ARTIFICIAL INTELLIGENCE: THE FUTURE OF SMART CONSTRUCTION

White paper Developed by Tauran Advisors for the World of Concrete, India and Informa Markets

Dr. Pradeep Mukherji | Alok Ranjan

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EXECUTIVE SUMMARY

In the rapidly evolving landscape of the construction industry, the adoption of digital technologies, including Artificial Intelligence (AI), Machine Learning, and Robotics & Automation, is heralding a new era of transformation. AI, in particular, is poised to play a pivotal role in reshaping the sector by addressing a range of challenges and delivering significant advantages.

AI's adaptability has enabled the construction industry to continuously enhance its performance. It promises to revolutionise the sector by automating manual tasks, improving decision-making, optimising processes, and mitigating risks. AI-driven automation allows for increased worker efficiency, freeing up human labor for more complex responsibilities.

This paper delves into the critical role of AI within the construction industry, emphasising its relevance and outlining the advantages it brings across construction processes.

Introduction

The construction industry is one of the oldest and largest industries in the world, contributing 13% to global GDP. The industry has remained resilient amid multiple challenges. The emergence of new-age technologies, such as artificial intelligence (AI), 3D printing, and robotics, offer the potential to help the industry address its challenges more effectively and capitalise on emerging opportunities.

The industry is poised for significant growth in the coming years, with an estimated CAGR of 11% from $8.2 trillion in 2022 to $17 trillion by 2029 driven by a number of factors, such as government initiatives, lower interest rates in a few developed economies, demand for renewal energy, public private partnerships, new-age technology and higher disposable income.

The industry, which is the second largest employer in India and contributes 9% to the GDP, is projected to reach $1.4 trillion by 2025, with significant growth driven by urbanisation.

With rapid urbanisation and investments, the Indian construction industry is expected to be among the third largest construction markets in the world by 2025. At present, only 20% of the infrastructure that will be needed by 2050 exists. This presents a significant opportunity for the construction industry to play a leading role in filling this gap in the coming decades.

To meet industry needs, AI has the potential to accelerate the growth and add value at all project stages, from design and financing to construction, operations, and business model changes. AI is estimated to boost industry productivity by increasing it from 1% to 1.5% annually.

This paper details the role of AI in the context of the construction industry and delves into the current challenges facing the industry. It underscores AI's relevance to construction and the benefits it presents for the industry. The paper also explores AI trends, opportunities and areas where AI can provide a new dimension to the industry.

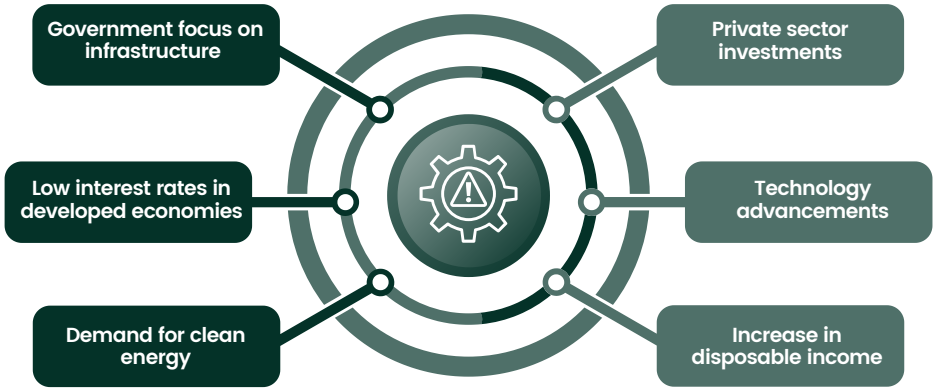


Figure 1: Factor driving the growth of the construction industry

Challenges in the Construction Industry

The construction industry, despite being a cornerstone of global infrastructure development, faces a multitude of pressing challenges.

