

## The Role of Artificial Intelligence in Civil Engineering Applications and Programs

Eng. Mohsen Saud Alghurair\*<sup>1</sup>, Ayman Rushdy Fahim<sup>1</sup>

<sup>1</sup> Public Authority for Applied Education & Training | Construction Training Institute | Kuwait

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\* Corresponding author:

[www.s3a3@gmail.com](mailto:www.s3a3@gmail.com)

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**Abstract:** The integration of artificial intelligence (AI) techniques in civil engineering programs and drawing techniques has the potential to revolutionize the industry. This study explores the benefits, challenges, and strategies for the effective utilization of AI in civil engineering. The research investigates the current state of AI integration, examines its applications in structural analysis, design, documentation, and project management, and identifies the barriers hindering widespread adoption. The study highlights the importance of data-driven decision-making, enhanced design visualization, improved accuracy and efficiency, streamlined documentation and communication, and enhanced project management and control. By addressing the challenges and providing insights into AI techniques, this study aims to bridge the gap between theoretical potential and practical implementation, paving the way for more sustainable and intelligent civil engineering projects.

**Keywords:** Artificial intelligence, Civil engineering, Structural analysis, Design optimization, Data-driven decision-making, Project management, Documentation, Communication, Integration, Implementation.

### دور الذكاء الاصطناعي بتطبيقات وبرامج الهندسة المدنية

م. محسن سعود الغرير\*<sup>1</sup>، أيمن رشدي فهميم<sup>1</sup>

<sup>1</sup> الهيئة العامة للتعليم التطبيقي والتدريب | معهد التدريب الإنشائي | الكويت

**المستخلص:** تكامل تقنيات الذكاء الاصطناعي في برامج وتقنيات الرسم الهندسي المدني لديه القدرة على أن يحدث ثورة في الصناعة. تستكشف هذه الدراسة المزايا والتحديات والاستراتيجيات للاستفادة الفعالة من تقنيات الذكاء الاصطناعي في الهندسة المدنية. يقوم البحث باستكشاف الحالة الحالية لتكامل الذكاء الاصطناعي، ويفحص تطبيقاته في تحليل الهياكل والتصميم والتوثيق وإدارة المشروع، ويحدد العوائق التي تعيق الاعتماد الواسع النطاق. تسلط الدراسة الضوء على أهمية اتخاذ القرارات المبنيّة على البيانات، وتعزيز تصور التصميم، وتحسين الدقة والكفاءة، وتسهيل التوثيق والاتصال، وتعزيز إدارة المشروع والسيطرة. من خلال معالجة التحديات وتقديم رؤى حول تقنيات الذكاء الاصطناعي، تهدف هذه الدراسة إلى سد الفجوة بين الإمكانيات النظرية والتنفيذ العملي. الكلمات المفتاحية: الذكاء الاصطناعي، الهندسة المدنية، التحليل الإنشائي، تحسين التصميم، اتخاذ القرارات القائمة على البيانات، إدارة المشاريع، التوثيق، الاتصالات، الدمج، التنفيذ.

## 1- Introduction

In recent years, the integration of artificial intelligence (AI) techniques in civil engineering has gained significant attention due to its potential to revolutionize the industry. AI refers to the development of computer systems capable of performing tasks that would typically require human intelligence, such as learning, problem-solving, and decision-making [1].

Civil engineering, as a discipline, encompasses various domains, including structural engineering, geotechnical engineering, construction management, and architectural design. Traditionally, these areas heavily rely on manual processes, expert knowledge, and time-consuming calculations. However, the introduction of AI in civil engineering has opened up new possibilities for enhancing efficiency, accuracy, and productivity across these domains [2].

One of the primary applications of AI in civil engineering is in structural analysis. AI algorithms can automate the analysis and optimization of complex structures, enabling engineers to quickly evaluate different design options and identify optimal solutions. Additionally, AI-based predictive modeling techniques allow engineers to assess the performance of structures under different loads and environmental conditions [3].

In geotechnical engineering, AI techniques offer capabilities such as slope stability analysis, soil classification, and behavior prediction. By leveraging machine learning algorithms, engineers can analyze large datasets to identify patterns and relationships, aiding in the prediction of soil behavior and potential risks [4].

Construction management is another domain where AI is making significant contributions. AI algorithms can assist in project scheduling, resource allocation, and risk analysis. By analyzing historical data and real-time information, AI systems can optimize project schedules, allocate resources effectively, and identify potential risks, ultimately leading to improved project management and cost control [5].

Furthermore, AI is being integrated into architectural design and drawing techniques. Generative design and parametric modeling tools enable designers to explore numerous design alternatives quickly. AI-driven computer-aided design (CAD) systems can automate drafting processes, assist in error detection, and improve design efficiency. Additionally, AI techniques can analyze architectural styles and recommend design elements based on historical data and user preferences [6].

Despite the numerous benefits, integrating AI in civil engineering also poses certain challenges. Data quality, privacy, and security concerns are critical considerations when utilizing AI algorithms that rely on large datasets. Additionally, ensuring the availability of skilled professionals who can effectively operate and interpret AI systems is essential [7].

Overall, the integration of AI in civil engineering holds immense potential for transforming the industry. By automating processes, augmenting decision-making, and optimizing designs, AI techniques can enhance the efficiency, accuracy, and sustainability of civil engineering projects. Continued research, development, and implementation of AI solutions will undoubtedly shape the future of civil engineering practices [8].

