Original Article
ISSN (Online): 2456-8651

International Journal of Engineering Science Technologies
July-August 2025 9(4), 43–59

CONSTRUCTION 5.0 IS ON THE WAY TO BECOMING THE STRONGEST INDUSTRY THAT ADVANCES SOCIAL SUSTAINABILITY IN THE DIGITAL AGE. A MATURITY ASSESSMENT

Dr. Bianca Weber-Lewerenz [1]

[1] Excellence Initiative for Sustainable, Human-Led AI in Construction, Independent Research, Aichtal, Germany

Received 20 June 2025
Accepted 28 July 2025
Published 31 August 2025

Corresponding Author

Bianca Weber-Lewerenz,
Bianca.christina@gmx.de

DOI 10.29121/IJOEST.v9.i4.2025.665

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ABSTRACT

Convincing use cases and reliable empirical values are essential for the construction industry and its decision-makers to face the questions and challenges of digital transformation and to shape their own digital strategy. In fact, a connection has been identified between the increasing acceptance of digitization in construction companies and the innovative creation of use cases. Therefore, the aim of this study is to examine the evidence that will greatly facilitate the development of such an innovation scenario and ensure even wider adoption. The study critically questions whether the perception of the construction industry as one that is lagging behind digitization and Artificial Intelligence (AI) is realistic or not, or whether the industry is rather a driver of a sustainable digital age.

The study used structured literature analysis and interviews with corporate best practices. The analysis and evaluation of the database follow the Hermeneutic Approach. Overall, this research led to the new aspects that underpin a convincing innovation scenario contributing to the broader use of digital methods and AI. With new findings, this study adds value to scientific literature and is evidence of the industry's leadership.

Motivation/Background: The holistic approach from the perspective of a Civil Engineer, examining Construction 5.0, its related success factor and compass for socially sustainable construction and fulfillment of sustainability goals and ESG, may add value to your academic reading community. This manuscript is part of the author`s larger scientific research work “CDR in Construction in-line with ESG and SDGs”.

Method: The study for this original article applies the so-called “Next Generation”-Method. It recognizes both challenges and limitations of digital transformation and the related human factors followed by normative questions. But it also deepens the holistic understanding of the explosive power and potential of new technologies such as AI catalyzing the construction branch into a more resilient, innovative one.

Results: The aim of this work is to assess such an innovative scenario and ensure even wider adoption. The study critically questions whether the perception of the construction industry as one that is lagging behind digitization and AI is realistic or not, or whether the industry is rather a driver of a sustainable digital age.

Conclusions: The paper´s discussion offers new aspects of this new scientific niche, to add value to scientific research. Furthermore, this paper aims to fully capture a new approach to assess the construction branch´s innovation strategy with a practicable framework for increasing both societal and corporate sustainability.

The paper consists in a connection between a discovery, new scientific findings and its practical application.

Keywords: Construction 5.0, Innovation, Social Sustainability, ESG

1. INTRODUCTION

There has been outstanding growth in innovative technology in recent years. The link between competitive advantages and innovation has emerged as one of the key topics in organizational and information sciences An et al. (2022), in achieving Sustainable Development Goals (SDGs) set by the United Nations Adhikari and Shrestha (2023) and recognizing the Environmental, Social and Governance (ESG) Criteria. Innovation has seen many advances and significant improvements in recent years. In the current economic climate, companies are striving to find ways to outperform the competition and remain profitable. An innovative approach helps in the company's strategic planning and decision-making. The study examines the central research question: Is the perception of the construction industry as an industry that is lagging behind digitalization and AI correct? Or is the construction industry not more of a driver of a sustainable digital age?

The aim of this work is to examine the drivers of innovation and social-technical concepts to achieve competitive advantages and social sustainability.

The development of the construction industry marks a move away from traditional investment-oriented models towards more innovation-oriented models. Digitalization, AI, shortage of skilled workers, delivery bottlenecks, rising material and energy costs and implementation of the energy and climate transition are key challenges. Stakeholders, contractors and regulators demand optimal projects within specified budgets, quality requirements and schedules and compliance with the 17 UN SDGs and ESG requirements Bal et al. (2013). However, it is one of the least digitized industries Zulu et al. (2023) and the lack of innovation in the technology development, management and operation of construction projects has led to declines in productivity and efficiency Klinc and Turk (2019). The construction industry lags behind other industries in terms of innovation and technology adoption Koscheyev et al. (2019), despite being critical to today's global challenges such as climate change, global warming and resource scarcity Ghaffar et al. (2022). Construction supply chains and project processes are facing a radical human and digital transformation in the next few years Daniotti et al. (2020) Jahanger et al. (2021). Therefore, this paper offers a systematic overview of the effects of digital transformation in construction, participation and value communication on social sustainability. This transformation in conjunction with the assumption of entrepreneurial, value-based responsibility characterizes Construction 5.0 Figure 1.

Figure 1

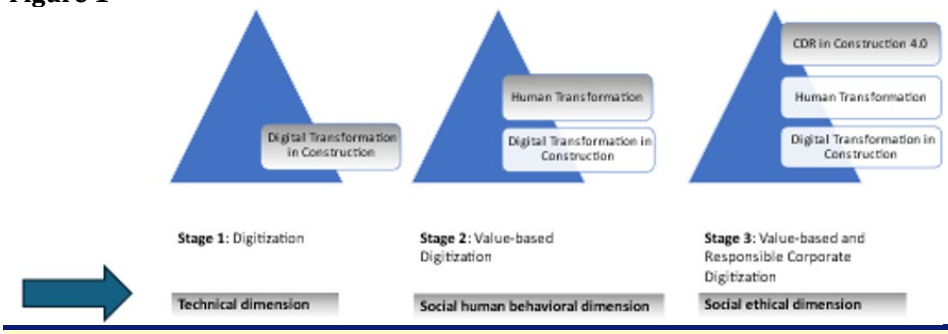


Figure 1 Construction 5.0 – Value-Based and Responsible Corporate Digitization

Initial experiences of corporate best practices provide orientation. The level of maturity, which is reflected in the assumption of corporate digital responsibility,

creates an assessable snapshot and new insights into the digitalization roadmap. The study identifies the need to consistently digitize all processes along a holistically thought-out construction life cycle Kraus and Drass (2020), Haghsheno et al. (2024) in order to determine the effectiveness of new, innovative, digital technologies based on entrepreneurial willingness and ability, i.e. h. to optimize your own level of maturity and to tackle the shared task responsibly.

