ISSN: 2633-4828 Vol. 5 No. S6, (Oct - Dec 2023)

International Journal of Applied Engineering & Technology

INTEGRATED APPROACH TO DESIGN AND CONSTRUCTION OF CIVIL ENGINEERING STRUCTURES IN INDIA: A MATERIALS-FOCUSED REVIEW

Vishwas Malik[1], Akash Malik[2] and Arun Kumar[3]

[1]University Institute of Engineering and Technology, MDU Rohtak

[2,3]Department of Civil Engineering, Galgotias College of Engineering and Technology, Greater Noida, 201310

Date of Submission: 4th August 2023 Revised: 28th Sept. 2023 Accepted: 21 th Oct. 2023

ABSTRACT

The abstract of the paper provides a concise overview of its main objectives, methodology and findings. It begins by identifying the need for innovative construction practices in India, driven by rapid urbanization and the quest for sustainable, durable and cost-efficient infrastructure. The focus of the study is on the integrated approach to the design and construction of civil engineering structures, particularly emphasizing the selection and utilization of materials. The paper aims to review current practices, pinpoint challenges and highlight recent advancements within the context of India's construction industry. By conducting an extensive literature review and analyzing various case studies, the study seeks to offer valuable insights into how the integration of design and construction phases can lead to improved project outcomes. Specifically, it explores how careful material selection contributes to the innovation, durability and cost-effectiveness of civil engineering projects.

Keywords: Construction, Industry, Environmental, Economic, Visibility

1 INTRODUCTION

The introduction of the paper sets the stage for a comprehensive examination of the integrated design and construction approach within India's civil engineering sector, with a specific focus on material selection and utilization. It contextualizes the urgency and relevance of this study against the backdrop of India's rapid urbanization and the pressing need for infrastructure development that is not only efficient and durable but also sustainable and cost-effective [1]. Traditional construction practices, characterized by a linear, sequential approach to design and construction, have often resulted in inefficiencies, increased costs and significant environmental impacts [2]. The paper posits that an integrated approach, which blurs the lines between the design and construction phases and promotes early collaboration among all stakeholders, could address these challenges. By emphasizing the role of materials in achieving innovative and resilient structures, the introduction argues for a shift towards practices that consider environmental sustainability, economic viability and architectural integrity from the outset. It lays the groundwork for a detailed exploration of how such an approach can revolutionize the construction process, particularly in the context of India's unique challenges and opportunities [3].

2 REVIEW OF LITERATURE:

Franco et al. (2022), delve into the transformative effects of Industry 4.0 on the civil construction sector, focusing on sustainability. This paper reviews literature and bibliometric data to uncover how technologies like sensors, robots, AI and drones can boost productivity, efficiency, safety and environmental management in construction. The authors highlight the persistent challenges of resource consumption and safety risks and propose that advanced technologies provide solutions to these issues. They emphasize the dual role of Industry 4.0 technologies in addressing operational inefficiencies and promoting sustainable practices, such as reducing material waste and enhancing material reuse, which align with environmental sustainability goals. The paper suggests that these technologies can create innovative solutions that streamline work processes, potentially catalyzing growth by balancing project management costs and benefits. This study underscores the importance of adopting Industry 4.0 technologies in the construction industry to foster a more sustainable, efficient and technologically integrated future.

Lamba, Kaur, Raj and Sorout (2021), in research paper exhaustive analysis of utilizing plastic waste in construction materials. They address the critical issue of plastic waste accumulation and its adverse effects on natural resources, noting the urgent need for sustainable recycling and reuse practices. The study categorizes and

examines the use of plastic waste in various construction applications, such as bricks, tiles, blocks, concrete and road construction, highlighting the environmental benefits of reducing natural resource exploitation. The document discusses the potential of different types of plastic waste materials for inclusion in manufacturing construction materials, shedding light on the significant gap in literature regarding comprehensive studies on the incorporation of plastic waste across different construction sectors.

Baghalzadeh et al. (2022), xplore the evolving landscape of the construction industry through BIM, IoT and DT lenses. Employing bibliometric and systematic literature review methodologies, they analyze these technologies' integration and impact on construction processes, leveraging data from numerous academic publications. The study reveals a growing trend in adopting digital technologies in construction to address challenges in productivity and project performance. It highlights BIM's role in improving communication among stakeholders and outlines the potential of DT and IoT in overcoming integration and collaboration failures, which are core performance concerns in construction projects. This comprehensive review identifies significant focus areas for future research, emphasizing these technologies' role in enhancing efficiency, project management and innovation in construction practices.

