**Decoding the Discourse: A Textual Analysis of AI's Influence on Civil Engineering Practices and Industry**

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**Abstract: -** The integration of artificial intelligence (AI) into the civil engineering industry represents a transformative shift with far-reaching implications for how infrastructure is designed, constructed, and maintained. This comprehensive exploration into AI’s role within civil engineering aims to elucidate the multifaceted impacts, challenges, and prospects associated with this technological evolution. Spanning the period from 2020 to 2024, this research delves into the advancements in AI technologies, such as machine learning, computer vision, and data analytics, and their applications in enhancing project efficiency, sustainability, and resilience. Civil engineering, in the world of the design, construction, and maintenance of vital infrastructure such as bridges, roads, buildings, and water systems, stands poised at the forefront of this technological revolution. The integration of AI promises to enhance every stage of the civil engineering lifecycle, from initial design and planning to construction management and ongoing maintenance. By harnessing the power of AI algorithms, machine learning, and data analytics, civil engineers can optimize project outcomes, minimize risks, and create more resilient and sustainable infrastructure solutions. The adoption of AI in civil engineering is not without its challenges and complexities. Ethical considerations, data privacy concerns, and the need for interdisciplinary collaboration present formidable obstacles that must be navigated to realize the full potential of AI-driven innovation in the field. Moreover, the rapid pace of technological advancement necessitates ongoing adaptation and upskilling within the civil engineering workforce to fully leverage the capabilities of AI technologies. This research endeavors to explore the complex role of AI in the development of the civil engineering industry. By examining current applications, identifying challenges, and envisioning future trends, this study seeks to provide insights that will inform strategic decision-making, inspire innovation, and drive positive change within the civil engineering profession.

**Key Words— *AI, Civil Engineering, Smart Infrastructure, AI Algorithms.***

# **Introduction**

In the ever-evolving landscape of modern engineering, the integration of artificial intelligence (AI) has emerged as a transformative force, promising to revolutionize traditional practices and propel industries towards unprecedented levels of efficiency, innovation, and sustainability. Nowhere is this transformative potential more evident than in civil engineering, where the intricacies of infrastructure development converge with cutting-edge technology. As articulated by Weimer, Zellner, and Schlueter (2019), the incorporation of AI in civil engineering holds the promise to reshape not only the methodologies governing project conception, design, and execution, but also the fundamental fabric of our built environment. However, the journey towards fully realizing the potential of AI in civil engineering is fraught with challenges. Technical impediments, regulatory complexities, and cultural reluctance present formidable barriers that must be surmounted to unleash the transformative capabilities of AI-driven innovation. Moreover, as underscored by Aparicio and Grijalvo (2021), the ethical ramifications of AI adoption in civil engineering, encompassing issues of bias, transparency, and accountability, necessitate meticulous consideration to ensure responsible and equitable outcomes.

On ongoing technological revolution stands civil engineering, the intricate planning of design, construction, and maintenance of critical infrastructure such as bridges, roads, buildings, and water systems. The integration of AI promises to augment every facet of the civil engineering lifecycle, spanning from initial design and planning to construction management and ongoing maintenance. Leveraging the prowess of AI algorithms, machine learning, and data analytics, civil engineers can optimize project outcomes, mitigate risks, and forge more resilient and sustainable infrastructure solutions.

Yet, the adoption of AI in civil engineering is not devoid of challenges and intricacies. Ethical dilemmas, concerns surrounding data privacy, and the imperative for interdisciplinary collaboration pose formidable hurdles that must be traversed to unlock the full potential of AI-driven innovation in the field. Furthermore, the relentless pace of technological progression mandates continuous adaptation and upskilling within the civil engineering workforce to fully harness the capabilities of AI technologies.

This research endeavors to delve into the complex role of AI and the civil engineering industry. Through an exploration of current applications, an elucidation of challenges, and a projection of future trends, this study aims to furnish insights that will inform strategic decision-making, galvanize innovation, and catalyze positive transformation within the realm of civil engineering.

# **REVIEW OF RELATED LITERATURE**

The integration of artificial intelligence (AI) technologies into the field of civil engineering has garnered significant attention in recent years, with researchers and practitioners alike exploring its potential to revolutionize traditional practices and address the complex challenges facing the built environment. This part (review of related literature) is from existing literature to provide a comprehensive understanding of the multifaceted role of AI in shaping the future of civil engineering.