This study explains how the innovative use of technology and best practices support in addressing current and future global challenges and in dealing with available resources Weber-Lewerenz (2021) Ernstsen et al. (2021). It includes practical examples of innovative projects that significantly improve productivity, quality and performance in the construction sector Kölzer (2022). This paper provides an overview of technologies that have already been used.

1.1. STATUS QUO

Efficient project management is crucial not only for meeting customer expectations, but also for minimizing disruptions and additional costs. On the other hand, cost efficiency means financial sustainability. Effective cost management enables stakeholders to use resources wisely, increase profitability and remain competitive in the market. AI has also become a transformative force in construction **Table 1** Wen and Gheisari (2020), Alaloul et al. (2022), Chung et al. (2009), Adriaanse et al. (2004).

Table 1

Table 1 Literature Overview

Auhtor/Year/Publication	Description	Key Findings
Bianca Weber-Lewerenz (2024): Diversity in Construction - The Gamechangers. Strengthening Innovation through diversity	The book explains why innovation and new digital technologies in the construction industry and beyond depend significantly on a new culture of thought.	Shows ways to achieve more diversity in construction and creates understanding for human transformation in construction: diversity in construction and entrepreneurial strategic ways to address the problem areas that hinder the innovation process. Definition of key factors and core competencies.
Bianca Weber-Lewerenz (2024): Innovation Empowerment in Construction 4.0 by the CDRApproach. A new field of scientific Research for the digital breakthrough.	The dissertation examines the corporate digital responsibility approach to innovations in construction 4.0.	The book shows how innovative technologies can support people efficiently, productively, safely and meaningfully. The responsibility that company management bears for this is explicitly highlighted and key factors for the success of digital corporate strategies are presented, without neglecting the necessary legal, political, social and educational framework conditions.
Bach et al. (2024). Datacentered AI as the basis for future information management. In Artificial Intelligence in Construction: Basics and Use Cases (pp. 25-39). Wiesbaden: Springer Fachmedien Wiesbaden.	Diversity as a basic requirement for unbiased AI.	In order to develop AI-based applications in the construction industry for the benefit of the actors involved, data formats and data types with a comparatively high variety are necessary.
Haghsheno et al. (2024). AI in Construction. Wiesbaden: Springer Fachmedien Wiesbaden.	Status Quo of AI in Construction	Motivation for gender-equal databases in order to avoid black boxes and thus biases and to set up sustainable AI.
Weber-Lewerenz (2023). Accents of Added Value in Construction 4.0. Wiesbaden: Springer Fachmedien Wiesbaden.	Presentation of the complexity of digital technologies and AI in construction and how human and technical potential can be kept in harmony.	Experiences from practical use show how digital change can be shaped sensibly and constructively through diversity in knowledge, skills, technologies, innovations and gender equality. The book highlights the key factors.

Bohland (2024). Die gerechte Mobilitätswende ist feministisch. (pp.1 ff.) FES impuls, Friedrich Ebert Stiftung Druck.	A new approach to transport and urban planning from a feminist perspective.	Both female and male perspectives are the starting point for needs analyzes in transport and urban planning. Diversity offers the basis for holistically integrating social factors, path patterns and social sustainability.
Dellenbaugh-Loose (2024). Gender-equitable urban development: How we build a city for everyone, 53. Springer Gabler Verlag	Communicates how the quality of public spaces can be improved through gender-friendly urban development Application-oriented on genderrelated aspects of mobility, neighborhood development, living, green and open spaces Tailored to the needs of the areas of urban planning, architecture and politics	Gender-equitable urban development and paths to better cities for everyone.
Sar (2024). S in ESG: Assessment of social sustainability in real estate – critical inventory of the social taxonomy and limits of certification systems (Doctoral dissertation, Technische Universität Wien).	Critical assessment of social sustainability in real estate based on socio-cultural and ESG aspects.	Social sustainability can only succeed through gender equality and diversity. ESG guidelines and social criteria are essential evaluation standards for implementation and need for action for optimization. Diversity is defined as enrichment.
Gräfe-Geusch (2024). Diversity, but how? German Center for Integration and Migration Research (DeZIM) Working Papers 02.2024	Demographic and social change is reflected in the need for more diversity and inclusion in construction and corporate culture. Diversity is defined as a catalyst for performance, personnel development and recruitment, communication and networks.	International and national best practice areas for diversity-oriented and discrimination-critical organizational development.
Giannakidis, et al. (2021): AI in Construction Industry, Fraunhofer IAO Publishing, Stuttgart.	Presentation of AI applications, based on conversations with decisionmakers from business, politics and teaching. Study on ethical aspects of AI.	This study by the Fraunhofer Institute IAO presents AI application areas in construction projects. An extensive series of interviews with experts from industry and research presents the first practical individual solutions in all life cycle phases.
Huning (2018). Feminism and City. Handbook Urban Concepts,107-127. In: Rink, R. und Haase, A. (2018). Handbuch Stadtkonzepte: Analysen, Diagnosen, Kriiken und Visionen. Verlag Barbara Budrich, Opladen und Toronto.	Feminist discussion of urban planning and urban politics.	Using gender diversity approaches, shows possibilities and best practices for how women-friendly cities can be developed and built.
Bielefeldt et al. (2018). Intersections between engineering ethics and diversity issues in engineering education. Journal of Professional Issues in Engineering Education and Practice, 144(2), 04017017.	Research on ethical education in engineering and computer science against the background of diversity.	Mutual condition of ethics, diversity and innovation.
Kempf and Wrede (2017). GenderEffects. How women are shaping the technology of tomorrow. Interdisziplinäres Zentrum für Geschlechterforschung (IZG).	Diversity as an enabler of technological developments.	Nature as our role model shows us how a system can become resilient and flexible at the same time through high diversity.
Kropp (2014). About cognitive and social diversity in the innovation process. Diversity and cohesion. Kongressband des, 36.	Motivating diversity and cohesion through innovation.	The ability to innovate is considered a central key in modern societies to success. Whether in the guise of technical progress, more profitoriented Product variation, as organizational innovations or creative social problem solutions: In all of these variants, innovations promise expansion options for action, resilience to crises or at least the ability to successfully face inevitable change.