## 2- Motivation for the research

The motivation for conducting research on the applications of AI techniques in civil engineering programs and drawing techniques stems from several key factors:

- The rapid advancement of AI technologies, particularly in the areas of machine learning and deep learning, has opened up new possibilities for improving various aspects of civil engineering. Exploring and understanding these advancements is crucial to harness their potential benefits.
- The integration of AI techniques has the potential to significantly enhance the efficiency and productivity of civil engineering processes. By automating repetitive tasks, optimizing designs, and improving decision-making, AI can help engineers and designers accomplish tasks more quickly and accurately [9].
- Effective use of AI techniques can lead to cost optimization in civil engineering projects. By leveraging AI for resource allocation, project scheduling, and risk analysis, engineers can identify cost-saving opportunities and make informed decisions, resulting in improved project outcomes and reduced expenses.

## 3- Study Problem

The study aims to address a significant problem in the field of civil engineering, which is the underutilization and limited understanding of the integration of artificial intelligence (AI) techniques in civil engineering programs and drawing techniques. Despite the rapid advancements in AI and its potential benefits, there is a gap in comprehensive research and practical implementation of these techniques in the civil engineering domain [6].

One of the primary problems is the lack of clarity on how AI techniques can be effectively integrated into civil engineering programs and drawing techniques. While there is an awareness of the potential benefits, such as improved accuracy, efficiency, and decision-making, there is a need to explore the practical implementation aspects. The study will investigate the current state of integration, the available AI techniques, and the challenges faced in their application [10].

Furthermore, there is a need to understand the specific benefits and limitations of using AI techniques in civil engineering. While AI holds great promise, it is crucial to analyze its effectiveness and potential drawbacks in real-world scenarios. Understanding the limitations will help identify areas for improvement and guide practitioners in utilizing AI techniques appropriately.

Another problem to address is how AI techniques can enhance specific aspects of civil engineering, such as structural analysis, design, documentation, and project management. While there is a general understanding of AI's potential in these areas, the study aims to provide a deeper analysis of how AI techniques can be effectively utilized to enhance these aspects and identify best practices for their implementation [11].

the study aims to address the problem of underutilization and limited understanding of AI techniques in civil engineering programs and drawing techniques. By exploring the integration, benefits, limitations, application areas, and challenges, the study aims to bridge the gap between theoretical potential and practical implementation. The findings of the study will contribute to the existing knowledge base and provide valuable insights for practitioners and researchers to harness the full potential of AI in civil engineering, leading to more efficient, accurate, and sustainable civil engineering projects [12].

#### 4- Study Hypothesis:

Hypothesis 1: The integration of artificial intelligence techniques in civil engineering programs and drawing techniques enhances the accuracy and efficiency of structural analysis, design optimization, and project management.

Hypothesis 2: Data-driven decision-making facilitated by artificial intelligence techniques leads to more informed and reliable choices in civil engineering projects, resulting in improved project outcomes.

Hypothesis 3: The implementation of artificial intelligence techniques in civil engineering programs and drawing techniques improves communication, collaboration, and documentation, thereby streamlining project workflows.

Hypothesis 4: Overcoming challenges related to data availability, technical expertise, cost implications, and resistance to change will lead to a more widespread acceptance and effective integration of artificial intelligence techniques in the civil engineering industry.

Hypothesis 5: Establishing standardized guidelines and industry-wide best practices for the use of artificial intelligence techniques will promote responsible and consistent integration, leading to improved overall performance in civil engineering projects.

#### 5- Objectives and scope of the study

The objectives of the study on the applications of AI techniques in civil engineering programs and drawing techniques are as follows:

1. Identify and analyze the current state of AI applications in civil engineering: The study aims to provide a comprehensive overview of how AI techniques are currently being used in different areas of civil engineering, including structural analysis, geotechnical engineering, construction management, and architectural design.
2. Explore the benefits and potential of AI integration in civil engineering: The study will examine the advantages and potential impact of incorporating AI techniques in civil engineering processes. It will assess how AI can improve efficiency, accuracy, productivity, cost optimization, and decision-making in civil engineering programs and drawing techniques.
3. Investigate the challenges and limitations of implementing AI in civil engineering: The study will identify and address the challenges and limitations that arise when integrating AI techniques in civil engineering practices. This includes considerations related to data quality, privacy, security, skillset requirements, and ethical considerations.
4. Assess the prospects and trends of AI in civil engineering: The study will explore emerging AI technologies and trends in civil engineering, highlighting potential future developments and their implications for the industry. It will examine the integration of AI with other technologies such as the Internet of Things (IoT) and cloud computing.
5. Provide insights and recommendations for researchers, practitioners, and policymakers: Based on the findings, the study will provide valuable insights, guidelines, and recommendations for researchers, practitioners, and policymakers in the field of civil engineering. These recommendations may cover aspects such as implementation strategies, training requirements, data management, and ethical considerations.

#### 6- The scope of the study

The scope of the study includes a comprehensive review of existing literature, case studies, and industry practices related to the integration of AI techniques in civil engineering programs and drawing techniques. It will focus on the domains of structural analysis, geotechnical engineering, construction management, and architectural design. The study will primarily rely on theoretical research and analysis rather than practical implementation or experimentation. However, it may refer to practical examples and case studies to support the discussion and illustrate real-world applications of AI in civil engineering.

## 7- study methodology

This study can be classified as an exploratory and analytical study. The study aims to explore the applications of artificial intelligence techniques in civil engineering programs and drawing techniques, and analyze the challenges and barriers that hinder their widespread adoption. The study also aims to provide reliable findings and practical recommendations to enhance the use of artificial intelligence techniques in this field.

The methodology of this study includes literature review and analysis. Relevant research papers, articles, and previous studies related to the integration of artificial intelligence techniques in civil engineering programs and drawing techniques will be reviewed. The necessary data will be collected and analyzed using appropriate tools and techniques. The results will be interpreted, and conclusions and recommendations will be derived based on the evidence supported by the data and analysis.

