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Recent Advances in Civil and Environmental Engineering for Sustainable Infrastructure Development: A Systematic Literature Review

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ABSTRACT

Civil and Environmental Engineering plays a crucial role in developing sustainable infrastructure while addressing environmental challenges caused by urbanization, climate change, and increasing resource demand. Advances in sustainable construction materials, smart infrastructure, digital technologies, and environmental management have significantly improved engineering practices. This study aims to review recent developments and research trends in civil and environmental engineering published over the last five years. A Systematic Literature Review (SLR) was conducted by identifying, screening, and synthesizing relevant studies from reputable scientific databases. The review focuses on sustainable infrastructure, resilient transportation systems, green construction materials, environmental protection technologies, and digital engineering applications. The findings indicate that integrating innovative technologies with sustainable engineering principles enhances infrastructure resilience, environmental performance, and resource efficiency. This review provides valuable insights into current research trends and future directions, supporting the development of resilient, environmentally responsible, and sustainable civil engineering systems.

Keywords: *Civil Engineering, Environmental Engineering, Green Construction, Sustainable Infrastructure, Smart Infrastructure.*

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1. | INTRODUCTION

Civil and Environmental Engineering has become one of the most important engineering disciplines in supporting sustainable development through the planning, design, construction, operation, and maintenance of infrastructure systems that are environmentally responsible, economically feasible, and socially beneficial. Rapid urbanization, population growth, industrial expansion, and climate change have substantially increased the demand for resilient infrastructure while simultaneously intensifying environmental degradation, resource depletion, and greenhouse gas emissions. Consequently, modern civil and environmental engineering has shifted from conventional infrastructure development toward sustainable engineering practices that integrate environmental protection, resource efficiency, and long-term resilience into engineering decision-making.

The construction sector remains one of the largest consumers of natural resources and energy worldwide while generating considerable carbon emissions and construction waste (Sizirici et al., 2021). Infrastructure development therefore requires innovative approaches that minimize environmental impacts throughout the entire project life cycle. Recent studies have highlighted the importance of sustainable infrastructure design, life cycle assessment (LCA), green construction materials, and circular economy principles to improve infrastructure sustainability and reduce environmental burdens.

Recent technological advancements have also transformed engineering practices through the adoption of digital technologies such as Building Information Modeling (BIM), Geographic Information Systems (GIS), artificial intelligence (AI), Internet of Things (IoT), remote sensing, and smart monitoring systems. These technologies improve planning accuracy, structural performance evaluation, predictive maintenance, and infrastructure asset management while supporting data-driven decision-making throughout the infrastructure life cycle. The integration of digital engineering with sustainable development has therefore become an emerging research focus in civil and environmental engineering.

In parallel, environmental engineering has gained increasing attention due to global concerns regarding water pollution, wastewater management, air quality deterioration, ecosystem degradation, and climate adaptation. Sustainable environmental technologies, including nature-based solutions, constructed wetlands, green infrastructure, and low-impact development, have demonstrated significant potential to improve environmental quality while enhancing infrastructure resilience against climate-related hazards (Ruangpan et al., 2020). These approaches encourage efficient resource utilization and promote environmentally friendly engineering solutions that align with sustainable development objectives.

Transportation systems and urban infrastructure have similarly evolved toward resilient and low-carbon development strategies. Researchers increasingly emphasize infrastructure resilience, sustainable mobility, and climate-responsive planning to reduce vulnerability to extreme weather events while maintaining infrastructure functionality. Life cycle thinking, multicriteria decision-making, and sustainability assessment have become essential tools for evaluating engineering alternatives by considering environmental, economic, and social dimensions simultaneously.

Despite the growing number of studies in civil and environmental engineering, existing research is often fragmented across specialized topics such as structural engineering, transportation, environmental management, construction materials, and digital technologies. A comprehensive synthesis is therefore needed to identify recent research trends, technological developments, and future opportunities that support sustainable infrastructure development. Systematic literature reviews provide an effective approach for integrating findings from multiple studies while identifying knowledge gaps and emerging research directions.