Rammert (2010). Innovations in Society. In: Howaldt, J., Jacobsen, H. (eds) Soziale Innovation. VS Verlag für Sozialwissenschaften. https://doi.org/10.1007/978-3-531-92469-4_2	Sustainable innovation through diversity.	When we talk about innovation, we usually mean economic innovations. It is about the introduction and distribution of new and improved products, processes, systems and devices for commercial use in the economy. But aren't there also many innovations of a non-economic nature in society, e.g. B. Science and education, politics and everyday life, art and culture change in a momentous way?
Gwisdalla (2007). A city for everyone? Gender and diversity in spatial planning. Femina Politica–Zeitschrift für feministische Politikwissenschaft, 16(1), 15-16.	The integration of the gender perspective into all political Fields of action and thus also in urban development policy and urban planning.	Answering the question: what will the women-friendly city of tomorrow look like?
Gale and Davidson (2006). Managing diversity and equality in construction: Initiatives and practice. Routledge.	Diversity and equality in construction.	Basis for mastering differences, team creativity, innovation and solution finding using diverse and inclusive environments in the construction industry.
Schäfer (2006). A new approach to increasing diversity in engineering at the example of women in engineering. European Journal of Engineering Education, 31(6), 661-671.	The topic of diversity is examined using the example of women in engineering.	In order to achieve sustainability and be a role model, the book suggests effectively increasing diversity within companies. This is a multidisciplinary, intersectional and social task.
Mehlau-Wiebking (2003). Quality women in construction: Guide for property developers; Equality controlling for planning and contract awarding. vdf Hochschulverlag AG.	The book gets to the bottom of the field of "women in construction".	Execution of the fact: increasing the quality of the construction product through the participation of women.
Keim (1994). News in the field " New Construction" and women. FKW//Zeitschrift für Geschlechterforschung und visuelle Kultur, (18).	A feminist examination of avant-garde architecture and however, architectural programs would have to take a critical look at this very idealism.	As early as 1994, the book highlighted how essential the participation of women in construction is in order to shape and expand gender equality in this field as well.

The construction sector has been slower to adapt to new technologies than other global sectors. Innovation has occurred to some extent at the corporate level. As an industry based on competitive procurement models, the construction industry has historically taken a conservative approach to product design and delivery, resulting in project management silos and a fragmented industry. Research and development (R&D) usually takes place in dedicated departments of large companies, and occasionally also in small and medium-sized companies (SMEs), but not across the board.

The construction industry consists mostly of SMEs of different capacities and configurations and represents a broad economic sector with value-adding companies. It acts as the backbone of economies, according to Alaloul et al. (2018) consists of 99.8% European companies with a gross domestic product of 6% and employs 70% of the total industrial workforce in European industry. The construction industry has always been an epic of innovative technology, more recently through its cutting-edge technologies. Alaloul et al. and Blayse and Manley Blayse and Manley (2004) believed that there had been technologies and innovative ideas that had revolutionized construction practices. For example, Oesterreich and Teuteberg Oesterreich and Teuteberg (2016) and Perkins and Skitmore Perkins and Skitmore (2015) highlight that the productivity increases through innovation brought about by Industry 4.0 has changed the rules of the game using traditional tools. The introduction of Building Information Modeling (BIM) has a huge impact on all construction activities. Blayse and Manley and Shang et al. Shang et al. (2004)

argue that innovations boost construction processes, motivation and productivity, but have stalled. With the transition to Industry 5.0, the focus is on social-ethical and normative aspects, corporate digital responsibility (CDR), ESG reporting and sustainability goals. Productivity results from innovations in the design and construction of buildings.

In fact, the study establishes the connection between growing acceptance of digitalization in construction companies and extremely positive business case creation and aims to examine the evidence that supports an innovation-conducive environment and broader acceptance. Productivity and completion time delays are, among other things, in the lack of willingness to innovate, qualified specialists and digital infrastructure, life cycles of construction projects that are not holistically thought through, and the lack of responsible use of innovative technologies. An aspect that is mainly due to the industry's inability to meet the increasing sustainability demands of investors and society as a whole. Therefore, the digital transformation towards Construction 5.0 is seen as a promising change in the reputation and strength of the industry, but the power of new technologies is not always realized. The digital transformation process is hampered by long production cycles, significant capital requirements and industry-specific characteristics. Despite proactive advocacy, the use of digital technology remains rather limited compared to other industries Chen et al. (2024). Building on numerous previous research works, the validation of the study aims to represent an industry that is on the way to becoming one of the strongest. The recorded positive influences on construction productivity take into account the factors of people, society, the environment, costs, feasibility, technological usage history and useful fields of application. The literature analysis confirmed that the success levels of “successful”, “inconclusive” and “unsuccessful” differ significantly in the actual implementation experience of technologies in construction Goodrum et al. (2011).

1.2. INNOVATION – CATALYST FOR SUSTAINABILITY

Innovation is often seen as crucial to meeting future demands on the construction industry Lemaitre (2022), Helmus et al. (2020) but is also considered a challenge Jacob (2022). A new culture of thinking and learning and of entrepreneurial will are considered key players. The question of whether innovation should be led primarily by the company, the customer or even politics, or how the promotion of innovation can be catalyzed, how legal requirements and guidelines influence the industry and how value creation can be strengthened, is being discussed publicly Lindblad and Guerrero (2020), Jäkel et al. (2024).

The sensible, responsible use of innovative technologies, such as transferring routine procedures to machines and robots and automated processes, opens up resource savings and reduction of environmental pollution, new opportunities for improvement for higher occupational safety on construction sites, transparent data structuring as a basis for decision-making processes, for more efficient risk management and for essential Improvement and transparency of cost, time and material management Obiuto et al. (2024). In addition, data platforms are accessible to everyone involved in the construction project, regardless of time and location. The illustration of the performance promise includes the effects of subsequent changes. Such environment strengthens the trust of everyone involved and promotes the flow of data and communication.

In fact, the industry previously used digital technologies but only limited to individual areas and not consistently digitized through all procedures, processes

and interfaces Gäbler and Otzdorff (2023), as the collaboration between companies, administration, architects and designers requires.

This includes BIM, the digital twin (digital twin), AI-based image and object recognition, augmented reality (AR) Schranz et al. (2020), virtual reality (VR) Schranz et al. (2021), Internet of Things (IoT), machine learning (ML). AI-supported language models Loeffler (2024) and ChatGPT Rane (2023) are used. Political and social demands for sustainability in relation to nature, the environment and society are becoming an increasingly integral part of R&D, design, implementation, maintenance and conversion, dismantling and new construction of buildings - the building life cycle - and the design of smart, societal sustainable cities of tomorrow.

