Stefano Cascone, Francesco Pittau, Marianna Rotilio
editors

PRODUCTION AND MANAGEMENT OF THE BUILT ENVIRONMENT

Research and Innovation for the Digital and Environmental Transition

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The book was financed by funds from the Department of Civil, Construction-Architectural and Environmental Engineering (DICEAA), Dipartimento di Eccellenza MUR 2023-2027, University of L'Aquila.

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ISBN: 978-88-916-7737-2
DOI: 10.30448/UNI.916.77372

Maggioli Editore è un marchio di Maggioli S.p.A.
Azienda con sistema qualità certificato ISO 9001:2015

47822 Santarcangelo di Romagna (RN) • Via del Carpino, 8
Tel. 0541/628111 • Fax 0541/622595
www.maggiolieditore.it
e-mail: clienti.editore@maggioli.it

Il catalogo completo è disponibile su www.maggiolieditore.it e www.theplan.it.

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Contents

The ISTeA Giovani initiative

This volume is the first outcome of the “ISTeA Giovani” initiative, which was launched officially at the ISTeA2024 Conference in Cagliari, within the activities promoted by the Italian Society of Science, Technology and Engineering of Architecture (ISTeA). This initiative was created with the objective of fostering a scientific cooperation framework specifically dedicated to early-stage researchers operating under the framework of the Italian Scientific Disciplinary Sector CEAR-08/B – Production and Management of the Built Environment.

ISTeA Giovani arose from the understanding that, in an increasingly complex, dynamic, and competitive scientific landscape, it is important to establish inclusive, stimulating, and challenging spaces for younger generations of researchers to consolidate scientific abilities and try new ways of working collaboratively and participatively.

Within this perspective, ISTeA Giovani was envisioned as a forum for discussion, development, and dialogue, but also an incubator for innovative ideas, techniques, and partnerships, creating scientific and human value within the wider community of the CEAR-08/B sector. This sector is characterized by an integrated and systemic approach to the built environment's knowledge, design, management, and transformation, focusing on its various dimensions – technological, performance-based, environmental, economic, and social – using advanced and interdisciplinary models, methods, and tools.

ISTeA Giovani established for itself the ambitious objective to offer young researchers a practical chance to work on the key challenges facing the sector today, i.e., ecological and digital transitions, integrated sustainability, resilience, resource efficiency, innovation within building processes and materials, information management, and heritage improvement.

The initiative found broad interest and participation, involving more than thirty young researchers – PhD candidates, post-doctoral researchers, and research fellowships – working at various universities in Italy.

During its inception, the initiative was distinguished by an innovative, participatory, and bottom-up working methodology, where young researchers assumed an active and conscious role within every phase: from the research theme definition, through the organization of working groups, to autonomous activity management and scientific production.

The design of the initiative was built through consecutive and connected phases, intending to assist participants through a step-by-step process of scientific and organizational empowerment:

- Phase 1: Skill mapping and research sharing – Participants submitted their research work through writing extended abstracts, collected in this volume, with the aim of bringing out individual research lines and determining likely synergies and interdisciplinary connections.
- Phase 2: Setting up thematic working groups – There were five interdisciplinary groups, each supported by tutors who helped facilitate, coordinate, and provide scientific guidance.
- Phase 3: Group work and review article production – The groups independently prepared literature review articles for submission to peer-reviewed scientific journals, trying out collaborative writing strategies, internal peer review, and critical discussion.
- Phase 4: ISTeA Giovani Workshop – L'Aquila, February 12-14, 2025 – The meeting was an important moment of confrontation, verification, and relationship-building, enriched by thematic seminars, round tables, group activities, and technical visits to strategic sites in the city of L'Aquila.
- Phase 5: Dissemination and valorization of outcomes – Ongoing, encompassing the publishing of this volume and submission of review articles by the group, as tangible evidence of the success and impact of the initiative.

The experience highlighted the necessity for encouraging research practices that can exceed disciplinary, institutional, and generational boundaries and promote new visions, integrated strategies, and innovative solutions to the complex issues facing the modern built environment.

In this view, ISTeA Giovani aims to be a replicable and scalable best practice within the CEAR-08/B sector to be replicated by the scientific community, as a reference model for future research networking and enhancement of early-career researchers. This volume therefore constitutes the first collective scientific outcome of this experience, and it proposes a representative image of the research directions,

methods, and perspectives that the ISTeA Giovani community is helping to outline for the future of research on the built environment.
The coordinator would like to express our thanks to all participants, tutors, and institutions who, through their enthusiasm, competence, and commitment, made this experience possible.