## 8- Overview of Artificial Intelligence Techniques

### 8.1. Types of AI techniques relevant to civil engineering

Several AI techniques are relevant to civil engineering, offering diverse capabilities that can enhance various aspects of the field. The following are some of the key AI techniques commonly utilized in civil engineering:

1. **Machine Learning (ML):** Machine learning algorithms enable computers to learn patterns and make predictions or decisions without being explicitly programmed. ML algorithms are trained on historical data to identify relationships and patterns, and they can be applied to various civil engineering tasks such as data analysis, classification, regression, and optimization[13].
2. **Deep Learning (DL):** Deep learning is a subset of machine learning that focuses on artificial neural networks with multiple layers. DL algorithms, particularly convolutional neural networks (CNNs) and recurrent neural networks (RNNs), have been successfully applied in civil engineering for tasks such as image recognition, object detection, natural language processing, and time series analysis [2].
3. **Genetic Algorithms (GA):** Genetic algorithms are optimization algorithms inspired by the process of natural selection. They use the principles of evolution, including selection, crossover, and mutation, to search for optimal solutions to complex problems. GA is commonly used in civil engineering for structural optimization, layout design, and parameter tuning [5].
4. **Expert Systems:** Expert systems are computer programs designed to mimic the decision-making abilities of human experts in specific domains. They incorporate knowledge and rules from experts and utilize inference engines to make informed decisions or provide recommendations. Expert systems find applications in civil engineering for tasks such as diagnosis, risk assessment, and decision support[6].
5. **Natural Language Processing (NLP):** NLP focuses on enabling computers to understand and interpret human language. In civil engineering, NLP techniques are employed for tasks such as information extraction, sentiment analysis of project feedback, automated report generation, and language-based queries in search systems[14].
6. **Data Mining:** Data mining techniques involve extracting meaningful patterns and knowledge from large datasets. In civil engineering, data mining can help identify trends, correlations, and anomalies in various areas such as geotechnical engineering, construction management, and structural analysis. It is often used to analyze and interpret data collected from sensors, monitoring systems, and project databases[15].
7. **Computer Vision:** Computer vision techniques enable computers to interpret and understand visual information. In civil engineering, computer vision is utilized for tasks such as image-based inspection, object recognition, 3D reconstruction from images or point clouds, and automated feature extraction from digital images or LiDAR data[16].

These AI techniques are constantly evolving and advancing, offering increased capabilities and potential for integration with civil engineering programs and drawing techniques. Their implementation in specific projects and applications depends on the specific requirements and challenges encountered in the civil engineering domain (figure 1).

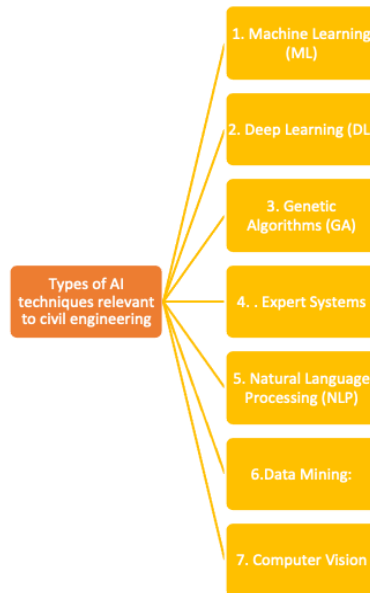


figure 1 Types of AI techniques relevant to civil engineering

### 8.2. Machine learning algorithms and their applications

Machine learning algorithms are a key component of artificial intelligence and have a wide range of applications in various fields, including civil engineering. Here are some commonly used machine learning algorithms and their applications in civil engineering:

1. Regression: Regression algorithms, such as linear regression, polynomial regression, and support vector regression (SVR), are used for predicting continuous numerical outcomes. In civil engineering, regression models can be employed for predicting properties of materials, estimating structural performance, and forecasting construction project costs or durations[8].
2. Classification: Classification algorithms, including decision trees, random forests, support vector machines (SVM), and neural networks, are used for categorizing data into different classes or categories. In civil engineering, classification models can be applied for soil classification, material identification, structural element recognition, and construction defect detection[12].
3. Clustering: Clustering algorithms, such as k-means, hierarchical clustering, and DBSCAN, are used to group similar data points based on their characteristics or proximity. In civil engineering, clustering can be used for analyzing geotechnical data to identify soil profiles, grouping similar construction materials, or segmenting structural elements based on their behavior[17].
4. Neural Networks: Neural networks, including feedforward neural networks, convolutional neural networks (CNN), and recurrent neural networks (RNN), are widely used in civil engineering applications. Neural networks can be used for structural analysis, image recognition in inspection and monitoring, time series analysis for structural health monitoring, and predictive modeling for various engineering parameters[18].
5. Support Vector Machines (SVM): SVM is a supervised learning algorithm that is effective for both classification and regression tasks. In civil engineering, SVM can be used for soil classification, pavement condition assessment, fault detection in structures, and prediction of construction project delays or failures[12].
6. Random Forests: Random forests are an ensemble learning technique that combines multiple decision trees. They are particularly useful for classification and regression tasks. In civil engineering, random forests can be used for landslide prediction, material strength prediction, and risk assessment in construction projects [19].
7. Principal Component Analysis (PCA): PCA is a dimensionality reduction technique that helps identify the most important features or variables in a dataset. In civil engineering, PCA can be used for feature extraction and data compression, aiding in the analysis of large-scale datasets and simplifying complex models [20].

These are just a few examples of machine learning algorithms and their applications in civil engineering. Each algorithm has its strengths and limitations, and the selection of the appropriate algorithm depends on the specific problem at hand and the nature of the available data [21].