A study from Mohsen Saud Alghurair, Ayman Rushdy Fahim (2023), the applications of deep learning and neural networks in civil engineering and AI assisted are Structural Analysis, Deep learning techniques can be applied to structural analysis tasks, including damage detection, structural health monitoring, and modal analysis. LiDAR Data Processing: Deep learning algorithms can process point cloud data captured from LiDAR scans. By training neural networks on large LiDAR datasets, the models can automatically segment objects, extract features, and classify elements like buildings, vegetation, or terrain. Deep learning techniques enable efficient and accurate processing of LiDAR data, facilitating tasks such as topographic mapping. Construction Site Monitoring, Deep learning models can analyze images or video feeds from construction sites to monitor progress, safety compliance, and identify potential risks.

AI algorithms have demonstrated remarkable capabilities in optimizing the design and planning phases of civil engineering projects. Li and Yang (2022) highlight the use of genetic algorithms and neural networks for structural optimization, enabling engineers to generate innovative design solutions that meet performance requirements while minimizing material usage and construction costs. Similarly, machine learning techniques such as reinforcement learning have been applied to optimize traffic flow patterns and urban planning strategies, as demonstrated by research conducted by Zhang et al. (2021).

In the realm of construction management, AI holds promise for enhancing project efficiency, productivity, and safety. Ahuja et al. (2023) discuss the use of AI-powered scheduling and resource allocation systems to optimize construction workflows and minimize project delays. Moreover, AI-driven predictive analytics tools enable proactive risk management and mitigation strategies, as evidenced by the work of Feng et al. (2020) on construction site safety prediction models.

The implementation of AI technologies in structural health monitoring (SHM) has emerged as a critical area of research within civil engineering. By integrating sensor data with AI algorithms, engineers can detect early signs of structural deterioration, predict maintenance needs, and extend the lifespan of critical infrastructure assets. Liang et al. (2024) propose a deep learning-based approach for real-time SHM of bridges, demonstrating its effectiveness in detecting structural anomalies and assessing the integrity of bridge components.

While the potential benefits of AI in civil engineering are undeniable, several challenges and considerations must be addressed to facilitate its widespread adoption. Ethical concerns surrounding data privacy, algorithmic bias, and job displacement require careful attention to ensure responsible and equitable deployment of AI technologies (Kroll et al., 2020). Moreover, the integration of AI into existing workflows necessitates interdisciplinary collaboration and ongoing education and training for civil engineering professionals (Wu et al., 2022).

Looking ahead, the future of AI in civil engineering holds immense promise for driving innovation and sustainability. Emerging trends such as the Internet of Things (IoT), digital twins, and autonomous construction machinery are poised to further enhance the capabilities of AI-driven systems and revolutionize the way infrastructure is designed, built, and maintained (Alavi et al., 2021).

In the Philippines, the integration of artificial intelligence (AI) technologies into civil engineering projects has gained momentum in recent years. According to the study by Santos et al. (2021), AI-powered tools and algorithms are increasingly being utilized in the design, planning, and construction phases of infrastructure projects. These technologies have been applied to optimize structural designs, improve construction management workflows, and enhance the efficiency of resource allocation in projects ranging from transportation infrastructure to urban development initiatives.

Given the Philippines' vulnerability to natural disasters such as typhoons, earthquakes, and floods, there is growing interest in leveraging AI for disaster resilience in civil engineering. Research by Reyes and Ramirez (2020) explores the use of AI-driven predictive modeling techniques to assess and mitigate the impact of natural hazards on infrastructure assets. By analyzing historical data and environmental factors, AI algorithms can help identify high-risk areas, predict potential damage, and inform proactive disaster preparedness and response strategies.

In line with global sustainability goals, the Philippines is increasingly prioritizing the development of environmentally friendly and resource-efficient infrastructure solutions. AI plays a crucial role in this endeavor by optimizing energy consumption, reducing carbon emissions, and promoting sustainable urban planning practices. The study by Cruz and Hernandez (2023) examines the integration of AI technologies into sustainable infrastructure projects in the Philippines, highlighting their potential to improve efficiency, minimize environmental impact, and enhance the resilience of communities to climate change-related challenges.

Despite the promising applications of AI in civil engineering, several challenges and opportunities exist in the Philippine context. Limited access to data, inadequate infrastructure, and a shortage of skilled professionals poses barriers to the widespread adoption of AI technologies. However, initiatives such as the National AI Strategy (Department of Science and Technology, 2022) aim to address these challenges by promoting research and development, fostering collaboration between academia and industry, and investing in AI education and training programs.

The Philippines is in the process of developing a comprehensive policy and regulatory framework to govern the responsible use of AI in civil engineering and other sectors. This framework aims to address ethical considerations, data privacy concerns, and ensure transparency and accountability in AI-driven decision-making processes. The study by Villanueva et al. (2024) provides insights into the evolving policy landscape surrounding AI in the Philippines, highlighting the need for stakeholder engagement and multi-sectoral collaboration to develop inclusive and equitable AI policies.

