

Artificial Intelligence in Civil Engineering: A Comprehensive Review on Smart Infrastructure, Urban Planning, and Sustainable Development

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Abstract

When artificial intelligence (AI) is used in civil engineering, it changes the future of infrastructure, urban environments, and sustainable growth. Robotics, computer vision, neural networks, and predictive analytics are some examples of artificial intelligence (AI) technologies that could change many important areas of civil engineering. AI makes smart infrastructure better in three ways: it can automatically check the health of buildings, handle construction projects smartly, and plan maintenance ahead of time. Tools for optimising traffic, GIS-based models, and AI-driven simulations in urban planning are helping to make cities that are strong, efficient, and liveable. how AI can improve the use of materials, save energy, and help with environmentally friendly designs, all of which are important for long-term growth. The review brings together the newest ideas, useful applications, and important scholarly advances by using case studies and cross-disciplinary research from both developed and developing countries. Using AI in civil engineering education, policy, and practice is important to encourage new ideas and make sure that the built world will last for a long time. However, there are persistent problems that need to be fixed. These include data protection, algorithmic bias, high implementation costs, and the need for people from different fields to work together. Still, the pros of using AI must also be thought about.

keywords Artificial Intelligence (AI), Civil Engineering, Smart Infrastructure, Urban Planning, Sustainable Development, Machine Learning

Introduction

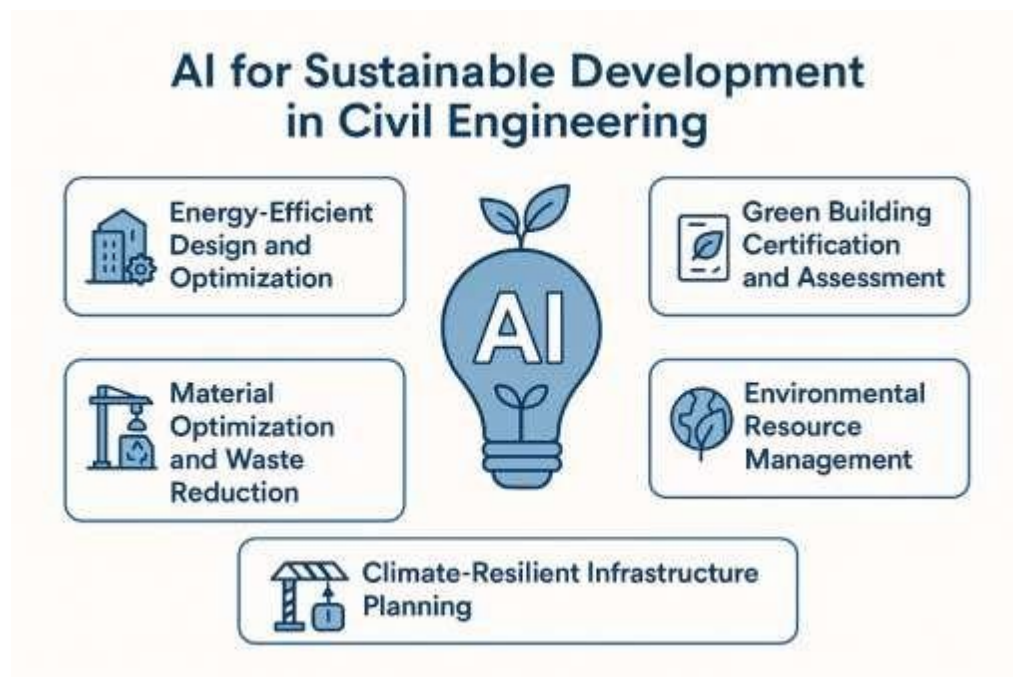
Artificial intelligence (AI) is changing civil engineering in a big way. For a long time, civil engineering has focused on empirical design and physical research. Due to the growing complexity, size, and long-term needs of infrastructure, traditional engineering methods are not enough to solve the pressing problems of urbanisation, environmental degradation, and limited resources. The way we create, plan, build, and maintain civil infrastructure has changed