Firstly, the industry faces labour shortage, which hampers its productivity and project timelines. This shortage is exacerbated by the ageing workforce and difficulties in attracting younger talent. Secondly, cost overruns and project delays undermine the financial stability of construction projects and affects investor confidence. Thirdly, safety risks and hazards jeopardise both workers and project outcomes. Finally, inefficiencies in design and planning continue to challenge the industry, leading to suboptimal resource allocation and design flaws. Embracing technology and innovative approaches are essential to address these challenges and drive the construction industry towards a more efficient and prosperous future.

Labour Shortage and Productivity Constraints: The construction industry faces a persistent labour shortage, hampering productivity and profitability.

The ageing workforce, fewer skilled labour availability combined with the physical demands of construction work, makes attracting younger talent increasingly difficult. This shortage slows down projects, drives up costs, and reduces quality. Additionally, it make it difficult for companies to meet contractual obligations.

To address this challenge, construction companies need to invest in workforce development and training programs, embrace technology to augment labour productivity and explore modular and prefabricated construction methods to reduce on-site labour demands.

Figure 2: Challenges in the Construction Industry

Cost Overruns and Project Delays:
Cost overruns and project delays plague the construction industry. Failure to stay within budget and meet deadlines can have significant financial repercussions. Poor project management, inaccurate cost estimates, design changes, and unforeseen site conditions have been common problems.

To mitigate this challenge, construction companies need to adopt robust project management and cost control practices. Advanced project management software and risk assessment techniques can help identify potential issues early and enable proactive problem-solving. Collaboration and clear communication among project stakeholders are also essential to keep projects on track and within budget.

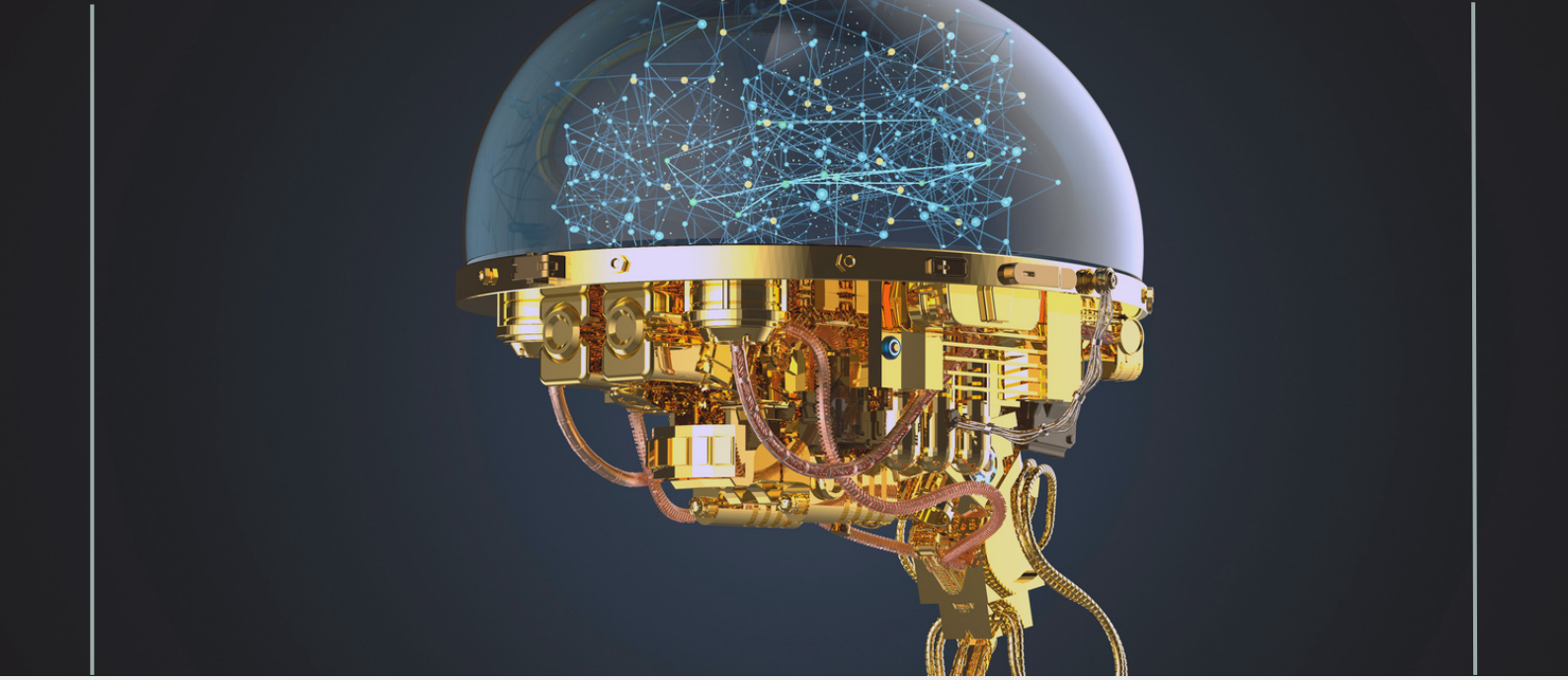
Safety Risks and Hazards:
Safety of construction worker remains a paramount concern in the industry. Despite stringent regulations, accidents still occur, leading to injuries and fatalities.