Engineers, architects and entrepreneurs in Construction 5.0 are required to deal and cope with the rapid pace of technological change Pan and Zhang (2021). Given the profound changes in daily construction life, the demand for engineering students who are professionally qualified for new tasks, and the application of AI increases rapidly Feirabend (2022).

The current foundations of training and assuming corporate responsibility cannot be sufficiently linked to the necessary new knowledge and ethical, social considerations. To achieve these goals, the entire construction industry and the education system would have to be adapted holistically, including language barrier-free access, scientific knowledge transfer and the flowing exchange between R&D, sciences and practice as well as using the knowledge gained and acquiring humanistic skills. Countering the industry's traditionally conservative mindset with a new approach in the digital context of the construction industry 5.0 represents the most important step. There is still a lot of untapped potential and there are high hurdles Young et al. (2021). However, there are numerous milestones achieved, which are discussed in more detail in Section 5.1. The study shows that the integration of technology has a significantly positive impact on social sustainability. Is Construction 5.0 on the way to becoming the strongest industry? What constitutes such a new culture of thinking and learning in Construction 5.0 in order to achieve a socially sustainable, digital and human transformation?

2. MATERIALS AND METHODS

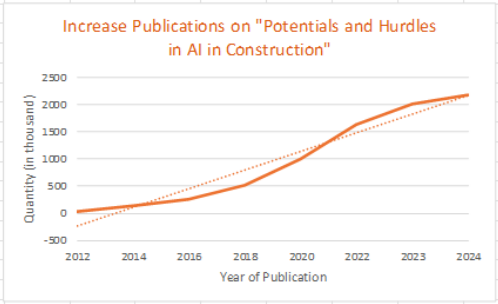
A so-called “next generation” methodology was used in three steps. Digital transformation itself represents an open challenge that requires a “next generation” research methodology.

1) Step: Literature- and Internet Research

A structured literature search with additional internet research on the keywords of the research question revealed: Despite the increasing number of publications on digitization in construction, research gaps still exist. Scientists criticize that the research flow focuses on purely technical aspects of digitization Abdulqader (2024). The social aspects, hurdles, potential and prevention factors of this phenomenon have only recently received more attention Figure 2, whereas publications on aspects of digital transformation in construction have only increased significantly since 2020 Figure 3. The numerical value given in Figure 2 and Figure 3 corresponds to that at the time in August 2024, when the manuscript was completed.

Figure 2

Year of Publication	Quantity
2012	38
2014	139
2016	254
2018	513
2020	995
2022	1630
2023	2000
2024	2170

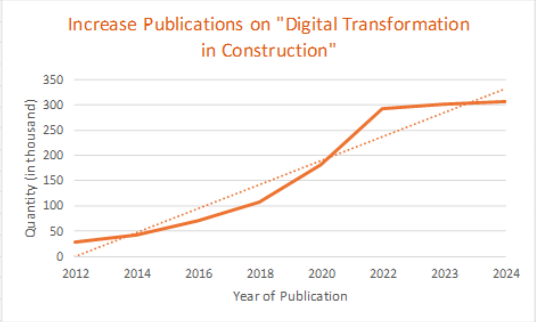


Source: Googlescholar, July 2024

Figure 2 Increase in Publications on "Potentials and Hurdles in AI in Construction" (Status: July 2024)

Figure 3

Year of Publication	Quantity
2012	27700
2014	41900
2016	70700
2018	108000
2020	182000
2022	293000
2023	301000
2024	307000



Quelle: Googlescholar, July 2024

Figure 3 Increase in Publications on "Digital Transformation in Construction" (Status: July 2024)

As the key challenges in construction are largely adequately addressed through digitization, adoption rates are expected to steadily grow to trigger industry change. There is a gap in existing research here. This study addresses this by examining overlooked normative factors that justify expanding digitization and AI technologies.

One of the key considerations that this paper proposes is to uncover the factors that influence an effective digitization scenario to sustainably emerge as the strongest Industry 5.0. Digital advocates in construction often struggle to justify the consequences of radical change, and literature is sparse in providing the evidence necessary to support decision-makers in adoption. The study supports digital advocates with comprehensive arguments.

2) Step: Corporate Best Practices and Role Models

To answer the core question of the study, personal interviews, by telephone and video calls, were conducted between March 2023 and July 2024 with innovative role models and companies in the construction and engineering sectors specifically selected for this study. They are familiar with the technologies or have played a pioneering role. The survey focused on statements assessing innovation ability, hurdles, fields of application, motivations, opportunities, risks, needs and sustainability. The study considers these to be sufficiently representative for an initial assessment and answer to the research question, as these respondents are

currently the most driving force behind new innovation technologies in construction.

3) Step: Analysis and Evaluation according to the Hermeneutic Approach

The hermeneutic research approach uses subjective interpretations of expert interviews, human and social phenomena and thinking Gadamer and Figal (2007), Pasternack (1983). This scientific approach proves to be particularly valuable in applied engineering sciences such as civil engineering, when technical issues are viewed through the human lens and the information obtained is to be evaluated. This applies to recognizing and formulating trends and defining courses of action and procedures and their motivations in the context of the previously defined research question. The study proceeds in four steps: understanding the historical, cultural and business context (structured literary analysis and internet research), understanding the literary context, making observations (expert interviews, public discussions) and drawing conclusions (publications, conferences). The method aims at a circular social and societal understanding (hermeneutic circle) based on technical feasibility and people who are willing to use the new technologies responsibly in accordance with human values, the common good and social sustainability. The approach recognizes data and information collected at the beginning of the research and the need to compare with the latest technology and put to the test with new frameworks that emerge as the research progresses. It therefore represents the most suitable method for assessing the central research question, making things explainable and interpreting the data obtained Weber-Lewerenz (2024).

3. RESULTS AND DISCUSSIONS

The trends shown regarding the rapidly growing scientific publications in the construction industry since 2020 on AI, digital transformation, human-centered engineering and socially sustainable AI provide information about the dynamics, maturity and penetration of innovative concepts over the years.

As technology matures, certain terms such as “AI”, “digitization” and “innovation” follow an S-curve, reflecting the growing interest in new developments once an initial innovation cycle has been defined. Some terms refer to groundbreaking developments that initiate new cycles of innovation, such as: B. new technologies and approaches, digitization and AI, effects on people, society and the environment and novelty/efficiency. The scientific output based on the total number of published articles enables a qualitative interpretation of insightful trends in keywords and their growth rate in the literature. Innovative technologies and approaches in R&D and practice have already proven themselves. It would therefore be expected that terms that appear earlier in the literature would gain importance more quickly. Articles dealing with various new methods and new ways of thinking such as Cradle-to-Cradle (C2C) and Corporate Social Responsibility (CSR) and Corporate Digital Responsibility (CDR) also go through an S-curve.