a lot because of artificial intelligence (AI). Deep learning, computer vision, machine learning, and smart data analytics are all parts of AI. AI (artificial intelligence) could be used in a number of ways in civil engineering. More and more, structural engineers are using AI programs to do things like finding failures, checking on the health of structures in real time, and planning maintenance ahead of time. AI solutions have changed the way building management is done by making it easier and safer to plan work, figure out costs, assess risks, and automate machines. AI helps planners make better decisions about cities through smart zoning, geospatial analysis, and predicting traffic patterns, among other things. AI is also very important for sustainability because it makes it easier to look at building projects over their whole life, uses energy more efficiently, and reduces waste. This combination not only changes the way engineers work, but it also aligns the goals of civil engineering with global goals like smart city development, climate resilience, and the UN Sustainable Development Goals (SDGs). There are still issues with using AI, like not having enough data, not being able to understand models, the high cost of implementation, and the requirement for talents from many other sectors. how much progress artificial intelligence (AI) has made in civil engineering so far, notably in areas like smart infrastructure, urban planning, and sustainable development. To obtain a better idea of how artificial intelligence (AI) will alter civil engineering and the built environment in the future, this study looks at material from a number of different sources, such as academic studies, technical changes, and case studies.



AI for Sustainable Development in Civil Engineering

AI has offered civil engineers new tools that can help them use resources more efficiently, have less of an impact on the environment, and design stronger building systems in general. All of these elements help make sure that growth will last for a long time. AI technology is becoming more and more crucial for designing, creating, and taking care of public assets that are good for the environment, inexpensive, and useful to society as sustainability becomes more and more important in infrastructure construction and use.



1 Energy-Efficient Design and Optimization

Because AI uses complex modelling, simulations, and optimisation methods, it is possible to build things that use less energy. Machine learning algorithms can predict how buildings and transportation systems will use energy. This helps engineers make better choices about how to plan things. Using AI-powered technologies to improve HVAC systems, lighting plans, and energy networks can help cut down on energy use and greenhouse gas emissions. Deep learning techniques can be used to look at data about how well buildings work. Then, these algorithms suggest changes to the building's plan that can make it more energy efficient and comfortable.

2 Green Building Certification and Assessment

Sustainable building methods and green building standards like LEED, BREEAM, and GRIHA often go hand in hand. AI systems can keep an eye on and compare how much material, water, and energy is used to government standards, so they could automate the approval process. Decision support systems and natural language processing (NLP) help check compliance

paperwork, simulate environmental performance, and streamline exams. All of these things make the certification process faster and less likely to make mistakes.

3 Material Optimization and Waste Reduction

AI could help people choose more eco-friendly building materials and figure out the best way to use them so that less waste and damage is done to the earth. When engineers use generative design and predictive analytics together, they can try out different building scenarios and choose the one that uses the fewest materials and has the least effect on the environment. Real-time monitoring by AI-driven construction management systems leads to less waste of resources, more reuse of materials, and support for circular building models.

4 Environmental Resource Management

With AI, we can better take care of our water, land, and air, which are all very important natural resources. AI can improve drainage or irrigation systems, find leaks, and guess how much water will be needed in building projects that involve water infrastructure. AI-based models look at the emissions that vehicles produce and suggest low-carbon routes and infrastructure designs for the transportation industry. Natural resource planning that is sustainable and environmental impact assessments (EIAs) are two areas that can benefit from GIS systems that use AI.

5 Climate-Resilient Infrastructure Planning

More extreme weather events are happening because of climate change, and AI helps make infrastructure stronger to handle these events. The area of civil engineering has predictive models that can be used to make buildings that can withstand the effects of climate change, heat waves, and earthquakes in the future. By looking at monitor data and using AI-based early warning systems, infrastructure can be made safer and last longer, which helps people be ready for disasters and act quickly.

shows how important AI is for making sustainable engineering methods possible. Please let me know if you'd like this to be shown with case studies (like green cities or smart buildings) or with a structure or table to help you understand.

review of literature

(Syed Wasim Nawaz Razvi, 2Hashmi Syed Suhel, and Abdul Aleem 2022) studied “AI Revolution in Civil Engineering: A Comprehensive Analysis and Future Prospects” The main point of this review piece is to show how Artificial Intelligence (AI) has changed civil engineering. By carefully reading and analysing ten important research papers, we look at the

many ways AI can be used, focussing on smart design, building, and maintenance. In these pieces, we learn about the many ways that artificial intelligence (AI) is changing civil engineering by making it more efficient, creative, and environmentally friendly. In this review, the most important conclusions from these pieces are put together. These include how AI is changing sustainable civil engineering, how it is changing estimates of construction costs and times, and how it is changing high-speed rail systems. The paper also talks about how civil engineering design is becoming more and more automated and how important Artificial Neural Networks (ANNs) are in civil engineering uses. The piece also talks about how AI could be used to make aeroplanes safer and help people make decisions. It does this by outlining new AI-driven computing methods in several engineering areas, such as deep learning, machine learning, and big data. It is also talked about what kinds of AI apps could be used together and how information moves through the information life cycle in bridge engineering. In the end, this thorough review paper draws a picture of AI's central role in civil engineering by talking about its pros, cons, and potential to make the field smarter and better for the environment in the future.