Construction companies need to prioritise safety by implementing comprehensive training, regular inspections, and wearable technology for real-time monitoring. Embracing a safety-first culture and fostering worker involvement in safety initiatives are key to achieving safer construction sites.

Inefficiencies in Design and Planning:
Design and planning inefficiencies challenge the construction industry. Manual scheduling, quality control, and risk management methods lead to suboptimal resource allocation and design flaws.

AI and technology-driven solutions can revolutionise these processes, automating scheduling, enhancing quality control through machine learning, and providing more comprehensive risk assessments. By adopting innovative approaches and leveraging data-driven decision-making, construction companies can overcome these inefficiencies and usher in a new era of efficiency and excellence.

Embracing technology and innovative approaches can mitigate challenges of the construction industry and can lead the industry towards a more efficient and prosperous future.



Demystifying Artificial Intelligence and Its Various Dimensions

Artificial intelligence (AI) has the potential to transform the industry and revolutionise various processes in the construction project lifecycle. AI facets, such as machine learning, deep learning, natural language processing, computer vision, and robotic process automation, offer diverse capabilities for the industry to harness.

AI empowers machines to mimic human intelligence, including reasoning, learning, and self-correction. AI is no longer a buzzword but a mainstream technology with various applications. This makes it imperative for the construction industry to embrace AI to stay ahead of the curve.

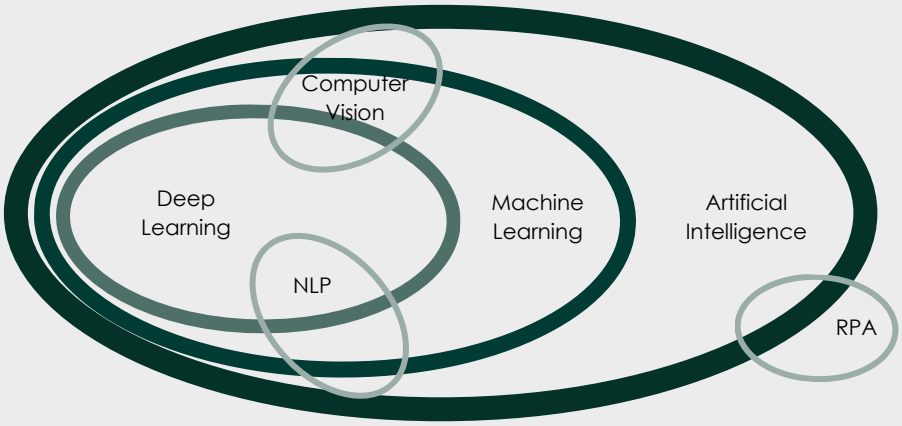
Dimensions of AI

Machine Learning
Machine Learning (ML) is a subset of AI that learns from data to improve performance without explicit human intervention. It powers applications such as voice-activated assistants, search engines, and content recommendations.