Hamza, Shahid, Hainin, & Nashwan (2020), delve into the crucial aspects that influence productivity within the construction sector. They meticulously sift through 88 studies to identify what significantly impacts construction labor productivity. The researchers find that productivity isn't solely dependent on having enough materials or the latest technology but heavily relies on the human element. Key factors include competent supervision, ensuring the team has sufficient materials and clear knowledge of tasks. The study also points out that geographical location plays a significant role, with manual labor reliance and technology adoption varying significantly between developing and developed regions. This research illuminates the multifaceted nature of construction labor productivity, highlighting both the importance of skilled human resources and the potential benefits of integrating advanced technologies to enhance overall efficiency and output in construction projects.

Lamba, Kaur, Raj, & Sorout (2021), undertake a critical examination of the role of plastic waste in the construction industry. Through a meticulous review of existing literature, they explore how plastic waste can be transformed from an environmental burden into a valuable resource for construction materials. The study systematically categorizes the application of recycled plastic in various construction components such as bricks, tiles and concrete, underscoring the potential for significant environmental benefits. The researchers emphasize that the vast production of plastic waste, with a staggering 300 million tonnes generated annually worldwide, presents both a challenge and an opportunity for sustainable development in construction. By integrating recycled plastic into building materials, the construction industry can not only mitigate the adverse environmental impact of plastic waste but also contribute to the conservation of natural resources. They advocate for a broader exploration of plastic waste types, including polyethylene, polypropylene and PET, among others, in construction applications. This call to action highlights the need for further research and innovation in incorporating diverse plastic waste materials in the construction sector, aiming for sustainability and environmental preservation.

3 MATERIALS IN CIVIL ENGINEERING:

This section provides an overview of the materials commonly used in civil engineering, particularly within the Indian context, drawing a contrast between traditional and modern materials. It highlights how historically, India's construction landscape was dominated by materials such as brick, stone and wood [4]. These materials, while being abundant and culturally significant, present limitations regarding durability, resistance to natural disasters and environmental sustainability [5]. The narrative then shifts to the advent of modern construction materials like concrete, steel and composites, which have significantly transformed the industry. These modern materials offer enhanced properties such as higher strength, better durability and greater design flexibility, which traditional materials cannot match. Furthermore, the discussion extends to sustainable materials and technologies, such as recycled aggregates and green concrete, emphasizing their growing importance in light of environmental concerns and regulatory demands [6]. This overview sets the stage for understanding the crucial role materials play in civil

engineering projects, underlining the need for thoughtful selection and application to achieve innovative, sustainable and cost-effective construction solutions [7].

4 INTEGRATED DESIGN AND CONSTRUCTION APPROACH:

The section on the integrated design and construction approach delves into a transformative methodology within the civil engineering and construction industry, characterized by a seamless, collaborative process that merges the design and construction phases of a project [8]. Unlike traditional methods, where design and construction are distinct and sequential phases, the integrated approach advocates for a concurrent and holistic consideration of both aspects from the project's inception [9]. This methodology emphasizes the early and active involvement of all stakeholders, including architects, engineers, contractors and clients, fostering a unified vision and objective for the project. The benefits of this approach are manifold. It leads to enhanced efficiency through streamlined communication and reduced conflicts, thereby saving time and reducing costs. Quality improvements are achieved by making informed decisions that consider both design intricacies and construction realities, resulting in structures that are not only aesthetically pleasing but also functional and durable [10]. Moreover, focusing on materials within this integrated framework allows for the selection of sustainable options, significantly reducing the environmental impact of construction projects. This integrated approach, particularly when applied in the context of India's burgeoning infrastructure needs, presents a promising avenue for addressing the challenges of urbanization while promoting sustainability and innovation in construction practices [11].

5 CASE STUDIES IN INDIA:

5.1 Case Study 1: Kochi Metro Rail Project:

The Kochi Metro Rail Project is a prime example of sustainable urban transportation development in India. Initiated to improve the public transport system in Kochi, the project is notable for its emphasis on environmental sustainability and the adoption of innovative construction techniques. This initiative aimed at offering an efficient, eco-friendly alternative to the city's existing transport options, marks a significant step forward in integrating sustainability into the core of urban infrastructure development.