(Thiago H. Carvalho et al. 2024) studied “Artificial Intelligence in Sustainable Smart Cities: A Systematic Study on Applications, Benefits, Challenges, and Solutions” In a time of rapid urbanisation and environmental problems, the rise of smart towns gives people hope for a better future. An important part of how well these cities work is artificial intelligence (AI). The main goal of this systematic literature study is to answer the important question, "How can AI be used in sustainable smart cities?" According to Kitchenham's three-step method, the review followed the Planning, Conducting, and Reporting steps. It took a lot of searching through Scopus, ACM, IEEEExplore, Science Direct, and Emerald to find 46 good works. Reading these pieces helped us understand smart city AI services, including their pros and cons, as well as how to make them work better. The results show that AI has an effect on many areas, such as transportation, energy management, and public participation. But there are still some problems that come up when you think about ethics and data handling. This review is a must-read for leaders and academics who want to know how to use AI to plan green cities.

(Rajneesh Kumar Jha 2024) studied “Artificial Intelligence in Civil Engineering Rajneesh” Using AI in building projects is a new idea that is very different from how things have always been done. Civil engineering has a lot of hard problems that AI could help solve. Some examples are predictive maintenance, smart city planning, and tracking the health of structures.

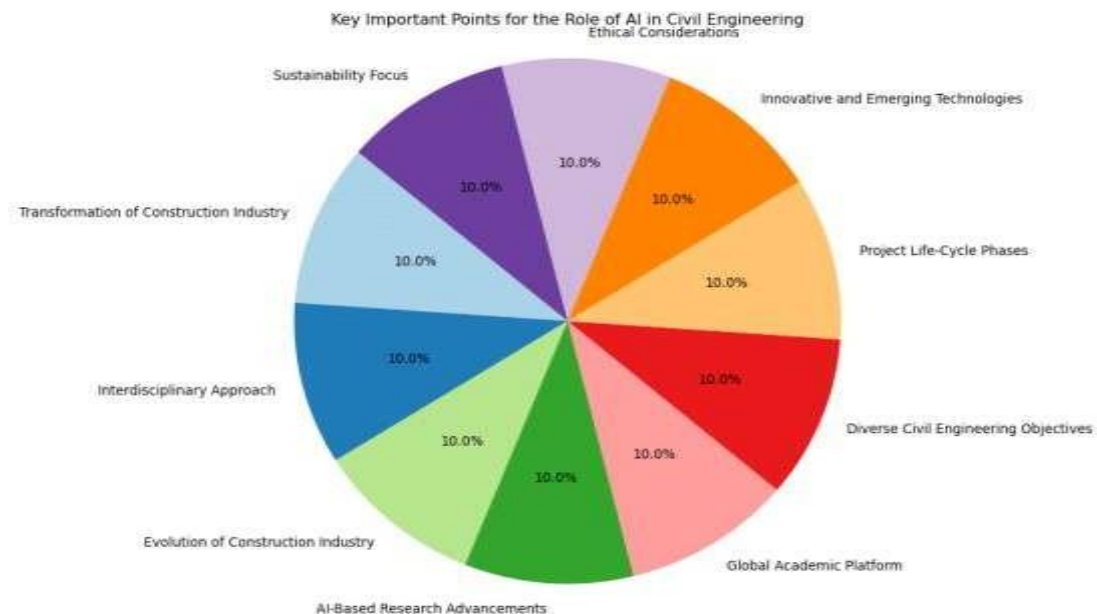
Using computer vision, neural networks, and machine learning methods in civil engineering projects can make them more accurate, faster, and better for the environment. Case studies called examples help us draw some conclusions about how these AI systems can improve the results of projects. This research gives us a look at a few different ways AI is being used in civil engineering right now. AI not only makes standard engineering better, but it also opens the door to new ways of planning cities and managing infrastructure. At the end of the document, the effects of AI on civil engineering are talked about, along with possible problems that might make it hard for AI to be used and ways that more study could make AI even more important in this field.