# **Scope and Limitation of the Study**

This textual analysis study will focus on exploring the role of AI in the development of the civil engineering industry, specifically within the Philippine context. It will analyze a variety of textual sources such as academic articles, industry reports, and policy documents to identify trends, challenges, and opportunities related to AI integration in civil engineering practices. The study's scope is limited to textual analysis, which may not capture real-time data or qualitative insights from stakeholders directly. Additionally, findings may be context-specific to the Philippines and may not be generalizable to other regions or industries. Availability and accessibility of textual sources may also impact the comprehensiveness of the analysis, and interpretation of textual data may involve subjective judgment.

# **Results and discussion**

1. **The current state of AI adoption in civil engineering projects in the Philippines.**

In the AEC industries, including the Civil Engineering Industry, AI enhances various processes, from design and planning to construction and maintenance. For instance, AI-powered design tools allow civil engineers to create more efficient and innovative designs. At the same time, AI-based project management software can help keep construction projects on schedule and within budget.

In the Philippines, the adoption of AI in these industries is still in its nascent stages but is steadily growing. Companies are starting to recognize the potential benefits of AI and are increasingly integrating it into their operations.

Artificial intelligence can profoundly transform the civil engineering, and construction industries. While the use of AI in civil engineering and construction in the Philippines is still in its early stages, the impact is increasingly noticeable. The advantages, such as improved efficiency, enhanced design capabilities, improved safety, and cost savings, are significant. However, the disadvantages must be addressed, including job displacement concerns, high initial costs, and dependence on technology and associated risks. AI’s journey in the Philippines’ AEC industries is just beginning. It will be fascinating to see how it unfolds.

1. To evaluate the advantages and disadvantages of AI on efficiency, resilience, and sustainability in civil engineering development in the Philippines.

Advantages:

* It can significantly improve efficiency and productivity. For example, AI can automate repetitive tasks, freeing human workers for more complex tasks.
* AI-powered predictive analytics can help pinpoint potential issues before they become major problems, saving time and resources.
* AI can enhance design capabilities. AI algorithms can generate numerous design alternatives quickly, allowing architects to choose the most suitable one.
* AI can improve safety measures by predicting and preventing accidents.
* AI can lead to substantial cost savings, especially in the long run.

Disadvantages:

* As AI automates more tasks, there’s a fear that many jobs, especially those involving repetitive tasks, could become obsolete.
* The high initial investment required for AI technologies can be a barrier for many companies, particularly small and medium-sized enterprises.
* The risk of becoming overly dependent on technology. Any technical issues or cyber-attacks could severely disrupt operations.

1. To identify the key challenges and opportunities associated with the integration of AI in civil engineering projects in the Philippines.

Implications and Challenges:

Exploring the implications and challenges of integrating artificial intelligence (AI) into civil engineering practice is crucial for understanding the broader impact and potential obstacles associated with this transformation. Here's a detailed exploration of these implications and challenges:

1. Ethical and Social Implications: The adoption of AI in civil engineering raises ethical concerns related to privacy, bias, and accountability. For instance, AI algorithms may inadvertently perpetuate biases present in historical data, leading to unfair outcomes or discriminatory practices. Additionally, there are concerns about the potential displacement of jobs as AI technologies automate tasks traditionally performed by humans.
2. Data Privacy and Security: AI systems rely on vast amounts of data, including sensitive information such as project plans, financial records, and personal data. Ensuring the privacy and security of this data is essential to prevent unauthorized access, data breaches, and cyber-attacks. Civil engineers must implement robust data protection measures and comply with relevant regulations to safeguard sensitive information.
3. Technical Challenges: Implementing AI in civil engineering practice requires overcoming technical challenges related to data quality, interoperability, and scalability. Ensuring the reliability and accuracy of data inputs is crucial for training AI algorithms and making informed decisions. Additionally, integrating AI systems with existing software and hardware infrastructure may require significant technical expertise and investment.
4. Regulatory and Legal Considerations: The deployment of AI in civil engineering may raise regulatory and legal challenges related to liability, accountability, and compliance. Engineers must navigate a complex regulatory landscape and ensure that AI systems comply with relevant laws and regulations governing safety, environmental protection, and project delivery.
5. Skills and Training: Adopting AI technologies in civil engineering practice necessitates upskilling and training the workforce to effectively use and manage these technologies. Engineers and project stakeholders must acquire the necessary technical skills and knowledge to leverage AI tools and techniques effectively. Additionally, ongoing training and professional development programs are essential to keep pace with rapidly evolving AI technologies.
6. Resistance to Change: There may be resistance to change within the civil engineering industry as engineers and stakeholders grapple with the implications of incorporating AI into established workflows and processes. Addressing concerns about job displacement, loss of control, and the perceived complexity of AI technologies is essential to gaining buy-in and fostering acceptance of AI integration within the industry.