Stefano Cascone
Francesco Pittau
Marianna Rotilio

1. Research advances and new frontiers in the production and management of the built environment

The first section is focused on the digitalization and the organization of technical and economic information in Architecture-Engineering-Construction (AEC) processes.
AEC industry has historically been characterized by fragmented workflows and the reliance on manual procedures. However, the increasing adoption of digital technologies, particularly Building Information Modeling (BIM), is radically transforming the sector by enabling more integrated, accurate, and efficient project management. The digitalization and the organization of technical and economic information is a central core of this transformation, which consists of advanced cost estimation, process automation, and informed decision-making processes.
Recent research involving the Lombardy Region has emphasized the strategic role of cost ontology in the digitalization of public works price lists. Particularly, traditional price lists, expressed in natural language, are affected by a difficult interpretation for machines, leading to errors and inefficiencies. The introduction of standardized cost ontologies—structured systems that define cost-related entities, attributes, and relationships—enables the transformation of unstructured textual descriptions into machine-readable formats, fostering interoperability across BIM environments and other project domains like geometry and time.
The use of the Industry Foundation Classes (IFC) schema, specifically entities like IfcCostItem and IfcCostSchedule, allows for detailed and relational representation of cost data. This approach supports the creation of a "standalone cost model" within the 5D BIM framework, connecting cost items to geometric elements and quantities. Tools such as IfcOpenShell and Python have been used to operationalize these models, although current BIM software still lacks native support for some of these advanced cost structures.
Other research contributes by elaborating on how analytical procedures and digital tools can validate cost estimations and ensure consistency across tendering documents. In particular, the use of Large Language Models (LLMs) and Natural Language Processing (NLP) are considered techniques for automating the extraction and validation of cost data from unstructured sources like specifications and bills of quantities. This marks a promising step toward automating traditionally manual and error-prone processes.

Another crucial issue is the alignment of digital processes with regulatory frameworks. An increasing concern on how the Public Contracts Code as well as standards (e.g., UNI EN ISO 19650 and UNI 11337) should mandate the adoption of standardized digital information flows in public procurement is affecting the research. This alignment is crucial for ensuring that digital innovations in cost management are legally compliant and operationally effective within the public sector.

At a broader level, digital transformation in the AEC industry also involves a cultural shift. Companies need to develop strategic digitalization plans, redefine professional roles, and adopt interoperable platforms that support collaboration among diverse stakeholders. Technologies such as Digital Twins, IoT, and real-time data integration further enrich the management and predictive capabilities of digitalized AEC processes.

In conclusion, the digitalization and structuring of technical and economic information in the AEC sector is a multi-dimensional challenge that combines technological innovation, standardization, and cultural adaptation. The integration of cost data into BIM, guided by formal ontologies and supported by AI and open standards, represents a foundational step towards smarter, more efficient, and transparent construction processes. These advancements not only enhance project control but also align with broader policy goals of sustainability, accountability, and public value creation.

The second section of this collection is dedicated to the digital transition of the building and built environment sectors, emphasizing the integration between digital platforms, data interoperability, and smart management strategies. This transition is enabled by the convergence of BIM, GIS, Digital Twins, IoT, AI, and immersive technologies, which, together, are opening new horizons for design, construction, operation, and maintenance process optimization, contributing to sustainability, resilience, and efficiency at different scales.

The first set of studies focuses on the integration between data models and digital platforms, which is the base for an effective digital transition. The integration between BIM and GIS using open standards like IFC and CityGML is addressed as one of the most important drivers for the digital management of systems for water networks and urban regeneration in historic contexts, supporting municipalities in the definition of scalable and sustainable interventions. This integrated method ensures spatial and semantic data are coordinated, enabling more informed decision-making processes at different governance scales.

Drawing from these insights, the interoperable e-government platform integrating built environment asset information using BIM, FM, and IoT systems is identified as a strategic resource for the monitoring and management of public buildings, where Digital Twins enable real-time performance analysis, prediction and planning for scheduled maintenance, and improvement for energy efficiency. Complementing this, the particular methodologies and toolkits are introduced for Digital Twin design and implementation for built environment management, with a structured framework for use case classification, data inputs, KPIs, and system capabilities to assist the stakeholder in the transition towards data-driven lifecycle management strategies.