(Patel Neel I et al. 2024) studied “Integration of Artificial Intelligence in Civil Engineering: A Review of Applications and Future Prospects” The major goal of this study is to look at how civil engineering is using AI right now. A lot has changed in the way civil engineers work due to the massive increase of AI methods like computer vision, deep learning, and machine learning. This article is about AI and how it may be applied in civil engineering in many different ways. It talks about things like smart infrastructure, predictive maintenance, managing development, and keeping an eye on the health of buildings. There are also suggestions for future research and a talk about the good and bad things about employing AI in this field.

(Taba Nyokum and Yamem Tamut 2025) studied Artificial intelligence in civil engineering: emerging applications and opportunities Artificial intelligence (AI) is altering civil engineering very swiftly because to complicated computer systems and a lot of data. This review presents a complete picture of the most current developments in civil engineering's use of artificial intelligence (AI). Some of the technologies that are talked about are deep learning, machine learning, computer vision, robotics, and generative AI. It also talks about how these technologies have been employed in design, building, monitoring, transportation, geotechnical, environmental, and asset management. This study looks at how AI-powered models and systems can make things more productive, safe, and long-lasting while also dealing with obstacles like not having enough data, models that are hard to grasp, and ethical concerns. As the need for AI in business grows, emerging topics like digital twins, smart cities, and quantum computing are also garnering a lot of interest. The purpose of this article is to describe recent research in civil engineering and draw some judgements about how AI is transforming the discipline.

(Islam et al. 2025) studied Artificial Intelligence in Civil Engineering Education” Civil engineers are in charge of numerous tasks, including planning, building, and taking care of buildings and public spaces. Civil engineering classes are usually hard to teach, though, because they are so sophisticated. Engineers who attended to traditional schools used to have trouble with these kinds of problems. But AI is transforming how we study and teach by improving both the material and the way students learn it. AI is particularly valuable in many areas, such as civil engineering, where it may help with creating and improving procedures, anticipating how materials will behave, and overall performance. Adding AI to civil engineering classrooms could change the way this crucial subject is taught and learnt, which would be a major change. This essay talks about the different methods that civil engineers can apply artificial intelligence (AI). Some of these are geotechnical engineering, environmental sustainability, BIM (building information modelling), condition and risk assessment, construction management, urban project and plan, smart infrastructure monitoring, geotechnical engineering, traffic management and transportation planning, and keeping an eye on the health of civil infrastructure structures. We looked at a lot of research to see how artificial intelligence algorithms like deep learning, machine learning, and image processing are changing the way we teach and giving academics the tools they need to deal with the difficult problems of building and running modern infrastructure. We discuss about how AI could revolutionise the way people learn by letting them work together more easily and providing them more hands-on experience. The purpose of this article is to show teachers, politicians, and businesspeople how to fully employ artificial intelligence (AI) in civil engineering education by mixing real-world examples with the best ways to accomplish things.

Key Important Points Role of AI in Civil Engineering



1. Ethical Considerations

AI systems must be built and used in a responsible way, making sure that decisions about infrastructure are fair, accountable, and open.

2. Innovative and Emerging Technologies

AI makes it possible for civil engineering to use cutting-edge technology like digital twins, machine learning, and the Internet of Things (IoT) to come up with better solutions.

3. Project Life-Cycle Phases

AI makes the planning, design, building, operation, and maintenance of civil projects better by making them more accurate and efficient.

4. Diverse Civil Engineering Objectives

AI can help with a number of goals, including lowering costs, making structures safer, choosing the right materials, and following environmental rules.

5. Global Academic Platform

AI encourages civil engineering researchers from different countries to work together, which helps them learn from each other and share best practices.

6. AI-Based Research Advancements

AI powers research that needs a lot of data, which lets building and infrastructure development use simulation, modelling, and predictive analysis.

7. Evolution of Construction Industry

The industry is moving away from old-fashioned processes and towards automated, AI-assisted ones that make work more efficient and lower hazards.

8. Interdisciplinary Approach

AI connects civil engineering with other subjects like computer science, environmental science, and economics, which leads to more complete solutions.

9. Transformation of Construction Industry

AI is important for changing the industry since it makes robotics, 3D printing, and real-time monitoring possible.

10. Sustainability Focus

AI helps with sustainable practices by making better use of energy, cutting down on waste, and making environmental effect assessments more accurate.

Annual Publications Trend of AI in Civil Engineering toward Sustainable Development

There were 105 papers in the study, from 1995 to April 2021. Researchers were most interested in the trajectory of publications in 2020, according to the study. In April 2021, there were 22 articles in the field of AI in civil engineering, although this figure is likely to rise because the publications that are now included were published between January and April 2021.