Deep Learning
Deep Learning (DL) is a machine learning technique that harnesses artificial neural networks to solve complex problems. DL networks process vast amounts of data to learn and improve over time. DL excels in handling large datasets and addressing intricate issues, making it a critical component of AI's evolution.

Natural Language Processing
Natural Language Processing (NLP) empowers computers to comprehend human language, enabling seamless interactions between humans and intelligent machines. Chatbots, language translation services, and voice assistants are examples of NLP applications.

Figure 3: Dimensions of AI



Computer Vision:
Computer vision empowers machines to understand visual information from images and videos. It is instrumental in industries such as retail, where it identifies products, manages inventory, and automates checkout processes.

Robotic Process Automation:
Robotic process automation (RPA) uses software bots to automate repetitive, rule-based tasks, freeing up human resources for more complex and creative work. RPA streamlines tasks like data entry, invoice processing, and data analysis, improving efficiency and reducing errors.

How can AI augment existing technologies in the industry?

- Learn & adapt continuously to improve performance over time
- Boost efficiency and reduce errors by automating labor-intensive tasks
- Improve accuracy and efficiency with automatic project scheduling
- Automate inspections, identifying defects more precisely
- Provide comprehensive and accurate risk assessments
- Handle dangerous and repetitive tasks at construction sites

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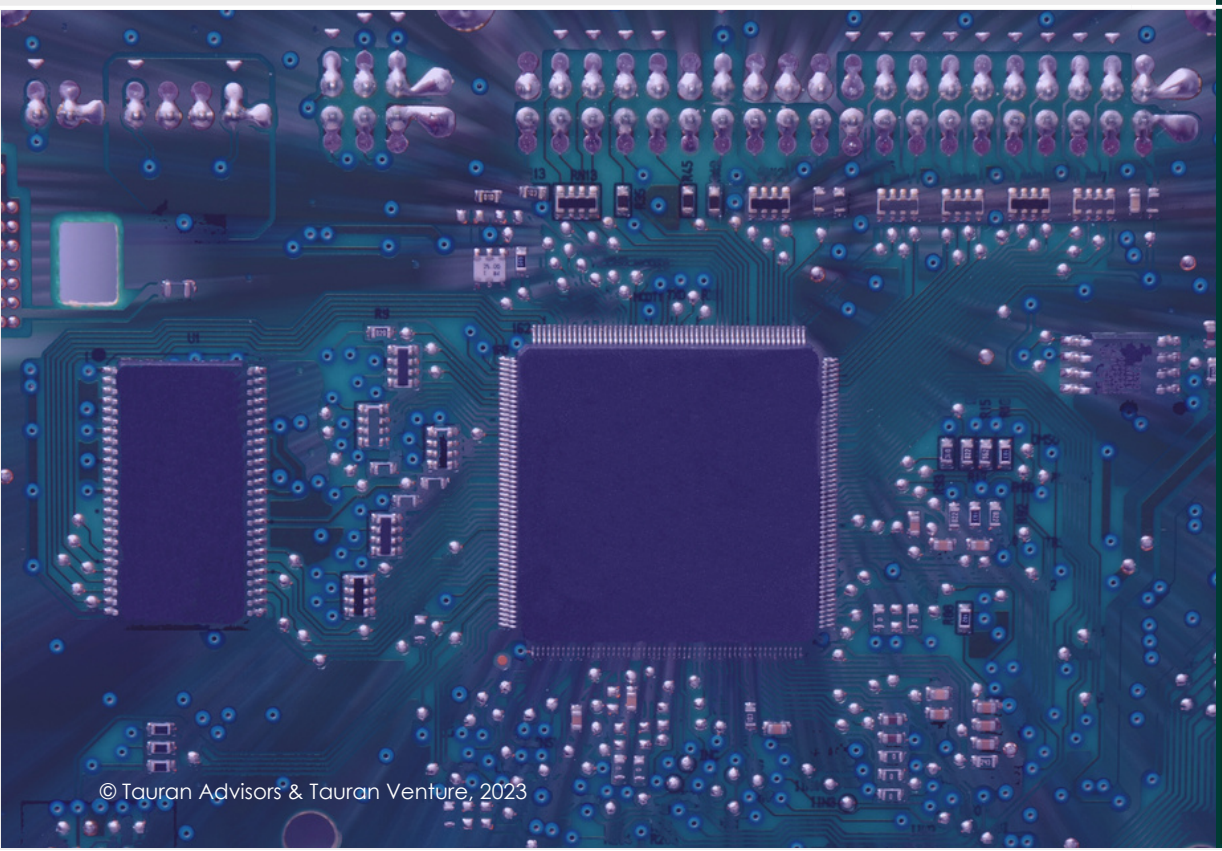