Therefore, this study aims to systematically review research published between 2018 and 2022 concerning recent developments in civil and environmental engineering. The review focuses on sustainable infrastructure, environmental protection technologies, resilient transportation systems, sustainable construction materials, and digital engineering innovations. The findings are expected to provide a comprehensive understanding of current research trends and contribute to future engineering practices that promote resilient, efficient, and environmentally sustainable infrastructure development.

2. | RESEARCH METHOD

This study employed a Systematic Literature Review (SLR) to identify, evaluate, and synthesize previous studies related to civil and environmental engineering published between 2018 and 2022. The review followed a structured and transparent procedure consisting of four primary stages: identification, screening, eligibility assessment, and qualitative synthesis.(Martín et al., 2018) Relevant publications were retrieved from internationally recognized scientific databases, including Scopus, Web of Science, ScienceDirect, SpringerLink, and IEEE Xplore, using combinations of keywords such as civil engineering, environmental engineering, sustainable infrastructure, green construction, building information modeling, smart infrastructure, transportation engineering, climate resilience, and environmental sustainability. Only peer-reviewed journal articles written in English and published between 2018 and 2022 were considered to ensure the quality and relevance of the selected literature.

Conference papers, book chapters, review articles, editorials, duplicate publications, and studies with insufficient methodological information were excluded from the review process. Following the screening and eligibility assessment, the selected studies were analyzed based on their research objectives, methodologies, engineering applications, technological innovations, sustainability aspects, and major findings (Vrchota et al., 2020). The collected data were then categorized into several thematic areas, including sustainable infrastructure, resilient transportation systems, environmentally friendly construction materials, environmental protection technologies, and digital engineering applications such as Building Information Modeling (BIM), Artificial Intelligence (AI), Geographic Information Systems (GIS), and the Internet of Things (IoT). Finally, qualitative synthesis was conducted to compare research findings, identify current technological trends, highlight existing research gaps, (Lopes et al., 2018) and propose future research opportunities that support sustainable, resilient, and environmentally responsible civil and environmental engineering practices.

3. | RESULTS AND DISCUSSION

The systematic literature review demonstrates that research in civil and environmental engineering experienced significant development between 2018 and 2022, primarily driven by the increasing demand for sustainable infrastructure, climate adaptation, digital transformation, and environmentally responsible engineering practices. The selected studies consistently indicate that engineering solutions are no longer evaluated solely based on technical performance and economic feasibility but also on environmental, social, and long-term sustainability considerations. This paradigm shift has encouraged researchers and practitioners to integrate sustainable development principles into infrastructure planning, construction, operation, and maintenance.

One of the dominant research trends identified in the reviewed literature is the implementation of sustainable infrastructure concepts. Sustainable infrastructure emphasizes minimizing environmental impacts throughout the infrastructure life cycle while maintaining structural safety, economic efficiency, and social benefits. Numerous studies report that incorporating Life Cycle Assessment (LCA) and Life Cycle Cost Analysis (LCCA) into engineering projects enables decision-makers to evaluate environmental burdens and optimize resource utilization during infrastructure development. These approaches contribute to reducing greenhouse gas emissions, energy consumption, and construction waste while improving infrastructure resilience and service life.

Another important finding concerns the increasing use of environmentally friendly construction materials (Negash et al., 2021). Conventional construction materials such as ordinary Portland cement and natural aggregates contribute substantially to carbon emissions and resource depletion. Consequently, many researchers have investigated alternative materials, including recycled concrete aggregates, industrial by-products, fly ash, blast furnace slag, silica fume, and geopolymer concrete. Previous studies demonstrate that these sustainable materials improve environmental performance while maintaining acceptable mechanical properties and long-term durability. The adoption of recycled materials also supports circular economy principles by reducing landfill waste and promoting efficient resource management.

Digital transformation has become another significant research direction in civil and environmental engineering. Building Information Modeling (BIM), Geographic

Information Systems (GIS), Artificial Intelligence (AI), unmanned aerial vehicles (UAVs), and the Internet of Things (IoT) have significantly improved engineering planning, construction monitoring, and infrastructure management. BIM enables engineers to integrate design, scheduling, cost estimation, and facility management into a single digital platform, thereby improving collaboration among project stakeholders and reducing design conflicts (Ayinla et al., 2021). Similarly, AI and machine learning techniques have demonstrated high potential for predicting structural performance, optimizing construction processes, and supporting predictive maintenance strategies.