Moving towards operational intelligence and monitoring systems, the next series of contributions focuses on integrating BIM, Building Energy Modeling (BEM), and Building Management Systems (BMS) to support bidirectional data flows and validation of the building systems' performance during the operational phase. This integrated approach facilitates proactive and user-centered energy management, guaranteeing the optimization of the HVAC systems based on simulation output and actual user behavior data. Complementary to these developments, decision support through AI is investigated for facility and safety management, enhancing knowledge extraction, safety planning, and inspection activities through Large Language Models (LLMs) and computer vision systems and streamlining report generation and decision support while maintaining human intervention for guaranteeing reliability, transparency, and regulatory compliance. In line with the same perspective, augmented reality is suggested as an immersive solution for improving safety inspections on-site, enabling the visualization of BIM-based safety information directly on-site, enhancing traceability, work efficiency, and compliance verification. Ultimately, the second section concludes with contributions covering process optimization and site management according to Industry 5.0 paradigms, where Product Lifecycle Management (PLM) platforms are integrated with BIM and agent-based simulation environments, which support data-driven, collaborative methods for managing projects. These methods enable coordination of complex projects under open-source workflows and clustered databases, leading to more adaptive and transparent collaboration between different disciplines and stakeholders. Expanding on the above, cutting-edge methodologies that bring together BIM, Agent-Based Modeling (ABM), and lean construction principles are shown, presenting the Construction Productivity Graph (CPG) as a novel tool for simulating and optimizing construction processes, resource allocation, and logistics within dynamic, human-centered environments, supporting the transition towards adaptive, intelligent, and sustainable construction ecosystems.

The third section explores the recent advancements in the area of sustainability, energy and resilience of buildings and constructions. The built environment is responsible for nearly 40% of global CO_2 emissions and over one-third of energy consumption, making sustainability and energy efficiency in buildings crucial priorities for environmental resilience. Contemporary research highlights the imperative to rethink construction processes, building systems, and energy strategies by adopting digital tools, innovative technologies, and circular principles across the building life cycle—from design to operation and end-of-life.

A key domain in sustainable construction is the integration of renewable energy systems, particularly Building-Integrated Photovoltaics (BIPV). Some researchers emphasize the multifunctionality of BIPV, wherein photovoltaic modules replace conventional building envelope components while generating clean energy. This strategy supports urban decarbonization and distributed energy generation. However, to ensure true sustainability, design must also consider the environmental impacts associated with manufacturing and disposal. A life-cycle-based approach, combining Life Cycle Assessment (LCA) and Circular Economy (CE) indicators, should be integrated in the evaluation to guide product development with reduced environmental footprints.

Operational energy remains a central aspect of building performance and Sensitivity Analysis (SA) as well as Building Performance Analysis (BPA) in energy-intensive facilities, e.g., refrigerated warehouses, is a key topic that needs to be investigated. These tools enable the identification of key design and operational parameters—such as insulation, air infiltration, and setpoint temperatures—that most significantly impact energy consumption. Applying SA helps tailor solutions to the specific needs of industrial users, aligning energy performance with the goals of Industry 5.0 and sustainable development.

Advancements in monitoring and data analytics, particularly through Artificial Intelligence (AI), also play a transformative role. Recent studies present comprehensive AI- and machine learning-based systems for monitoring and forecasting photovoltaic (PV) energy production. These tools enhance operational efficiency, predict energy outputs, and allow timely maintenance, thus increasing the resilience and productivity of energy systems. The implementation of real-time monitoring supports adaptive strategies against climate variability and promotes energy security.

Digitalization in the AEC sector, including the use of Building Information Modeling (BIM), further strengthens sustainability assessments. The development of frameworks which integrate BIM, visual programming languages (e.g., Dynamo), and AI models to automate the evaluation of green certifications and sustainability metrics is able to streamline data management, support early design decision-making, and enhance the precision and scalability of environmental assessments, thereby reinforcing sustainable construction practices from the conceptual phase.

From a procedural standpoint, other researchers introduce decision-support tools based on environmental certification protocols and Minimum Environmental Criteria (CAM), focusing on sustainable construction site practices. Such tools allow stakeholders to estimate the cost and effectiveness of adopting sustainable practices during construction, aligning ecological benefits with economic viability. Practices

such as resource reuse, pollution control, and eco-friendly materials are emphasized as critical to reducing the site-level environmental footprint.
Moreover, others address resilience from post-disaster recovery perspectives by proposing safety protocols for dismantling post-seismic temporary shoring. Those protocols ensure operational safety while also evaluating the environmental footprint of materials through LCA. This reinforces the idea that sustainability in construction must also encompass temporary and transitional structures, particularly in emergency contexts.
In conclusion, the integration of advanced digital tools, renewable systems, and circular design methodologies is a fundamental step to foster sustainability and resiliency in building. By embracing multidisciplinary approaches—from energy simulations and real-time monitoring to digitalized sustainability assessments and safe dismantling protocols—the construction industry can align with the broader goals of climate adaptation, decarbonization, and environmental resilience.

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