The author refers to her publications on “CDR in construction” and the sharply increasing focus on the responsible use of digitization and AI since 2018 Weber-Lewerenz (2024). Scientific publications on ethical discussions about impacts on society as a whole reflect similar trends. Innovations that have filled previous research gaps demonstrate their continued appeal. The best practices study results suggest that existing adoption of such arguments has already enabled digital advocates to persuade decision-makers to increasingly embrace digitalization. Four examples provide guidance:

1) Modulina Pylypchuk (2024)

With the help of prefabricated, load-bearing straw panel walls, decarbonization, economic efficiency and environmentally sustainable efficiency can be achieved. With its sustainable, innovative construction practices and the use of building material cycles, the company not only meets ESG regulations but also expands value creation along the construction life cycle, meets and promotes sustainability goals - in accordance with the UN Charter "Building Better Lives" educational initiatives.

2) HILTI Kling (2024)

Digital planning and construction are increasingly being designed with construction robotics and BIM, for example in dimensioning, drawing and BIM design services. A semi-autonomous drilling robot called "Jaibot" was developed, enabling to convert the data from the digital model into real drilling points on the construction site in a highly productive and efficient manner without specialist personnel. The robot drills, marks holes for various trades according to the data model, precisely maintains the depth and diameter and vacuums up the dust. It synchronizes via the mobile data network so that the installation progress can be tracked in real time. This allows construction site processes to arise more productive and efficient, and that optimization potential in terms of materials and time is fully exploited. The entrepreneurially responsible approach to technological innovations aims to provide the best possible relief and support for human work, reliability, real-time data retrieval and sustainability in terms of time and quality of all processes.

3) BIM in Architecture and Design Offices Mühlbauer (2024)

BIM supports architects in creating virtual 3D models of buildings and technical building equipment, planning maintenance work more efficiently and simulating sustainability aspects. BIM coordinates all project phases up to digital defect management and data transfer to facility management. AR helps to project virtual models into the real environment, for example to provide construction processes and instructions onsite in real time. This entrepreneurial culture of innovation catalyzes productivity development and process automation. Digital tools provide recommendations and a strategical decision-making base for the design of buildings to improve energy efficiency or user-friendliness in the green building segment. Metaverse expands possibilities for networking and communication. The technologies used responsibly provide a basis for decision-making for sustainable construction, promote social sustainability aspects at all levels, strengthen trust in innovations, expand and adapt education and the recruitment of skilled workers as well as design in the construction life cycle.

4) VALOON Cisterna (2024)

Digital communication, as developed by Valoon, counteracts stagnating productivity in the industry. Data from the transmitted information recognizes patterns through compilation and statistical analysis and are used to train AI models to automate processes. According to a study by BauInfoConsult. (2020), 72% of construction workers in Germany use WhatsApp for internal coordination and 55% for monitoring and documenting Construction site activities. The widespread adoption of messaging apps effectively overcomes the hurdle of low adoption of new technologies Ahmad Pozin et al. (2019). This leads to widespread acceptance of AI-based technologies and user-friendliness, optimized data collection, management and structuring directly on the construction site. AI implementation significantly advances digital development and increases overall project efficiency and

effectiveness. By switching from traditional communication methods to modern digital platforms, long-standing productivity problems can be addressed.

This study identifies challenges of digital transformation: lack of knowledge, lack of training, lack of resources and digital infrastructure, lack of a contemporary organizational and thought culture, as well as gaps in recent research and available literature with a focus on digital transformation in construction. Although some studies have been conducted, few discuss barriers and critically examine normative aspects. There is an urgent need to generate primary data on these specific challenges and recognize their constant change according to technological developments and societal expectations.

In an early innovation phase, it is necessary to take stock and assess key factors, problem areas and trends. Research shows that the cultural context in which the construction industry operates influences the level of innovation. Research into the connections is still limited. Shared beliefs and values and the desire to innovate are the key success factors for sustainable, trusting business relationships in human and digital change. The corporate role model function has a significant influence on the development and progress of innovation in the industry as a whole. Promotion measures can more effectively improve the willingness of SMEs to innovate. At the same time, they attract qualified experts and specialists Lijauco et al. (2020). The study concludes that its role model effect strengthens the identification of employees, shapes the framework for enabling and promoting innovation. It additionally contributes to the assumption of social responsibility, inspires as a construction influencer in recruiting young talent and inspires people to shape a sustainable, resilient and competitive construction industry. The positive experiences gained during the study encourage the further development of such new approaches.

One of the gamechangers is communication, the way new knowledge is exchanged between research and development, scientific work and practice. This includes the manner of transparent, neutral and investigative reporting that is conducive to public perception of the construction industry, namely an innovative, growing industry in which people, society, humane and democratic values and the environment are the focus.

In approaching the research question, the study identifies a flaw in the system: far from a holistic, fact-based inventory, reporting with biased assessments ensures that the industry is downplayed, innovation and progress in the industry are denied, and “chaos” construction sites like Stuttgart21 or Berlin BER Airport putting their stamp on the industry. There is sparse reporting on existing pioneers and growing fields of successes and innovations that are considered drivers of digital transformation. An outdated way of thinking is being maintained and further cultivated: the fragmentation is to blame, which is why the industry is not fully digitalized, the education system, progress needs more time, the shortage of skilled workers, order books are full, but things are running smoothly. In addition, there are well-established generalities and sometimes even the opinion that legal requirements limit the ability to innovate and there is a lack of freedom in research. The impulses that the industry is providing with a variety of innovations and measures to meet sustainability goals are reported sparingly compared to the public communication of other industries.

However, the interview results and discussion feedback to the author show that there is a great desire for an increasingly critical, value-based and interdisciplinary debate about the sensible use of digital methods and AI, including the possibilities of ad hoc use. Awareness is growing, the need is there, the will to help shape

Construction 5.0 and to fully exploit the opportunities of digital transformation is growing significantly Weber-Lewerenz (2022).