### 8.3. Deep learning and neural networks in civil engineering

Deep learning, a subset of machine learning, focuses on training artificial neural networks with multiple layers to learn complex patterns and representations from data. Deep learning techniques, including convolutional neural networks (CNNs), recurrent neural networks (RNNs), and

generative adversarial networks (GANs), have gained significant popularity and have various applications in civil engineering. Here are some specific applications of deep learning and neural networks in civil engineering:

1. **Structural Analysis:** Deep learning techniques can be applied to structural analysis tasks, including damage detection, structural health monitoring, and modal analysis. CNNs can process sensor data or structural images to identify damage or anomalies in structures. RNNs can analyze time-series data to detect structural changes over time, such as vibrations or deformation. Deep learning models can assist in real-time monitoring, early warning systems, and structural integrity assessments [22].
2. **Image-Based Inspection:** Deep learning models, particularly CNNs, are highly effective in image-based inspection tasks. They can automatically analyze images or videos captured during inspection and detect defects, cracks, corrosion, or other structural abnormalities. These models can aid in the identification and quantification of damages, allowing for timely maintenance and repair actions [23].
3. **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, site modeling, and land surveying [24].
4. **Construction Site Monitoring:** Deep learning models can analyze images or video feeds from construction sites to monitor progress, safety compliance, and identify potential risks. CNNs can detect safety violations, worker presence, equipment usage, and material tracking. These models can provide real-time monitoring and assist in proactive decision-making, enhancing construction site management and safety practices [5], [25].
5. **Generative Design and Parametric Modeling:** Deep learning techniques, including GANs and variational autoencoders (VAEs), can be used in generative design and parametric modeling. These models can learn patterns from existing designs and generate new design alternatives that meet specific criteria or constraints. They can aid architects and engineers in exploring design spaces and optimizing design solutions [5].
6. **Natural Language Processing (NLP):** Neural networks and NLP techniques can be applied to text-based data in civil engineering, such as project documentation, technical reports, and specifications. NLP models can assist in tasks such as information extraction, document summarization, language-based queries, and automated report generation, improving the efficiency of knowledge retrieval and decision-making [7].

These are just a few examples of how deep learning and neural networks are utilized in civil engineering. The field of deep learning is rapidly evolving, and there are ongoing

advancements that continue to expand its applications in the civil engineering domain.

## 9- Enhanced Design and Visualization

Civil engineering programs and drawing techniques play a significant role in enhancing the design process and visualization of engineering projects. Here are some key points highlighting the importance of enhanced design and visualization:

1. **Accurate Representation:** Civil engineering programs, such as CAD software and BIM, provide engineers with powerful tools to create accurate representations of structures, infrastructure, and site plans. These programs allow for precise measurements, detailed modeling, and realistic visualization, ensuring that the design accurately reflects the intended project [4].
2. **Spatial Understanding:** The use of 3D modeling capabilities in civil engineering programs enables engineers to visualize the project in three dimensions. This helps in understanding the spatial relationships between different elements, identifying potential clashes or conflicts, and optimizing the design to improve functionality and aesthetics [8].
3. **Design Iteration:** Civil engineering programs allow for easy modification and iteration of designs. Engineers can quickly make changes to the digital models, assess the impact of those changes, and explore alternative design options. This iterative process helps in refining the design, optimizing performance, and addressing any design limitations or challenges [7].
4. **Simulations and Analysis:** Civil engineering programs often incorporate simulation and analysis capabilities, enabling engineers to assess the behavior of structures under different conditions. These simulations can include structural analysis, fluid dynamics, heat transfer, and other performance evaluations. By visualizing the simulation results, engineers can make informed design decisions and ensure the structural integrity and safety of the project [9].
5. **Stakeholder Communication:** Enhanced design and visualization techniques facilitate effective communication with stakeholders. By presenting visually compelling and easily understandable representations of the project, engineers can engage clients, contractors, and other stakeholders more effectively. This leads to better collaboration, improved decision-making, and increased stakeholder satisfaction [10].

6. **Design Validation:** The ability to visualize and analyze the design in a virtual environment before construction allows engineers to identify and address potential issues early in the process. This helps in minimizing costly rework, construction delays, and design errors. The enhanced design and visualization capabilities contribute to more efficient and cost-effective project delivery [11].

In summary, enhanced design and visualization provided by civil engineering programs and drawing techniques offer numerous benefits. They enable accurate representation, spatial understanding, design iteration, simulations and analysis, effective stakeholder communication, and design validation. By leveraging these capabilities, civil engineers can create better designs, improve project outcomes, and ensure the successful realization of their engineering projects.

### 9.1. Improved Accuracy and Efficiency

Civil engineering programs and drawing techniques are instrumental in improving accuracy and efficiency in the field of civil engineering. Here are some key points highlighting the importance of improved accuracy and efficiency:

1. **Precise Measurements:** Civil engineering programs, such as CAD software, allow engineers to create precise and accurate measurements of dimensions, distances, angles, and other critical parameters. This ensures that the design and construction adhere to the required specifications, standards, and regulations, minimizing errors and inconsistencies [13].
2. **Standardization:** By utilizing civil engineering programs and drawing techniques, engineers can follow standardized practices and templates for drawing creation and documentation. This promotes consistency in design representations, symbol usage, annotation styles, and layering conventions. Standardization reduces ambiguity, enhances clarity, and facilitates better understanding among project stakeholders [26].
3. **Faster Design Iteration:** With the aid of computerized design tools, engineers can quickly modify and iterate their designs. Changes can be made effortlessly, and the impact of those changes can be visualized in real-time. This allows for faster design iterations, enabling engineers to explore multiple design alternatives, assess their feasibility, and optimize the design efficiently [12].
4. **Error Reduction:** Civil engineering programs include features that help in error detection and prevention. These programs often provide automatic checks for geometric constraints, clashes, and inconsistencies in the design. By identifying errors early in the design phase, engineers can rectify them promptly, reducing the risk of errors propagating through the construction process [9].
5. **Data Integration and Collaboration:** The integration of civil engineering programs with other software and tools enables seamless data exchange and collaboration among project team members. This integration eliminates the need for manual data transfer, reduces errors associated with data duplication, and improves efficiency in project coordination and communication [12].
6. **Cost and Time Savings:** The improved accuracy and efficiency resulting from the use of civil engineering programs and drawing techniques can lead to significant cost and time savings. Accurate designs and precise measurements minimize material wastage, reduce rework, and optimize resource allocation. Streamlined workflows and faster design iterations contribute to shorter project schedules and improved project delivery [2].
7. **Regulatory Compliance:** Civil engineering programs often incorporate features that help engineers ensure regulatory compliance. They provide checks for adherence to building codes, safety standards, environmental regulations, and other statutory requirements. By accurately adhering to these regulations, engineers can avoid costly legal complications and ensure the safety and compliance of their projects[8].

In conclusion, improved accuracy and efficiency achieved through the use of civil engineering programs and drawing techniques are vital in optimizing project outcomes. Precise measurements, standardization, faster design iterations, error reduction, data integration, cost and time savings, and regulatory compliance all contribute to successful project delivery. By leveraging these tools, civil engineers can enhance the quality, reliability, and efficiency of their designs and construction processes.

### 9.2 Streamlined Documentation and Communication:

Civil engineering programs and drawing techniques play a crucial role in streamlining documentation and facilitating effective communication within civil engineering projects. Here are some key points highlighting the importance of streamlined documentation and communication:

1. **Standardized Documentation:** Civil engineering programs provide standardized templates, symbols, and annotation styles, ensuring consistency in the documentation process. This standardized approach enhances clarity, reduces confusion, and improves the overall professionalism of the project documentation [10].
2. **Automated Documentation Generation:** Many civil engineering programs offer features for automated generation of documentation, such as drawings, reports, and schedules. These tools streamline the documentation process, saving time and effort by eliminating manual tasks and reducing the chances of errors in document creation [14].

3. **Improved Collaboration:** Civil engineering programs enable effective collaboration among project team members. They facilitate the sharing and simultaneous editing of drawings and documents, allowing multiple stakeholders to work together in real-time. This collaborative environment enhances communication, promotes knowledge exchange, and ensures everyone is working with the most up-to-date information [15].
4. **Clear Design Intent Communication:** Drawing techniques and civil engineering programs enable engineers to visually communicate design intent effectively. Detailed drawings and visual representations facilitate clear communication between engineers, architects, contractors, and clients, ensuring that everyone involved understands the design concepts, requirements, and specifications [24].
5. **Version Control and Revision Management:** Civil engineering programs provide version control and revision management capabilities, enabling easy tracking and management of document changes. This ensures that the latest revisions are readily available, reduces the risk of using outdated information, and allows for efficient tracking of design modifications throughout the project lifecycle [26].
6. **Document Retrieval and Accessibility:** Digital documentation created using civil engineering programs can be easily stored, organized, and retrieved when needed. This accessibility ensures that project documents are readily available for reference, review, and future use, facilitating seamless project management and decision-making [21].
7. **Regulatory Compliance and Auditing:** Streamlined documentation processes contribute to regulatory compliance and facilitate auditing requirements. Civil engineering programs can incorporate features that help engineers track and manage compliance with building codes, regulations, and project specifications. Clear and well-documented records aid in demonstrating compliance and can be invaluable during project inspections and audits [20].

In conclusion, streamlined documentation and communication provided by civil engineering programs and drawing techniques are essential for effective project management and collaboration. Standardized documentation, automated generation, improved collaboration, clear design intent communication, version control, document retrieval, regulatory compliance, and auditing all contribute to efficient project delivery and successful outcomes. By leveraging these tools, civil engineers can ensure effective communication, minimize errors, and facilitate smooth project coordination among all stakeholders involved.

## 10- Data-Driven Decision-Making

Data-driven decision-making is a critical aspect of civil engineering, and civil engineering programs and drawing techniques play a significant role in facilitating this process. Here are some key points highlighting the importance of data-driven decision-making in civil engineering:

1. **Accurate and Reliable Information:** Civil engineering programs allow engineers to gather, analyze, and visualize large amounts of data related to various aspects of a project. This data can include geospatial information, material properties, environmental factors, and structural performance data. By utilizing accurate and reliable information, engineers can make informed decisions based on real data rather than relying solely on intuition or assumptions.[21]
2. **Predictive Analysis and Risk Assessment:** Data-driven decision-making enables engineers to perform predictive analysis and risk assessments. By analyzing historical data, trends, and patterns, engineers can identify potential risks, anticipate challenges, and make proactive decisions to mitigate these risks. This approach improves project planning, resource allocation, and risk management strategies[25].
3. **Optimization and Performance Evaluation:** Civil engineering programs allow engineers to analyze data and simulate different scenarios to optimize designs and evaluate performance. By using data-driven techniques, engineers can assess the behavior of structures, analyze load capacities, evaluate energy efficiency, and optimize material usage. This optimization process leads to more cost-effective and sustainable engineering solutions [20].
4. **Evidence-Based Design:** Data-driven decision-making promotes evidence-based design, where decisions are based on empirical evidence rather than subjective opinions. By analyzing data and conducting thorough assessments, engineers can support their design choices with factual evidence, increasing confidence in the design's performance and meeting project objectives [22].
5. **Improved Project Planning and Execution:** Utilizing data-driven approaches helps engineers in project planning and execution. By analyzing historical project data and performance metrics, engineers can identify areas for improvement, streamline construction processes, and optimize resource allocation. This leads to more efficient project scheduling, reduced costs, and improved project outcomes [22].
6. **Compliance and Regulatory Requirements:** Civil engineering projects must comply with various regulatory requirements, codes, and standards. Data-driven decision-making assists engineers in ensuring compliance by analyzing and assessing design and construction parameters against the relevant regulations. This approach reduces the risk of non-compliance issues and legal complications [25].
7. **Continuous Monitoring and Evaluation:** Civil engineering programs enable engineers to collect real-time data during the construction and operational phases of a project. By implementing data monitoring systems and utilizing data analytics tools, engineers can