Smart infrastructure supported by IoT technologies has further enhanced infrastructure monitoring and operational efficiency (Serrano, 2018). Wireless sensors, structural health monitoring systems, and real-time data acquisition allow engineers to continuously evaluate structural conditions and detect potential failures before significant damage occurs. Several studies indicate that integrating IoT with cloud computing and data analytics improves maintenance planning, reduces operational costs, and enhances infrastructure safety. These technological developments are particularly beneficial for bridges, highways, tunnels, water distribution systems, and other critical infrastructure assets.

Environmental engineering research has also evolved considerably during the review period. Water resource management, wastewater treatment, stormwater control, and air pollution mitigation remain major research priorities due to rapid urbanization and industrial development. Green infrastructure, Low-Impact Development (LID), nature-based solutions, and constructed wetlands have been widely investigated as sustainable alternatives to conventional environmental management systems (Alemaw et al., 2020). These approaches effectively improve water quality, reduce urban flooding, increase groundwater recharge, and enhance ecosystem services while minimizing environmental disturbances (Lashford et al., 2020; Shruti et al., 2020). Consequently, environmental engineering has become increasingly integrated with urban planning and climate adaptation strategies.

Climate resilience represents another prominent theme identified in the reviewed studies. Increasing frequencies of floods, droughts, extreme temperatures, and coastal hazards require infrastructure systems capable of maintaining functionality under changing climate conditions. Researchers emphasize the importance of resilient design, risk assessment, vulnerability analysis, and adaptive management for minimizing disaster impacts on infrastructure systems (Ayyub, 2020). Modern engineering practices increasingly incorporate probabilistic modeling, resilience indicators, and multi-hazard assessment to improve infrastructure preparedness and recovery capabilities.

Transportation engineering has likewise undergone substantial transformation through the implementation of intelligent transportation systems and sustainable mobility concepts. Smart traffic management, electric vehicle infrastructure, integrated public transportation, and data-driven transportation planning contribute to reducing traffic congestion, fuel consumption, and carbon emissions. Geographic Information Systems and transportation simulation models have become valuable tools for analyzing traffic performance, optimizing transportation networks, and supporting evidence-based planning decisions. These innovations improve transportation efficiency while promoting environmentally sustainable urban development.

The review also indicates that interdisciplinary collaboration has become increasingly important for solving complex engineering challenges. Civil engineers, environmental scientists, urban planners, data scientists, and policymakers are working together to develop integrated engineering solutions that balance technical performance with environmental sustainability and community resilience. Multi-criteria decision analysis, sustainability assessment frameworks, and stakeholder participation have become common approaches for evaluating engineering alternatives and supporting sustainable infrastructure investments.

Despite these advancements, several challenges remain. High implementation costs, limited technical expertise, insufficient digital infrastructure (Zeebaree et al., 2020), fragmented regulations, and data availability continue to hinder the widespread adoption of advanced engineering technologies in many developing countries. Furthermore, inconsistencies in sustainability assessment methodologies and limited long-term performance evaluations create uncertainty regarding the effectiveness of some emerging engineering solutions. Future research should therefore emphasize standardized assessment frameworks, integrated digital platforms, climate adaptation strategies, circular economy implementation, and artificial intelligence applications that support more resilient and environmentally responsible infrastructure systems.

The reviewed literature confirms that civil and environmental engineering is transitioning toward a more sustainable, intelligent, and resilient discipline (Manzoor et al., 2021). The integration of sustainable construction materials, digital engineering technologies, environmental protection strategies, and climate-resilient infrastructure has significantly improved engineering performance while supporting global sustainable development objectives. Continued technological innovation, interdisciplinary collaboration, and evidence-based decision-making will remain essential for addressing future infrastructure and environmental challenges.