Materials/Technologies Used

Eco-friendly Building Materials: One of the foundational elements of the Kochi Metro Rail Project was the use of eco-friendly building materials. These materials are selected based on their minimal environmental impact, aligning with the project's overarching goal of sustainability. By opting for such materials in the construction of stations and related infrastructure, the project demonstrates a commitment to reducing its ecological footprint.

Solar Panels: A groundbreaking aspect of the Kochi Metro is its use of solar panels across all metro stations. This initiative made Kochi Metro the first metro project in India to harness solar energy on a significant scale, aiming to diminish its reliance on traditional energy sources. The adoption of solar panels represents a pivotal step towards sustainable energy usage in public infrastructure.

Rainwater Harvesting Systems: The project incorporated rainwater harvesting systems into the metro station designs. These systems are engineered to collect and repurpose rainwater, showcasing the project's dedication to water conservation. By implementing such systems, Kochi Metro contributes to alleviating the demand on the municipal water supply, underlining the project's water-conservative approach.

Building Information Modeling (BIM): The extensive use of Building Information Modeling (BIM) technology was a critical factor in the project's planning and management phases. BIM facilitated efficient coordination among different teams, optimizing the construction process and minimizing the likelihood of errors. This technology served as a collaborative tool, enhancing decision-making and project efficiency.

The Kochi Metro Rail Project serves as a sterling example of how sustainable design and construction methodologies can lead to the development of eco-friendly and efficient public transportation systems. It stands as a benchmark for future urban transit solutions in India and elsewhere, demonstrating the tangible benefits of integrating sustainability and innovation in infrastructure projects. This project not only addresses the immediate

need for improved public transportation but also contributes to the broader goals of environmental sustainability and urban development.

Figure 1: Kochi Metro Rail Project

1.5.2 Case Study 2: Gujarat International Finance Tec-City (GIFT City):

GIFT City stands as a groundbreaking endeavor to position India on the map as a host for a global financial hub. This project transcends traditional urban development by merging cutting-edge infrastructure with smart city innovations, setting the stage for a high-quality living environment alongside a robust business ecosystem. The vision behind GIFT City is to craft an urban space that not only serves as a cornerstone for financial activities on a global scale but also promotes a sustainable and efficient lifestyle for its residents. This dual focus on economic prosperity and quality of life is what distinguishes GIFT City from other urban development projects, aiming to attract businesses and talent from around the world through its advanced facilities and smart living conditions.

Materials/Technologies Used

Advanced Simulation Models and Building Information Modeling (BIM): GIFT City's planning and construction phases leveraged advanced simulation models and Building Information Modeling (BIM) technology. These tools enabled the project team to visualize complex designs, simulate environmental impacts and streamline the construction process. Advanced simulation models provided insights into how the city would respond to various challenges, including traffic flow, energy consumption and environmental stresses. BIM, on the other hand, offered a collaborative platform for architects, engineers and construction professionals to work together efficiently, reducing errors and ensuring that all aspects of the city's development were aligned with the project's sustainability goals.

Green Building Materials and Practices: The emphasis on sustainability is evident in GIFT City's extensive use of green building materials and construction practices. Eco-friendly materials that have a lower environmental impact were prioritized, including sustainable timber, recycled steel and low-VOC (volatile organic compounds) paints and finishes. These materials contribute to healthier indoor air quality and reduce the overall environmental footprint of the buildings. Moreover, construction practices were designed to minimize waste and promote recycling, ensuring that the development of GIFT City was in harmony with environmental conservation principles.

Energy-Efficient Buildings and LEED Certification: Aiming for high ratings under LEED and other green building certification systems, GIFT City features energy-efficient buildings equipped with state-of-the-art technologies to minimize energy consumption. This includes the use of high-performance glazing, energy-efficient HVAC (heating, ventilation and air conditioning) systems and smart lighting controls. These technologies not only reduce the operational costs of buildings but also contribute to a lower carbon footprint for the city.

Waste Recycling Systems: Integral to the city's sustainable infrastructure are its waste recycling systems. GIFT City implements comprehensive waste management practices, including the segregation of waste at source, recycling of materials and the conversion of organic waste into compost. These systems are designed to reduce the amount of waste sent to landfills, promote the reuse of materials and contribute to the overall sustainability of the city.

Extensive Green Spaces: GIFT City incorporates extensive green spaces to enhance biodiversity and provide residents with lush, natural environments. These spaces are not only aesthetically pleasing but also play a critical role in improving air quality, reducing urban heat island effects and providing habitats for various plant and animal species. The integration of green spaces into the urban fabric is a testament to GIFT City's commitment to creating a living environment that values and preserves nature.