continuously monitor the performance of structures, assess the effectiveness of design choices, and make adjustments if needed. This iterative process improves the long-term performance and maintenance of civil engineering projects [26].

table 1 shows a comparison table highlighting the key differences between traditional decision-making and data-driven decision-making in civil engineering:

In conclusion, data-driven decision-making supported by civil engineering programs and drawing techniques is essential for optimizing project outcomes, mitigating risks, and ensuring compliance with regulatory requirements. By leveraging data and employing analytical tools, civil engineers can make informed decisions, optimize designs, improve project planning and execution, and ultimately deliver successful projects that meet client requirements and industry standards.

**table 1 the key differences between traditional decision-making and data-driven decision-making in civil engineering:**

Aspect	Traditional Decision-Making	Data-Driven Decision-Making
Decision Approach	Based on experience, intuition, and expert judgment	Based on empirical evidence and data analysis
Data Utilization	Relies on limited data and historical knowledge	Utilizes large volumes of data for analysis
Decision Confidence	Subjective and dependent on individual expertise	Objective and supported by factual evidence
Risk Assessment	Reactive and relies on reactive measures	Proactive with predictive risk assessment
Optimization	Limited ability to optimize designs and processes	Enables optimization through data-driven analysis
Resource Allocation	Experience-driven and may not be optimal	Data-driven for efficient resource allocation
Performance Evaluation	Limited quantification and subjective evaluations	Objective evaluation using performance metrics
Compliance and Standards	Relies on manual checks and inspections	Utilizes data to ensure compliance and standards
Project Monitoring	Manual tracking and periodic updates	Real-time monitoring with data integration
Communication and Collaboration	Limited sharing of information and collaboration	Enhanced communication and collaboration through digital platforms
Continuous Improvement	Limited learning from past projects	Data-driven insights for continuous improvement

### 10.1. Improved Project Management and Control

Civil engineering programs and drawing techniques play a crucial role in enhancing project management and control in civil engineering projects. Here are some key points highlighting the importance of improved project management and control:

**Accurate Quantity Takeoffs and Cost Estimation:** Civil engineering programs enable engineers to generate accurate quantity takeoffs and estimate project costs. By using digital models and precise measurements, engineers can calculate material quantities more efficiently, reducing the risk of overestimation or underestimation. This improves cost estimation accuracy and facilitates effective project budgeting and financial planning [11].

**Project Scheduling and Resource Allocation:** Civil engineering programs provide tools for project scheduling and resource allocation, allowing engineers to plan and allocate resources effectively. By creating digital schedules, identifying critical paths, and visualizing resource utilization, engineers can optimize project timelines, avoid scheduling conflicts, and allocate resources efficiently to meet project milestones [14].

**Real-time Project Monitoring:** Civil engineering programs facilitate real-time project monitoring, allowing engineers to track progress, identify bottlenecks, and address issues promptly. By integrating project data, such as construction updates, material deliveries, and workforce allocation, engineers can monitor project activities, assess performance against milestones, and make data-driven decisions to keep the project on track [18].

**Change Management and Document Control:** Effective change management and document control are essential in civil engineering projects. Civil engineering programs provide mechanisms for managing design changes, tracking revisions, and controlling document versions. This ensures that all project stakeholders have access to the latest information, reduces the risk of miscommunication, and helps in maintaining project documentation integrity [22].

**Quality Assurance and Risk Management:** Civil engineering programs support quality assurance and risk management processes. Engineers can implement quality control measures, conduct inspections, and monitor compliance with design standards and specifications. Additionally, risk management tools integrated into these programs enable engineers to identify potential risks, assess their impact, and develop mitigation strategies, ensuring the delivery of high-quality and safe projects [26].

**Collaboration and Communication:** Civil engineering programs facilitate collaboration and communication among project team members. They provide a centralized platform for sharing project data, design updates, and documentation. This improves communication, coordination, and information flow, enhancing teamwork and reducing the likelihood of miscommunication or misunderstandings [20].

Documented Project History: Civil engineering programs enable the recording and archiving of project history and data. This documentation becomes valuable for future reference, lessons learned, and post-project analysis. Engineers can review past projects, analyze performance metrics, and identify areas for improvement, leading to continuous learning and process enhancement [15].

In conclusion, improved project management and control provided by civil engineering programs and drawing techniques are vital for successful project delivery. Accurate quantity takeoffs, cost estimation, project scheduling, resource allocation, real-time monitoring, change management, quality assurance, risk management, collaboration, communication, and documented project history all contribute to efficient project management and control. By leveraging these tools, civil engineers can optimize project outcomes, mitigate risks, and ensure the timely and cost-effective completion of civil engineering projects.