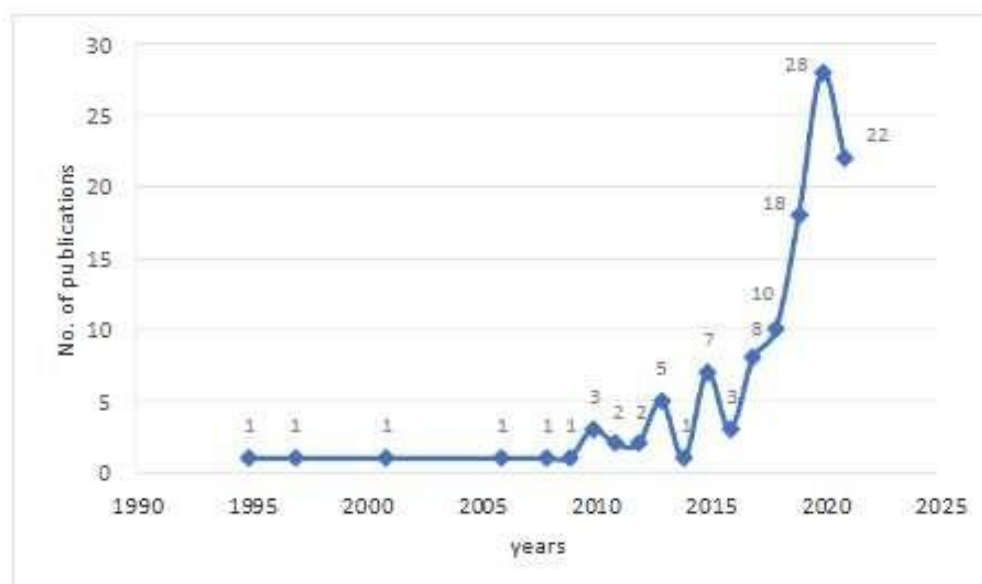


Figure: Annual publication trend of AI in civil engineering toward sustainable development.

Source:

https://www.researchgate.net/publication/353731405_Influence_of_Artificial_Intelligence_in_Civil_Engineering_toward_Sustainable_Development-A_Systematic_Literature_Review

The figure “*Annual Publication Trend of AI in Civil Engineering Toward Sustainable Development*” the growth of scholarly study in this area between 1990 and 2024. In the early years, especially from 1990 and 2005, there weren't many publications. Only one came out per year or so. This shows that people didn't know much about or look into how artificial intelligence may be used in civil engineering at that time. But from 2006 to 2012, there was a slow rise, which shows that people were starting to see how AI may help solve problems in the sector. There was a big jump in 2014, when there were seven publications, but then there was a short drop in 2015. From 2016 on, there is clear and steady growth, with the number of publications going from 8 in 2016 to a peak of 28 in 2020. This increase is in line with the world's focus on sustainable development goals, improvements in AI technology, and the rising relevance of smart infrastructure and building in a way that is good for the environment. Even if there has been a little drop in the number of publications in recent years, with 22 reported in 2023, the overall trend shows that AI is playing a bigger role in promoting innovation and sustainability in civil engineering. The data shows that more and more researchers are starting to see how AI may change the way engineers work to make it more efficient, resilient, and sustainable.

Conclusion

Civil engineers are using AI to assist them deal with the growing difficulty of building infrastructure, making cities bigger, and protecting the environment. AI could be used in many areas of civil engineering, such as monitoring the health of buildings, automating construction tasks, enhancing city planning, and keeping track of resources that are good for the environment. AI-powered tools have made it much easier to make sure that engineering techniques are in line with global environmental goals. These technologies have also made it easier to plan, do, and keep up with your work. Civil engineers now have the information they need to make choices that are good for the environment, their wallets, and the long-term performance of the infrastructure thanks to smart design systems, machine learning models, and predictive analytics. Even though AI has clear benefits, it isn't widely used in civil

engineering. This is because there isn't enough data, the methods aren't obvious, the expenses are high, and people in different fields don't know enough about it. Businesses, schools, and the government all need to work together to solve these problems and make things better for growth and integration. AI doesn't replace traditional engineering methods; it works with them. If you plan and follow out your ideas thoroughly, you can develop better towns, stronger infrastructure, and a future that lasts longer. To get the most out of AI's revolutionary potential in civil engineering, we need to keep funding research, training, and making new rules.

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