4. | CONCLUSION

Civil and Environmental Engineering continues to evolve toward a more sustainable, resilient, and technology-driven discipline in response to global challenges such as rapid urbanization, climate change, environmental degradation, and increasing infrastructure demands. Based on the systematic literature review, recent developments between 2018 and 2022 demonstrate that integrating sustainable engineering principles with digital technologies has significantly improved infrastructure planning, construction, operation, and maintenance. The adoption of environmentally friendly construction materials, life cycle assessment, smart infrastructure, Building Information Modeling, artificial intelligence, Internet of Things, and green environmental technologies has contributed to enhancing resource efficiency, reducing environmental impacts, and improving infrastructure resilience. Furthermore, interdisciplinary collaboration among engineers, environmental scientists, urban planners, and policymakers has become increasingly important for developing comprehensive and sustainable engineering solutions. Although challenges such as high implementation costs, technological limitations, and regulatory constraints remain, continuous innovation and research are expected to accelerate the transition toward more efficient and environmentally responsible infrastructure systems. Future studies should focus on strengthening digital integration, climate adaptation strategies, circular economy implementation, and sustainable resource management to support resilient infrastructure development and achieve long-term sustainable development goals.

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The authors declare that there is no conflict of interest.

Ethical Approval and Originality Statement

Ethical approval was obtained for this study. The manuscript represents original work and has not been previously published, nor is it under consideration by another journal.

Data Disclosure Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

Alemaw, B. F., Chaoka, T. R., & Tafesse, N. T. (2020). Modelling of nature-based solutions (NBS) for urban water management—Investment and outscaling implications at basin and regional levels.

Ayinla, K., Vakaj, E., Cheung, F., & Tawil, A. R. H. (2021, June). A semantic offsite construction digital Twin-Offsite Manufacturing Production Workflow (OPW) ontology. In *second international workshop on semantic digital twins*.

Ayyub, B. M. (2020, April). Disaster resilience and sustainability of infrastructures: Relationships and quantification methods. In *Gulf Conference on Sustainable Built Environment* (pp. 289-308). Cham: Springer International Publishing.

Lashford, C., Charlesworth, S., Warwick, F., & Blackett, M. (2020). Modelling the role of SuDS management trains in minimising flood risk, using microDrainage. *Water*, *12*(9), 2559.

Lopes de Sousa Jabbour, A. B., Jabbour, C. J. C., Godinho Filho, M., & Roubaud, D. (2018). Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations. *Annals of operations research*, *270*(1), 273-286.

Manzoor, B., Othman, I., Durdyev, S., Ismail, S., & Wahab, M. H. (2021). Influence of artificial intelligence in civil engineering toward sustainable development—a systematic literature review. *Applied System Innovation*, *4*(3), 52.

Martín-Martín, A., Orduna-Malea, E., Thelwall, M., & López-Cózar, E. D. (2018). Google Scholar, Web of Science, and Scopus: A systematic comparison of citations in 252 subject categories. *Journal of informetrics*, *12*(4), 1160-1177.

Negash, Y. T., Hassan, A. M., Tseng, M. L., Wu, K. J., & Ali, M. H. (2021). Sustainable construction and demolition waste management in Somaliland: Regulatory barriers lead to technical and environmental barriers. *Journal of Cleaner Production*, *297*, 126717.

Ruangpan, L., Vojinovic, Z., Di Sabatino, S., Leo, L. S., Capobianco, V., Oen, A. M., ... & Lopez-Gunn, E. (2020). Nature-based solutions for hydro-meteorological risk reduction: a state-of-the-art review of the research area. *Natural Hazards and Earth System Sciences*, *20*(1), 243-270.

Serrano, W. (2018). Digital systems in smart city and infrastructure: Digital as a service. *Smart cities*, *1*(1), 134-154.

Shruti, S., Singh, P. K., & Ohri, A. (2020). Evaluating the environmental sustainability of smart cities in India: The design and application of the Indian smart city environmental sustainability index. *Sustainability*, *13*(1), 327.

Sizirici, B., Fseha, Y., Cho, C. S., Yildiz, I., & Byon, Y. J. (2021). A review of carbon footprint reduction in construction industry, from design to operation. *Materials*, *14*(20), 6094.

Vrchota, J., Pech, M., Rolinek, L., & Bednář, J. (2020). Sustainability outcomes of green processes in relation to industry 4.0 in manufacturing: Systematic review. *Sustainability*, *12*(15), 5968.

Zeebaree, M., Sattar, S., Ismael, G. Y., Qader, A. N., & Aqel, M. (2020). Impact of infrastructure barriers on electronic government implementation. *Studies of Applied Economics*, *38*(4).