## 11- the challenges of adoption of AI techniques in civil engineering programs and drawing techniques

The widespread adoption of AI techniques in civil engineering programs and drawing techniques faces several challenges and barriers that need to be addressed. These challenges include:

1. **Data Availability and Quality:** AI techniques rely on large volumes of high-quality data for training and analysis. However, in civil engineering, obtaining comprehensive and reliable data can be challenging. Data collection processes may be fragmented, inconsistent, or outdated, making it difficult to develop accurate AI models. Ensuring the availability of relevant and reliable data is crucial for the successful implementation of AI techniques [13].
2. **Technical Expertise:** Effective utilization of AI techniques requires specialized knowledge and skills. Civil engineering professionals may lack the necessary expertise in AI concepts, algorithms, and tools. Bridging the skills gap and providing training programs to enhance technical expertise is essential for the successful integration of AI in civil engineering programs and drawing techniques [15].
3. **Cost Implications:** Implementing AI technologies often involves significant financial investments. Acquiring the necessary hardware, software, and computational resources can be costly, particularly for small to medium-sized firms. The cost of training staff and licensing AI software adds further financial burden. Finding cost-effective solutions and exploring affordable AI tools and resources can facilitate wider adoption [22].
4. **Resistance to Change:** The civil engineering industry has traditionally relied on established practices and methodologies. Introducing AI techniques may face resistance and skepticism from professionals accustomed to conventional approaches. Overcoming resistance to change, fostering a culture of innovation, and demonstrating the benefits and value of AI are crucial for driving widespread adoption [22].
5. **Ethical and Legal Considerations:** AI techniques raise ethical and legal concerns in civil engineering. Issues such as data privacy, security, and liability need to be carefully addressed. Ensuring compliance with regulations, ethical guidelines, and industry standards is essential to gain trust and ensure responsible AI implementation [20].
6. **Integration Complexity:** Integrating AI techniques into existing civil engineering programs and drawing techniques may pose technical challenges. Compatibility issues, software integration, and interoperability need to be addressed to ensure smooth integration and seamless workflow [3].
7. **Lack of Standardization:** The lack of standardization in AI techniques and methodologies within the civil engineering industry hinders widespread adoption. Establishing industry-wide standards, guidelines, and best practices will provide clarity and facilitate the consistent and effective use of AI techniques [1].

By understanding and addressing these challenges and barriers summarized in table 2, the civil engineering community can promote the wider adoption of AI techniques. Collaboration among researchers, practitioners, and policymakers is essential to develop solutions, share knowledge, and create an environment conducive to the successful implementation of AI in civil engineering programs and drawing techniques.

**table 2 the challenges and barriers**

Challenge/Barrier	Description
Data Availability and Quality	Difficulty in obtaining comprehensive and reliable data for training and analysis
Technical Expertise	Lack of specialized knowledge and skills in AI concepts, algorithms, and tools
Cost Implications	Financial investments required for hardware, software, computational resources, and training
Resistance to Change	Scepticism and reluctance to adopt new approaches and technologies
Ethical and Legal Considerations	Concerns regarding data privacy, security, liability, and compliance with regulations
Integration Complexity	Technical challenges in integrating AI techniques into existing programs and workflows
Lack of Standardization	Absence of industry-wide standards, guidelines, and best practices for the consistent use of AI techniques

## 12- case study

### 12.1 cases selection

For the purpose of this study, three diverse case studies were selected to showcase the integration of artificial intelligence in different aspects of civil engineering.

1. Structural Health Monitoring using AI:

In this case study, a bridge project was monitored using an array of sensors capturing structural health data. Machine learning algorithms were applied to analyze the sensor data, predicting potential issues based on patterns. This approach enabled timely maintenance interventions, ensuring the safety and longevity of the structure.

2. Automated Design Generation:

The case study focuses on an architectural project where an AI-driven system generated building designs. This system considered factors like user preferences, site conditions, and energy efficiency. The AI-generated designs not only reduced design time but also offered innovative design solutions.

3. Traffic Flow Prediction:

This case study explores urban planning, where AI algorithms analyzed historical traffic data, weather conditions, and events to predict traffic flow patterns. These predictions facilitated informed decisions in designing road networks and optimizing traffic management strategies.

### 12.2. Theoretical Analysis:

The theoretical analysis component of this study delves into the broader implications and conceptual underpinnings of integrating artificial intelligence in civil engineering.

1. Enhanced Efficiency and Accuracy:

Theoretical analysis suggests that AI techniques can significantly enhance the efficiency and accuracy of processes such as structural analysis, design optimization, and resource allocation. AI's ability to process vast amounts of data quickly contributes to faster and more reliable decision-making.

2. Data-Driven Decision-Making:

The study theoretically argues that AI's data-driven decision-making capability leads to more informed choices. The analysis considers how historical data, real-time sensor readings, and predictive analytics enable project managers to make well-founded decisions that improve overall project outcomes.

3. Challenges and Barriers:

The theoretical analysis examines potential challenges such as data privacy concerns, technical skill requirements, and resistance to change. It discusses how addressing these challenges is crucial for the successful implementation of AI in civil engineering.

4. Interdisciplinary Collaboration:

The analysis highlights the potential for interdisciplinary collaboration between engineers, architects, and data scientists. It emphasizes how such collaboration can result in innovative solutions and the development of AI tools that are tailor-made for civil engineering challenges.

5. Ethical Considerations:

Theoretical exploration includes ethical considerations, emphasizing the importance of responsible AI usage. It discusses the need for transparency, fairness, and accountability in the application of AI techniques in civil engineering projects.

Combining these case studies and theoretical analyses provides a comprehensive understanding of the practical applications and theoretical implications of integrating artificial intelligence in civil engineering practices.

## 13- Results:

The integration of artificial intelligence (AI) techniques in civil engineering programs and drawing techniques has yielded substantial improvements across various domains. The case studies, along with the theoretical analysis, provide compelling insights into the tangible benefits and theoretical implications of AI integration.