Through the strategic use of these materials and technologies, GIFT City embodies the principles of integrated design and construction. It sets a precedent for future urban development projects, demonstrating that it is possible to achieve economic growth while prioritizing environmental sustainability and enhancing the quality of life for residents.

Figure 2: Gujarat International Finance Tec-City (GIFT City)

1.5.3 Case Study 3: Bengaluru Green Corridors

The Bengaluru Green Corridors initiative is a forward-thinking project designed to tackle some of the most pressing environmental issues faced by urban areas today, specifically urban heat islands and deteriorating air quality. Bengaluru, as one of India's rapidly expanding metropolitan areas, has been at the forefront of urbanization challenges. This initiative seeks to mitigate these challenges by introducing interconnected green spaces throughout the city. By adhering to sustainable landscaping and urban planning principles, the project aims not only to enhance the aesthetic appeal of the city but also to provide significant ecological benefits, such as temperature regulation and improved air quality. The creation of these green corridors represents a holistic approach to urban planning, integrating the need for urban expansion with environmental preservation and community well-being.

MATERIALS/TECHNOLOGIES

Sustainable Landscaping Materials: A cornerstone of the Bengaluru Green Corridors initiative is the use of sustainable landscaping materials. This includes the selection of native plants and trees which are more adapted to the local climate and therefore require less water and maintenance, contributing to the overall sustainability of the project. Permeable paving materials are another key component, chosen for their ability to reduce runoff and increase groundwater recharge. These materials are essential in walkways and other pedestrian areas within the green corridors, enhancing the functionality and environmental friendliness of the spaces. Additionally, the initiative prioritizes the use of recycled water for irrigation purposes, further emphasizing water conservation and the reuse of resources.

Renewable Energy Sources: In line with its commitment to sustainability, the Bengaluru Green Corridors project incorporates renewable energy sources, specifically solar lighting, to illuminate the corridors. This not only reduces the carbon footprint associated with traditional energy sources but also ensures that the green corridors remain accessible and safe for public use after dark. The adoption of solar lighting exemplifies the project's holistic approach to environmental sustainability, harnessing clean energy to power essential services and contribute to the creation of energy-efficient urban spaces.

Geographic Information Systems (GIS): The strategic planning and design of the green corridors are facilitated by Geographic Information Systems (GIS). This technology allows planners to analyze various environmental and urban data to determine the optimal locations for these green spaces, maximizing their environmental impact and accessibility to the public. GIS technology supports the integration of the green corridors with existing urban infrastructure, ensuring that they serve as effective links between different parts of the city. By utilizing GIS for planning purposes, the initiative is able to create a network of green spaces that not only enhance urban biodiversity and improve air quality but also provide accessible recreational areas for the city's inhabitants, promoting a healthier urban environment.

The Bengaluru Green Corridors initiative represents a multifaceted approach to urban environmental challenges. By leveraging sustainable landscaping materials, renewable energy sources and advanced planning technologies like GIS, the project embodies a comprehensive strategy for enhancing urban livability and sustainability. Through the creation of interconnected green spaces, the initiative aims to mitigate the effects of urban heat islands, improve air quality and provide accessible green spaces for the community, setting a precedent for sustainable urban development.

Figure 3: Bengaluru Green Corridors

Table 1: Projects on Integrated Design and Construction Approach

Project	Materials/Technologies	Characteristics	Functions
Kochi Metro Rail Project	Eco-friendly Building Materials, Solar Panels, Rainwater Harvesting Systems, Building Information Modeling (BIM)	Renewable, Energy-efficient, Water-conservative, Collaborative Design Tool	Reduce carbon footprint, Generate clean energy, Conserve water, Enhance project efficiency
Gujarat International Finance Tec-City (GIFT City)	Green Building Materials, Advanced Simulation Models and BIM, Waste Recycling Systems, Green Spaces	Sustainable, Digitalized Planning, Waste Minimizing, Biodiversity Enhancing	Build sustainably, Streamline design and construction, Reduce waste, Improve urban ecology
Bengaluru Green Corridors	Sustainable Landscaping Materials, Renewable Energy Sources, Geographic Information Systems (GIS)	Eco-friendly, Renewable, Data-driven Landscape Planning	Improve air quality, Generate sustainable energy, Plan urban green spaces effectively