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. MILESTONES

Figure 4 shows the milestones of digitization and AI in the construction industry over the past decades, compared to general developments. Digital technologies such as BIM have been around since 1970, and the first AI-based tools since 2017. Large companies that have their own R&D departments and startups based at universities are increasingly relying on AI as the author's previous study results prove. Once again, the increasing interest in topic-related events such as the Digital Summit, Construction Summit and training courses shows that there is an increased search for orientation and knowledge acquisition to define an individual corporate strategy, participation and synergy opportunities. It has already been recognized that such exchange platforms form important foundations for creating trust in new technologies, their sustainable, responsible implementation in user practice and strengthening the willingness to innovate.

It is only since 2020 that the term “digital transformation” has become established in the construction industry, and only since 2023 has AI been increasingly used in construction with technologies tailored to the construction life cycle and everyday life.

Figure 4

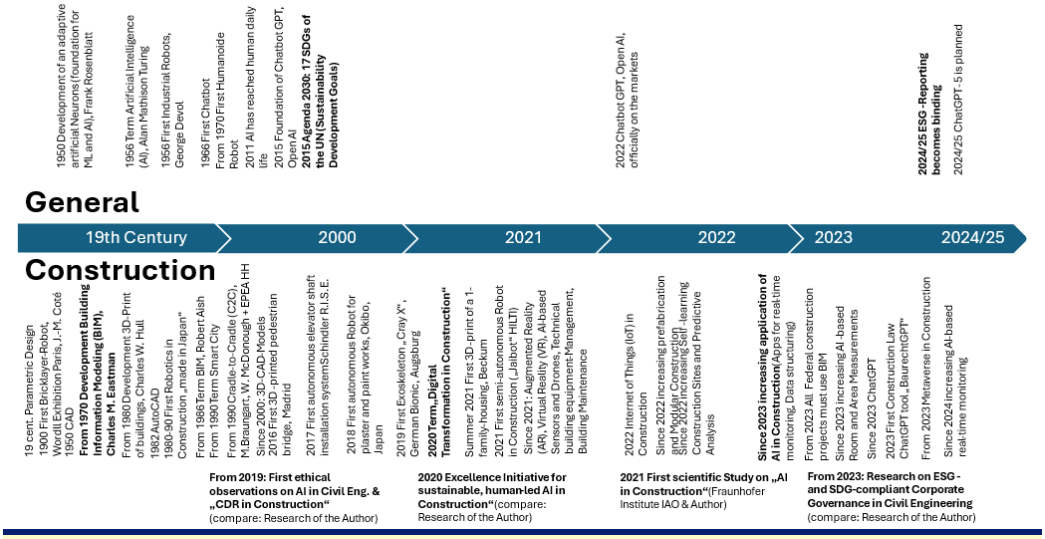


Figure 4 Milestones of Digitization and AI in Construction

4.2. SCIENTIFIC RESEARCH PRACTICE

The research results presented in this study make a significant contribution to the scientific literature on innovation mechanisms in construction. Integrating AI into construction offers a transformative opportunity to adjust traditional approaches to project planning and execution. At the same time, AI represents a paradigm shift towards increased efficiency, productivity, safety, transparency and sustainable project success. These transformative technologies mean evolution and revolution while simultaneously increasing the level of responsibility. The construction industry is expected to have the courage to innovate and an even greater sense of duty to meet sustainability goals and ESG.

Systematic literature searches have identified essential theoretical and business-practical implications: (i) construction innovations, (ii) innovation inputs, (iii) innovation process drivers and (iv) innovation results, in order to clearly identify the tendency of further research on construction innovations and their hurdles. To the best of the author's knowledge, the present study represents one of the few attempts to conduct a comprehensive literature review that also focuses on practical applications of the innovation and diversity paradigm in the construction sector, as well as the innovation phenomenon within the entire value chain of the industry.

4.3. THE URGENT NEED TO BREAK NEW GROUND

This study provides new insights that are otherwise rarely examined in the construction context and, with its knowledge and experience, convinces those who are still hesitant about concrete, practical approaches.

The evaluation method used makes a significant theoretical contribution to answering the research question and in the context of normative aspects, new needs, entrepreneurial orientation and consideration of the goals of overall socially sustainable development. In view of such a complex topic, new approaches are needed in science and research.

A group of experts surveyed as part of this study provides an additional maturity assessment of construction 5.0: "…getting rid of old role models is a goal… consciously set…" says Jutta Beeke. Nicola Marsden knows, "…. Diversity as a driving force for innovation and creativity... The future of construction: gender equality as a key factor" Beeke (2024). Katharina Hölzle is convinced that "Change and innovation always begins with and through people…and the questions arise for all engaged in the construction ecosystem: which technologies do we need, how do we use them…to support…" Hölzle (2024).

Annemarie Mulder explains that "…digital transformation is an overarching theme: a mix of human resources development, training, technology and research & development. …… BIM or AI is no longer a nice-to-have. …… on a scale of 1-10, I estimate the willingness of construction companies to integrate digitalization to be very high (8-9), the level of implementation to be very low (4) … and the need for information about digitalization and AI to be very high….a new culture of thinking construction must take hold" Mulder (2024).

For Susanne Haus one thing is certain: "…sustainability is in the DNA of the craft." Haus (2024)

Jule Janson: "I notice that digital change and innovations in construction are improving the image of the construction industry as a whole…. By helping to shape and actively tackle this change, the construction industry is also sending an important signal to the outside world, namely: Construction is making progress!" Janson (2024). Based on the study results, the author assesses the construction industry as one that has a long history and fundamentally high values with the aim of high customer satisfaction, the innovative strength proven by the milestones, increasing diversity and the design of all living and working environments on the way to becoming the most sustainable industry. Future research in this scientific field is crucial.

CONFLICT OF INTERESTS

None.

ACKNOWLEDGMENTS

This acknowledgement goes to the multidisciplinary networks who support this research including “CDR in Construction” and get engaged in the value-based development and implementation of technological innovation in Construction.

REFERENCES

Abdulqader, Z. A. (2024). Responsible AI Development for Sustainable Enterprises: A Review of Integrating Ethical AI with IoT and Enterprise Systems. Journal of Information Technology and Informatics, 3(2), 129–156.