1. Enhanced Structural Monitoring and Safety:

The case study involving structural health monitoring demonstrated that AI-enabled sensor data analysis can detect subtle changes in structural behavior, predicting potential issues. This real-time monitoring enhances safety by enabling timely maintenance and minimizing the risk of structural failures.

2. Efficient Design Innovation:

The automated design generation case study showcased how AI-driven systems can accelerate the design process and foster innovative solutions. Architects and engineers can explore a wide range of design possibilities while adhering to site-specific constraints.

### 3. Optimized Resource Allocation:

The traffic flow prediction case study revealed that AI can contribute to optimized urban planning and traffic management. Accurate traffic flow predictions empower city planners to design road networks and traffic control strategies that alleviate congestion and enhance overall transportation efficiency.

### 4. Data-Driven Decision-Making:

The theoretical analysis emphasized the transformative power of data-driven decision-making facilitated by AI. The integration of AI techniques enables project managers and engineers to base their decisions on empirical data, resulting in more precise and informed choices.

### 5. Challenges and Barriers Mitigation:

The theoretical analysis shed light on the challenges associated with AI integration, such as data availability and resistance to change. Addressing these challenges through training programs, data management strategies, and change management initiatives can pave the way for smoother AI adoption.

### 6. Interdisciplinary Collaboration Potential:

The theoretical analysis highlighted the potential for interdisciplinary collaboration between civil engineers, architects, and data scientists. This collaboration can lead to holistic solutions that combine engineering expertise with AI-driven insights.

### 7. Ethical and Social Considerations:

The results underscored the importance of ethical considerations when integrating AI in civil engineering. Responsible AI usage, transparency in decision-making algorithms, and fairness in AI models emerged as critical factors in achieving positive outcomes.

In conclusion, the results from the case studies and theoretical analysis collectively illustrate the substantial contributions of AI techniques to civil engineering programs and drawing techniques. These contributions extend beyond technical enhancements, encompassing data-driven decision-making, interdisciplinary collaboration, and ethical considerations. The findings emphasize the potential for AI to revolutionize the field, leading to safer, more efficient, and ethically conscious civil engineering practices.

## 14- Conclusion

In conclusion, the integration of civil engineering programs and drawing techniques brings numerous benefits to the field of civil engineering. These technologies have revolutionized the way civil engineers approach design, analysis, documentation, and project management. Through the application of artificial intelligence techniques, such as machine learning and deep learning, civil engineering programs have become more powerful and efficient, enabling engineers to tackle complex challenges with greater accuracy and speed.

The use of AI techniques in civil engineering programs, such as structural analysis, has significantly improved the accuracy and reliability of structural design and evaluation. Engineers can now analyse complex structural systems, predict their behaviour under various conditions, and optimize their performance. This has resulted in safer and more efficient structures, reducing the risk of failures and improving overall structural integrity.

Additionally, civil engineering programs and drawing techniques have enhanced the design and visualization process, allowing engineers to create realistic and detailed representations of projects. This improves spatial understanding, facilitates design iteration, and supports effective communication with stakeholders. The ability to simulate and analyse different scenarios using AI techniques provides valuable insights into project performance and assists engineers in making informed decisions.

Moreover, civil engineering programs have streamlined documentation and communication processes. Through standardized documentation, automated generation of drawings and reports, and improved collaboration, engineers can effectively communicate design intent, ensure regulatory compliance, and facilitate project coordination. The use of data-driven decision-making enables engineers to leverage accurate and reliable information, optimize designs, assess risks, and improve project management and control.

Overall, the integration of AI techniques in civil engineering programs and drawing techniques has revolutionized the field, enhancing accuracy, efficiency, and effectiveness. These advancements have led to improved project outcomes, cost savings, and enhanced safety in civil engineering projects. As technology continues to evolve, the potential for further advancements and innovation in the field of civil engineering is vast, paving the way for more sustainable, resilient, and intelligent infrastructure.

## 15- Recommendations

**Invest in Training and Education:** Provide comprehensive training programs to civil engineering professionals, focusing on AI concepts, algorithms, and tools. This will enhance their technical expertise and enable them to effectively implement and utilize AI techniques in civil engineering programs and drawing techniques.

**Establish Collaborative Partnerships:** Foster collaboration between academia, industry, and research institutions to facilitate knowledge exchange and the sharing of best practices. This collaboration will help accelerate the integration of AI techniques in civil engineering and promote innovation in the field.

**Develop Standardized Guidelines:** Create industry-wide standards and guidelines for the integration of AI techniques in civil engineering programs and drawing techniques. These guidelines should address data management, ethical considerations, interoperability, and performance evaluation to ensure consistency and responsible implementation.

**Encourage Data Sharing and Quality:** Promote data sharing initiatives among civil engineering stakeholders to build comprehensive and reliable datasets for AI applications. Emphasize the importance of data quality, accuracy, and integrity to ensure the effectiveness of AI techniques.

**Foster a Culture of Innovation:** Encourage a culture of innovation within the civil engineering community, promoting the exploration and implementation of AI techniques. Recognize and reward innovative projects that utilize AI to drive efficiency, accuracy, and sustainability in civil engineering programs and drawing techniques.

**Address Ethical and Legal Considerations:** Ensure compliance with ethical guidelines and legal regulations regarding data privacy, security, and liability. Establish protocols to address ethical concerns and build trust in the responsible use of AI techniques.

**Support Research and Development:** Governments and funding agencies should provide support and funding for research and development initiatives in AI integration for civil engineering. This will drive innovation, enable the development of new AI technologies, and facilitate their practical implementation.

**Demonstrate Successful Implementations:** Showcase successful case studies and pilot projects that highlight the benefits and potential of AI techniques in civil engineering. This will serve as inspiration and evidence for stakeholders to embrace and adopt AI integration.

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