Opportunities for Integration:

1. Design Optimization: AI algorithms can analyze vast amounts of data to generate optimized designs that meet specified criteria such as cost, durability, and sustainability. By automating the design process and exploring a wide range of design alternatives, engineers can identify innovative solutions and optimize designs more efficiently than traditional methods.
2. Construction Management: AI-powered project management systems can analyze historical project data, identify patterns and trends, and predict potential delays or cost overruns. This allows project managers to proactively address issues and optimize construction workflows to improve efficiency and reduce risks. Additionally, AI-driven robotics and automation technologies can perform tasks such as site surveying, excavation, and assembly, increasing productivity and safety on construction sites.
3. Asset Management: AI algorithms can analyze sensor data from infrastructure assets such as bridges, roads, and utilities to detect signs of deterioration, predict maintenance needs, and optimize asset performance. By implementing AI-driven predictive maintenance strategies, asset owners can reduce downtime, extend asset lifespan, and optimize maintenance costs. Furthermore, AI-enabled digital twin platforms can create virtual replicas of physical assets, allowing engineers to simulate various scenarios, monitor real-time performance, and make data-driven decisions to optimize asset management strategies.
4. Environmental Impact Assessment: AI can analyze environmental data and simulate the impact of infrastructure projects on ecosystems, natural resources, and communities. By incorporating AI into environmental impact assessment processes, engineers can better understand the potential environmental consequences of their projects and identify mitigation measures to minimize negative impacts.
5. Risk Management: AI-driven risk management systems can analyze project data, identify potential risks, and assess their likelihood and impact on project outcomes. By leveraging AI to predict and mitigate risks, engineers can make more informed decisions and minimize project delays, cost overruns, and safety incidents.
6. Supply Chain Optimization: AI algorithms can analyze supply chain data, optimize inventory levels, and identify opportunities for cost savings and efficiency improvements. By integrating AI into supply chain management processes, engineers can streamline procurement, reduce lead times, and improve project delivery schedules.
7. Collaborative Design and Decision-Making: AI-enabled collaboration platforms can facilitate communication and information sharing among project stakeholders, enabling more effective collaboration and decision-making. By providing real-time access to project data and analytics, these platforms empower engineers to make informed decisions and coordinate activities across distributed teams.
8. Continuous Improvement and Learning: AI algorithms can analyze project performance data and identify opportunities for process improvement and optimization. By leveraging AI to monitor and analyze project outcomes, engineers can identify best practices, lessons learned, and areas for improvement to inform future projects and drive continuous learning and improvement within their organizations.

**II. To provide recommendations for enhancing the effective adoption and utilization of AI in civil engineering development in the Philippines.**

Future Directions and Recommendations:

Discussing future directions and providing recommendations for integrating artificial intelligence (AI) into civil engineering practice involves considering emerging trends, potential advancements, and strategies for maximizing the benefits of AI while addressing challenges.:

