the Industry Foundation Classes (IFC) model, facilitating more accurate and efficient cost estimation by ensuring coherence and validation with geometric data. Meanwhile, in the asset management domain, Biagini et al. (2024) proposed a valuable strategy for improving operational efficiency by integrating IoT data with BIM data. By creating data-driven workflows that facilitate better decision-making, this approach emphasizes the significance of linked data in enhancing asset management processes.

Lastly, recognizing the importance of integrating human well-being into digital construction processes, the work of Getuli et al. (2024b) addressed the application of stress detection strategies, parameters and tools with a systematic review of the literature. This research advocates for a holistic approach that combines ergonomics and neuroscience with digital practices, ensuring that occupant well-being is prioritized in increasingly automated environments.

In conclusion, the insights presented in this special issue underscore the critical importance of embracing digital transformation in the AECO sector while addressing its complexities and challenges. The contributions collectively emphasize the need for ongoing collaboration among experts to advance our understanding of the impact of digital tools and methodologies on productivity, safety and building and environmental sustainability. Moving forward, the construction industry must tackle essential challenges, including enhancing interoperability between digital systems, fostering sustainable practices, and ensuring worker well-being amid rapid technological advancements. By leveraging the wealth of knowledge shared within these publications, stakeholders can develop informed strategies that adapt to the evolving landscape of the construction industry, ultimately creating a safer, more efficient, and sustainable future.

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