Through the analysis of various projects, such as the Delhi Metro, the Bandra-Worli Sea Link and several green building initiatives, this section illustrates the practical benefits and challenges of implementing this methodology in India. These case studies serve as tangible evidence of how integrating design and construction phases, with a particular emphasis on material selection, can lead to significant advancements in project efficiency, sustainability and innovation. The Delhi Metro project, for instance, showcases the efficiency and safety improvements achieved through collaborative design and construction efforts, while the Bandra-Worli Sea Link highlights the innovative use of materials and engineering techniques to overcome geographical and environmental challenges. Green building initiatives across urban centers further underscore the sustainability benefits that can be realized by adopting an integrated approach. Collectively, these case studies not only validate the theoretical advantages discussed in earlier sections but also present a nuanced understanding of the obstacles faced during implementation, such as regulatory hurdles, market dynamics and the need for stakeholder education and collaboration. This exploration into successful Indian projects thus reinforces the potential of the integrated design and construction approach to revolutionize the country's construction industry.

Delhi Metro: Precast Concrete Segments, these were used extensively in the construction of tunnels and elevated tracks. Precast concrete is known for its durability, strength and ability to be manufactured in controlled environments before being transported and assembled on-site. This material choice facilitated rapid construction and ensured quality control, crucial for the metro's infrastructure, which demands high safety standards and durability. Bandra-Worli Sea Link: High-Strength Steel, selected for its superior structural properties, high-strength steel provided the necessary tensile strength for the cable-stayed bridge. It's particularly valued for its ductility, weldability and resistance to corrosion, essential qualities for structures exposed to harsh marine environments. Concrete, high-performance concrete was used for its excellent compressive strength and durability, especially important in the bridge's foundation and towers. The concrete was likely enhanced with admixtures to improve its properties, such as increased resistance to the aggressive saline environment.

Green Building Initiatives: Recycled Materials, tese include recycled aggregates, glass and plastic used in various construction applications, from structural components to finishes. Using recycled materials reduces the environmental footprint by minimizing waste and conserving natural resources. Sustainable Materials, Bamboo, known for its rapid growth and structural strength, serves as a sustainable alternative to traditional wood or steel in some applications. Other sustainable materials include fly ash in concrete, which improves concrete properties while utilizing waste byproducts from coal power plants. Energy-Efficient Systems, not a traditional 'material,'

but integral to green buildings are systems like solar panels and green roofs. Solar panels reduce reliance on non-renewable energy sources, while green roofs offer insulation, reduce runoff and improve air quality.

6 CONCLUSION

The exploration of an integrated design and construction approach, with a particular focus on innovative material use in India, reveals a promising avenue for revolutionizing the construction industry. By marrying the phases of design and construction into a cohesive, collaborative process and prioritizing the selection of materials not just for their structural qualities but also for their sustainability, this approach can address some of the most pressing challenges faced by the industry today. They demonstrate that with thoughtful selection of materials and a commitment to collaboration, projects can achieve greater efficiency, sustainability and resilience. However, the transition to this integrated approach is not without its challenges. Resistance to change, regulatory hurdles, skill gaps and cost concerns are significant obstacles that need to be navigated. Despite these challenges, the opportunities presented by this approach are too significant to ignore. The potential for creating more sustainable and efficient buildings, enhancing collaboration among project stakeholders, leveraging technological advancements and aligning with government initiatives for infrastructure development opens up new horizons for the construction industry in India. Moreover, adopting such forward-thinking practices can elevate India's position on the global stage, showcasing its commitment to sustainable development and innovation.

The journey towards widespread adoption of an integrated design and construction approach in India may be fraught with challenges, the rewards promise a future of more sustainable, efficient and innovative infrastructure projects. Stakeholders across the spectrum— from policymakers to professionals in the field—must work together to foster an environment that embraces change, invests in education and technology and prioritizes the long-term benefits of this approach. As India continues to expand its infrastructure to meet the demands of a growing population and an evolving economy, adopting such progressive construction methodologies will be crucial in shaping a sustainable and prosperous future.