Adhikari, D. R., & Shrestha, P. (2023). Knowledge Management Initiatives for Achieving Sustainable Development Goal 4.7: Higher Education Institutions' Stakeholder Perspectives. Journal of Knowledge Management, 27(4), 1109–1139. https://doi.org/10.1108/JKM-03-2022-0172

Adriaanse, A. M., et al. (2004). Alignment Between ICT and Communication in Construction Projects. International Journal of Human Resources Development and Management, 4(4), 346–357. https://doi.org/10.1504/IJHRDM.2004.005043

Ahmad Pozin, M. A., et al. (2019). An Ability of WhatsApp Usage in Industrialised Building System (IBS) Construction Project. International Journal of Interactive Mobile Technologies, 13(4), 188. https://doi.org/10.3991/ijim.v13i04.10548

Alaloul, W. S., et al. (2018). Industry Revolution IR 4.0: Future Opportunities and Challenges in Construction Industry. MATEC Web of Conferences, 203, 02010. https://doi.org/10.1051/matecconf/201820302010

Alaloul, W. S., et al. (2022). Productivity Monitoring in Building Construction Projects: A Systematic Review. Engineering, Construction and Architectural Management, 29(7), 2760–2785. https://doi.org/10.1108/ECAM-03-2021-0211

An, L., et al. (2022). Knowledge Management and Innovation. Data and Information Management, 6(3), 100018. https://doi.org/10.1016/j.dim.2022.100018

Bal, M., Bryde, D., Fearon, D., & Ochieng, E. (2013). Stakeholder Engagement: Achieving Sustainability in the Construction Sector. Sustainability, 5(2), 695–710. https://doi.org/10.3390/su5020695

BauInfoConsult. (2020). Social Media am Bau: Stärkerer Einsatz von WhatsApp im Berufsalltag.

Beeke, J. (2024). Gastvorwort. In B. Weber-Lewerenz (Ed.), Diversität im Bauwesen—Die Gamechanger. Springer. https://doi.org/10.1007/978-3-658-45632-0

Blayse, A. M., & Manley, K. (2004). Key Influences on Construction Innovation. Construction Innovation, 4(3), 143–154. https://doi.org/10.1108/14714170410815060

Chen, Z. S., et al. (2024). Dynamic Collective Opinion Generation Framework for Digital Transformation Barrier Analysis in the construction industry. Information Fusion, 103, 102096. https://doi.org/10.1016/j.inffus.2023.102096

Chung, J. K. H., et al. (2009). Improving Megaproject Briefing Through Enhanced Collaboration with ICT. Automation in Construction, 18(7), 966–974. https://doi.org/10.1016/j.autcon.2009.05.001

Cisterna, D. (2024). Von Walkie-Talkies bis hin zu Messaging-Apps: Erkundung der Herausforderungen und Chancen bei der Kommunikation und

Datenerfassung bei Bauprojekten. In B. Weber-Lewerenz (Ed.), Diversität im Bauwesen—Die Gamechanger. Springer.
Daniotti, B., Gianinetto, M., & Della Torre, S. (2020). Digital Transformation of the Design, Construction and Management Processes of the Built Environment (p. 400+). Springer Nature. https://doi.org/10.1007/978-3-030-33570-0
Ernstsen, S. N., Whyte, J., Thuesen, C., & Maier, A. (2021). How innovation Champions Frame the Future: Three Visions for Digital Transformation of Construction. Journal of Construction Engineering and Management, 147(1). https://doi.org/10.1061/%28ASCE%29CO.1943-7862.0001928
Feirabend, S. (2022). Digitale Kompetenz im Bauwesen—Quo vadis? In 1. Fachkongress Konstruktiver Ingenieurbau (pp. 25–34).
Gadamer, H. G., & Figal, G. (2007). Wahrheit und Methode (pp. 395–396). Akademie Verlag.
Ghaffar, S. H., et al. (2022). Innovation in Construction: A Practical Guide to Transforming the Construction Industry. Springer. https://doi.org/10.1007/978-3-030-95798-8
Goodrum, P., et al. (2011). Model to Predict the Impact of a Technology on Construction Productivity. Journal of Construction Engineering and Management, 137(9), 678–688. https://doi.org/10.1061/%28ASCE%29CO.1943-7862.0000328
Gäbler, J., & Otzdorff, M. (2023). Digitale Transformation im Bauwesen: Digitale Werkzeuge und Agiles Arbeiten im Modernen Hochbau. In Agile Digitalisierung im Baubetrieb (pp. 261–278). Springer. https://doi.org/10.1007/978-3-658-43247-8_13
Haghsheno, S., Satzger, G., Lauble, S., & Vössing, M. (2024). Künstliche Intelligenz im Bauwesen: Grundlagen und Anwendungsfälle. Springer. https://doi.org/10.1007/978-3-658-42796-2
Haus, S. (2024). Diversität aM Bau—Wege Ins Handwerk: Es Zählt Nicht, Wo Du Herkommst, Sondern Wo Du Hinwillst. In B. Weber-Lewerenz (Ed.), Diversität im Bauwesen—Die Gamechanger. Springer.
Helmus, M., et al. (2020). Building Information Modeling (BIM) Als Basis fÜr Den Umgang Mit Digitalen Informationen Zur Optimierung Von Stoffkreisläufen im Bauwesen. DBU. https://www.dbu.de/projekt_33110/01_db_2848.html
Hölzle, K. (2024). Grußwort. In B. Weber-Lewerenz (Ed.), Diversität im Bauwesen—Die Gamechanger. Springer. https://doi.org/10.1007/978-3-658-45632-0
Jacob, C. (2022). Der traditionelle Weg Der Bau- Und Immobilienwirtschaft in Die Digitalisierte Welt. In Auf Dem Weg Zu Einer Nachhaltigen, Effizienten Und Profitablen Wertschöpfung Von Gebäuden (pp. 3–23). Springer. https://doi.org/10.1007/978-3-658-34962-2_1
Jahanger, Q. K., Louis, J., Pestana, C., & Trejo, D. (2021). Potential Positive Impacts of Digitalization of Construction-Phase Information Management for Project Owners. Journal of Information Technology in Construction, 26. https://doi.org/10.36680/j.itcon.2021.001
Janson, J. (2024). Handwerk hat Goldenen Boden. In B. Weber-Lewerenz (Ed.), Diversität im Bauwesen—Die Gamechanger. Springer.
Jäkel, J. I., Zoghian, P. M., & Klemt-Albert, K. (2024). Anwendungsfelder und Implementierungsmodelle von Robotik im Bauwesen. In S. Haghsheno et al. (Eds.), Künstliche Intelligenz im Bauwesen (pp. 395–412). Springer. https://doi.org/10.1007/978-3-658-42796-2_23
Klinc, R., & Turk, Ž. (2019). Construction 4.0—Digital Transformation of one of the Oldest Industries. Economic and Business Review, 21(3). https://doi.org/10.15458/ebr.92

Kling, H. (2024). My Story: Ein Berufsleben Zwischen Familie, Vertrieb und Engineering. In B. Weber-Lewerenz (Ed.), Diversität im Bauwesen—Die Gamechanger. Springer.