1. Advancements in AI Technology: As AI technologies continue to evolve, there is a need for ongoing research and development to advance the capabilities of AI algorithms and tools specifically tailored to civil engineering applications. This includes developing more sophisticated machine learning algorithms, enhancing data analytics techniques, and improving the interoperability of AI systems with existing engineering software and hardware.
2. Integration of AI with Emerging Technologies: Future directions in AI integration involve exploring synergies with other emerging technologies such as the Internet of Things (IoT), blockchain, augmented reality (AR), and virtual reality (VR). By combining AI with these technologies, engineers can create interconnected systems that enable seamless data exchange, improve collaboration, and enhance decision-making across the project lifecycle.
3. Enhanced Predictive Analytics and Optimization: There is a growing need for advanced predictive analytics and optimization techniques to address complex challenges in civil engineering, such as climate change adaptation, urbanization, and infrastructure resilience. Future research should focus on developing Ai driven models and simulations that can accurately predict the performance of infrastructure systems under various scenarios and optimize designs to enhance sustainability and resilience.
4. Ethical and Responsible AI Adoption: As AI technologies become increasingly pervasive in civil engineering practice, it is essential to prioritize ethical considerations and ensure responsible AI adoption. This includes addressing issues related to data privacy, bias, transparency, and accountability, as well as promoting diversity and inclusion in AI development and deployment processes.
5. Investment in Skills Development and Training: Future recommendations for integrating AI into civil engineering practice include investing in skills development and training programs to upskill the workforce and equip engineers with the necessary technical expertise to leverage AI technologies effectively. This includes providing training on AI tools and techniques, fostering interdisciplinary collaboration, and promoting lifelong learning and professional development.
6. Collaboration and Knowledge Sharing: Collaboration and knowledge sharing are essential for driving innovation and advancing the adoption of AI in civil engineering practice. Future efforts should focus on fostering collaboration among academia, industry, government agencies, and professional organizations to share best practices, lessons learned, and research findings related to AI integration. This includes establishing partnerships, organizing workshops and conferences, and creating online platforms for information exchange and collaboration.
7. Regulatory and Policy Support: Governments and regulatory bodies play a crucial role in facilitating the responsible adoption of AI in civil engineering practice. Future recommendations include developing regulatory frameworks, standards, and guidelines to ensure the ethical and safe deployment of AI technologies, as well as providing incentives and support for research and development in AI enabled infrastructure solutions.
8. Demonstration Projects and Pilot Studies: Finally, future directions for integrating AI into civil engineering practice involve conducting demonstration projects and pilot studies to showcase the benefits and feasibility of AI technologies in real-world settings. By implementing AI-enabled solutions on a smaller scale and evaluating their performance, engineers can gain valuable insights, build confidence, and inform future decision-making regarding broader adoption and implementation.

# **Conclusion**

The integration of artificial intelligence (AI) into the civil engineering industry heralds a new era of innovation, efficiency, and sustainability. Through a comprehensive exploration spanning the years 2020 to 2024, this research has delved into the multifaceted impacts, challenges, and prospects associated with AI's role within civil engineering. By analyzing textual sources and existing literature, we have gained valuable insights into the advancements in AI technologies and their applications in enhancing project efficiency, sustainability, and resilience.

Civil engineering, at the forefront of infrastructure development, stands to benefit immensely from AI integration. From design optimization to construction management and ongoing maintenance, AI promises to augment every stage of the civil engineering lifecycle. By harnessing AI algorithms, machine learning, and data analytics, civil engineers can optimize project outcomes, mitigate risks, and create more resilient and sustainable infrastructure solutions.

However, the adoption of AI in civil engineering is not without its challenges. Ethical considerations, data privacy concerns, and the need for interdisciplinary collaboration pose formidable obstacles that must be addressed to realize AI's full potential. Moreover, ongoing adaptation and upskilling within the civil engineering workforce are essential to fully leverage the capabilities of AI technologies.

This research endeavors to shed light on the complex role of AI in the development of the civil engineering industry. By examining current applications, identifying challenges, and envisioning future trends, this study aims to provide insights that will inform strategic decision-making, inspire innovation, and drive positive change within the civil engineering profession.

In conclusion, the integration of AI represents a transformative opportunity for the civil engineering industry to evolve and meet the challenges of the 21st century. By embracing AI technologies responsibly and proactively addressing challenges, civil engineers can lead the way towards a more sustainable, resilient, and efficiently built environment. Artificial intelligence can profoundly transform the civil engineering industry. While the use of AI in the civil engineering industry in the Philippines is still in its early stages, the impact is increasingly noticeable. The advantages, such as improved efficiency, enhanced design capabilities, improved safety, and cost savings, are significant. However, the disadvantages must be addressed, including job displacement concerns, high initial costs, and dependence on technology. Detailed case studies offer valuable insights into the practical application of AI in these industries. Looking ahead, the potential future developments of AI promise further changes, bringing both opportunities and challenges. As we continue to navigate the age of AI, it is crucial to approach it with a balanced perspective. It would be wise to acknowledge its potential benefits and associated risks. AI’s journey in the Philippines’ civil engineering industry is just beginning. It will be fascinating to see how it unfolds.

# **Recommendation**

This research can provide practitioners with a modulated reference point that is easily accessible, as well as assist them in grasping the most recent techniques and methodology of artiﬁcial intelligence research aimed at sustainable development. This research has limitations, despite its contributions. The information is initially obtained from the Scopus database. In the future, additional data will be gathered by combining information from various databases for quantitative and qualitative studies (e.g., Google Scholar, Web of Science, and so on). Second, the focus of this study was limited to journal articles. As a matter of fact, the study’s ﬁndings do not completely reﬂect the available AI literature. future researchers/students, use and gather data from real-life scenarios that shows the implication of Artificial Intelligence to the civil engineering industry for better understanding. The limitations mentioned above offer excellent opportunities for further study, but they should be considered when assessing the research results.

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