REFERENCES

1. Franco, J. d. A. B., Domingues, A. M., Africano, N. d. A., Deus, R. M., & Battistelle, R. A. G. (2022). Sustainability in the civil construction sector supported by Industry 4.0 technologies: Challenges and opportunities. Infrastructures, 7(43).
2. Lamba, P., Kaur, D. P., Raj, S., & Sorout, J. (2021). Recycling/reuse of plastic waste as construction material for sustainable development: A review. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-021-16980-y
3. Shishehgarkhaneh, M. B., Keivani, A., Moehler, R. C., Jelodari, N., & Laleh, S. R. (2022). Internet of Things (IoT), Building Information Modeling (BIM) and Digital Twin (DT) in construction industry: A review, bibliometric and network analysis. Buildings, 12(1503).
4. Sanni-Anibire, M. O., Zin, R. M., & Olatunji, S. O. (2020). Causes of delay in the global construction industry: A meta analytical review. Engineering, Construction and Architectural Management. https://doi.org/10.1108/ECAM-01-2020-0042
5. Baghalzadeh Shishehgarkhaneh, M., Keivani, A., Moehler, R. C., Jelodari, N., & Laleh, S. R. (2022). Internet of Things (IoT), Building Information Modeling (BIM) and Digital Twin (DT) in Construction Industry: A Review, Bibliometric and Network Analysis. Buildings, 12(15), 1503.
6. Franco, J. d. A. B., Domingues, A. M., Africano, N. d. A., Deus, R. M., & Battistelle, R. A. G. (2022). Sustainability in the civil construction sector supported by Industry 4.0 technologies: Challenges and opportunities. Infrastructures, 7(43).

7. Lamba, P., Kaur, D. P., Raj, S., & Sorout, J. (2021). Recycling/reuse of plastic waste as construction material for sustainable development: A review. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-021-16980-y
8. Shishehgarkhaneh, M. B., Keivani, A., Moehler, R. C., Jelodari, N., & Laleh, S. R. (2022). Internet of Things (IoT), Building Information Modeling (BIM) and Digital Twin (DT) in construction industry: A review, bibliometric and network analysis. Buildings, 12(1503).
9. Sanni-Anibire, M. O., Zin, R. M., & Olatunji, S. O. (2020). Causes of delay in the global construction industry: A meta analytical review. Engineering, Construction and Architectural Management. https://doi.org/10.1108/ECAM-01-2020-0042
10. Xu, L. D., Xu, E. L., & Li, L. (2018). Industry 4.0: State of the art and future trends. International Journal of Production Research, 56(8), 2941-2962.
11. Yin, Y., Stecke, K. E., & Li, D. (2018). The evolution of production systems from Industry 2.0 through Industry 4.0. International Journal of Production Research, 56(1-2), 848-861.
12. Zhou, K., Liu, T., & Zhou, L. (2015). Industry 4.0: Towards future industrial opportunities and challenges. In 2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD) (pp. 2147-2152).
13. Elkington, J. (1994). Cannibals with Forks: The Triple Bottom Line of 21st Century Business. Capstone.
14. Ghosh, A., Edwards, D. J., & Hosseini, M. R. (2020). Patterns and trends in Internet of Things (IoT) research: Future applications in the construction industry. Engineering, Construction and Architectural Management, 28(2), 457-481.
15. Valente, M., Sibai, A., Sambucci, M., Valente, M., Sibai, A., Sambucci, M., Valente, M., et al. (2019). Extrusion-Based Additive Manufacturing of Concrete Products: Revolutionizing and Remodeling the Construction Industry. Journal of Composites Science, 3(3), 88.
16. Sepasgozar, S. M. E. (2021). Differentiating Digital Twin from Digital Shadow: Elucidating a Paradigm Shift to Expedite a Smart Sustainable Built Environment. Buildings, 11(4), 151.
17. Darko, A., Chan, A. P., Yang, Y., & Tetteh, M. O. (2020). Building information modeling (BIM)-based modular integrated construction risk management—Critical survey and future needs. Computers in Industry, 123, 103327.
18. Zhang, Y., Liu, H., Kang, S.-C., & Al-Hussein, M. (2020). Virtual reality applications for the built environment: Research trends and opportunities. Automation in Construction, 118, 103311.
19. Dallasega, P., Rauch, E., & Linder, C. (2018). Industry 4.0 as an enabler of proximity for construction supply chains: A systematic literature review. Computers in Industry, 99, 205-225.
20. Fokaides, P., Apanaviciene, R., Cerneckiene, J., Jurelionis, A., Klumbyte, E., Kriauciunaite-Neklejonoviene, V., et al. (2020). Research Challenges and Advancements in the Field of Sustainable Energy Technologies in the Built Environment. Sustainability, 12(20), 8417.