Koscheyev, V., Rapgof, V., & Vinogradova, V. (2019). Digital Transformation of Construction Organizations. IOP Conference Series: Materials Science and Engineering, 497(1), 012010. https://doi.org/10.1088/1757-899X/497/1/012010

Kraus, M. A., & Drass, M. (2020). Künstliche Intelligenz im Bauingenieurwesen: Hintergründe, Status Quo und Potenziale. Bauingenieur, 95(10). https://doi.org/10.37544/0005-6650-2020-10-39

Kölzer, T. (2022). Nachhaltige Und Digitale Konzepte im Bauwesen—Komplex, Konträr, Kompatibel, Konstruktiv. In Nachhaltige Und Digitale Baukonzepte (pp. 1–36). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-36776-3_1

Lemaitre, C. (2022). Vollgas Richtung Nachhaltiger Ingenieurbau! Der Bauingenieur, 97(3), A3.

Lijauco, F., Gajendran, T., Brewer, G., & Rasoolimanesh, S. M. (2020). Impacts of Culture on Innovation Propensity in Small to Medium Enterprises in Construction. Journal of Construction Engineering and Management, 146(2). https://doi.org/10.1061/%28ASCE%29CO.1943-7862.0001753

Lindblad, H., & Guerrero, J. R. (2020). Client's Role in Promoting BIM Implementation and Innovation in Construction. Construction Management and Economics, 38(5), 468–482. https://doi.org/10.1080/01446193.2020.1716989

Loeffler, J. (2024). Exploration der Möglichkeiten und Einflussfaktoren von großen Sprachmodellen zur digitalen Transformation, Effizienzsteigerung und Förderung nachhaltiger Praktiken \[Master's thesis]. HTWG Konstanz.

Mulder, A. (2024). SAchlich Konstruktiv + Lächeln Aber Bestimmt Sein = Gefährliche Frau! In B. Weber-Lewerenz (Ed.), Diversität im Bauwesen—Die Gamechanger. Springer.

Mühlbauer, M. (2024). Aktuelle Chancen für Diversität im Kontext von BIM, KI, Metaverse und Augmented Reality. In B. Weber-Lewerenz (Ed.), Diversität im Bauwesen—Die Gamechanger. Springer.

Obiuto, N. C., Adebayo, R. A., Olajiga, O. K., & Festus-Ikhuoria, I. C. (2024). Integrating Artificial Intelligence in Construction Management: Improving Project Efficiency and Cost-Effectiveness. International Journal of Advanced Multidisciplinary Research Studies, 4(2), 639–647. https://doi.org/10.62225/2583049X.2024.4.2.2550

Oesterreich, T. D., & Teuteberg, F. (2016). Understanding the Implications of Digitisation and Automation in the Context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. Computers in Industry, 83, 121–139. https://doi.org/10.1016/j.compind.2016.09.006

Pan, Y., & Zhang, L. (2021). Roles of Artificial Intelligence in Construction Engineering and Management: A Critical Review and Future Trends. Automation in Construction, 122. https://doi.org/10.1016/j.autcon.2020.103517

Pasternack, G. (1983). Interpretation as Methodical Procedure: Methodological Fundaments of Normed Hermeneutics. Poetics, 12(2–3), 185–205. https://doi.org/10.1016/0304-422X%2883%2990027-X

Perkins, I., & Skitmore, M. (2015). Three-Dimensional Printing in the Construction Industry: A Review. International Journal of Construction Management, 15(1), 1–9. https://doi.org/10.1080/15623599.2015.1012136

Pylypchuk, P. (2024). 6 Strategien zur Skalierung Der Bauinnovation. In B. Weber-Lewerenz (Ed.), Diversität im Bauwesen—Die Gamechanger. Springer.

Rane, N. (2023). Role of ChatGPT and Similar Generative Artificial Intelligence (AI) in Construction Industry. SSRN. https://doi.org/10.2139/ssrn.4598258

Schranz, C., Gerger, A., & Urban, H. (2020). Augmented Reality im Bauwesen: Teil 1—Anwendungs- und Anforderungsanalyse. Der Bauingenieur, 95(10), 379–388. https://doi.org/10.37544/0005-6650-2020-10-49

Schranz, C., et al. (2021). AR-AQ-Bau: Einsatz von Augmented Reality zur Abnahme und Qualitätssicherung auf Baustellen. In Agile Digitalisierung im Baubetrieb. Springer. https://doi.org/10.1007/978-3-658-43247-8_13

Shang, C., et al. (2004). Study on the Standard System of the Application of Information Technology in China's Construction Industry. Automation in Construction, 13(5), 591–596. https://doi.org/10.1016/j.autcon.2004.04.005

Weber-Lewerenz, B. (2021). Die unternehmerisch verantwortungsvolle Digitalisierung im Bauwesen. Bauingenieur, 96(1–2), 19–25. https://doi.org/10.37544/0005-6650-2021-01-02-45

Weber-Lewerenz, B. (2022). Wertakzente im Bauwesen 4.0: Ethische Beobachtungen im Umgang mit der Digitalisierung und KI. Springer. https://doi.org/10.1007/978-3-658-38238-4

Weber-Lewerenz, B. (2024). Innovation Empowerment in Construction 4.0 by the CDR-Approach: A new field of Scientific Research for the Digital Breakthrough \[Doctoral dissertation]. Springer. https://doi.org/10.1007/978-3-658-43905-7

Weber-Lewerenz, B. (2024). KI im Bauwesen: Wie Wollen Wir Sie Einsetzen? [Podcast interview]. Springer Verlag Podcast Hören.Lesen.Wissen.

Wen, J., & Gheisari, M. (2020). Using Virtual Reality to Facilitate Communication in the AEC Domain: A Systematic Review. Construction Innovation, 20(3), 509–542. https://doi.org/10.1108/CI-11-2019-0122

Young, D., Panthi, K., & Noor, O. (2021). Challenges Involved in Adopting BIM on the Construction Jobsite. EPiC Series in Built Environment, 2(2), 302–310. https://doi.org/10.29007/f8r3

Zulu, S. L., et al. (2023). Exploring Leaders' Perceptions of the Business Case for Digitalisation in the Construction Industry. Buildings, 13(3), 701. https://doi.org/10.3390/buildings13030701