The Construction Process & AI Use Cases

The Construction industry follows a structured process, from design and planning to post-construction, which often faces numerous challenges.

AI when effectively integrated across construction process can automate systems, boost competitiveness, and complement Building Information Modelling (BIM) and management systems. AI has the potential to reshape building design, construction operation, ushering in a new era of efficiency and innovation, in the future.

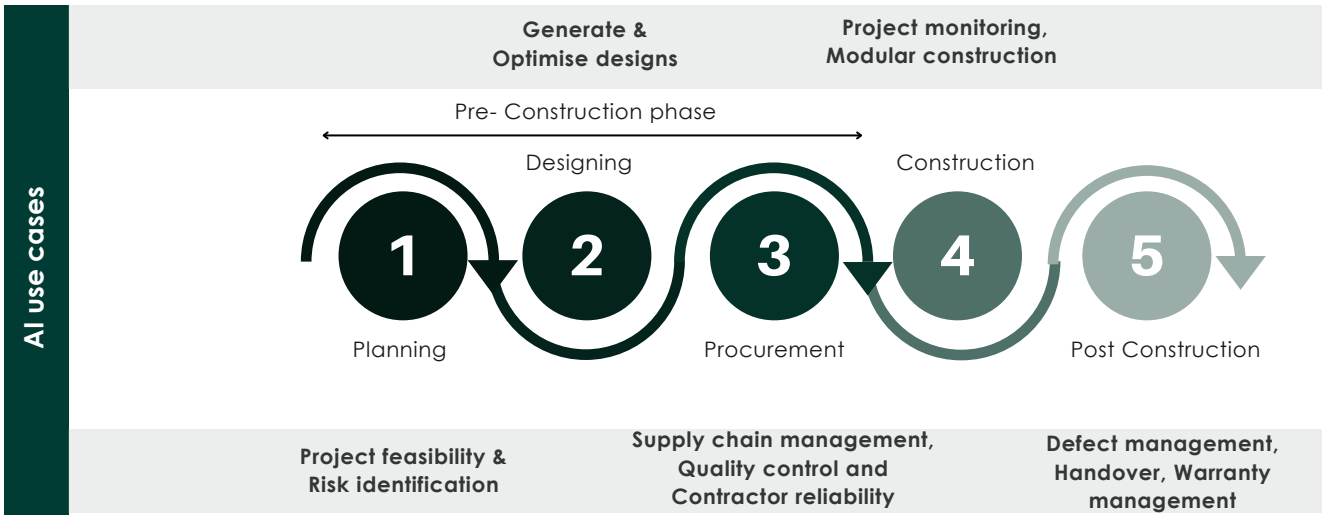
Planning & Designing
Integrating AI at the planning stage can augment feasibility studies in the conceptual design and project implementation. This can help in assessing the viability of ideas and plans, including conceptualisation, planning, and project development.

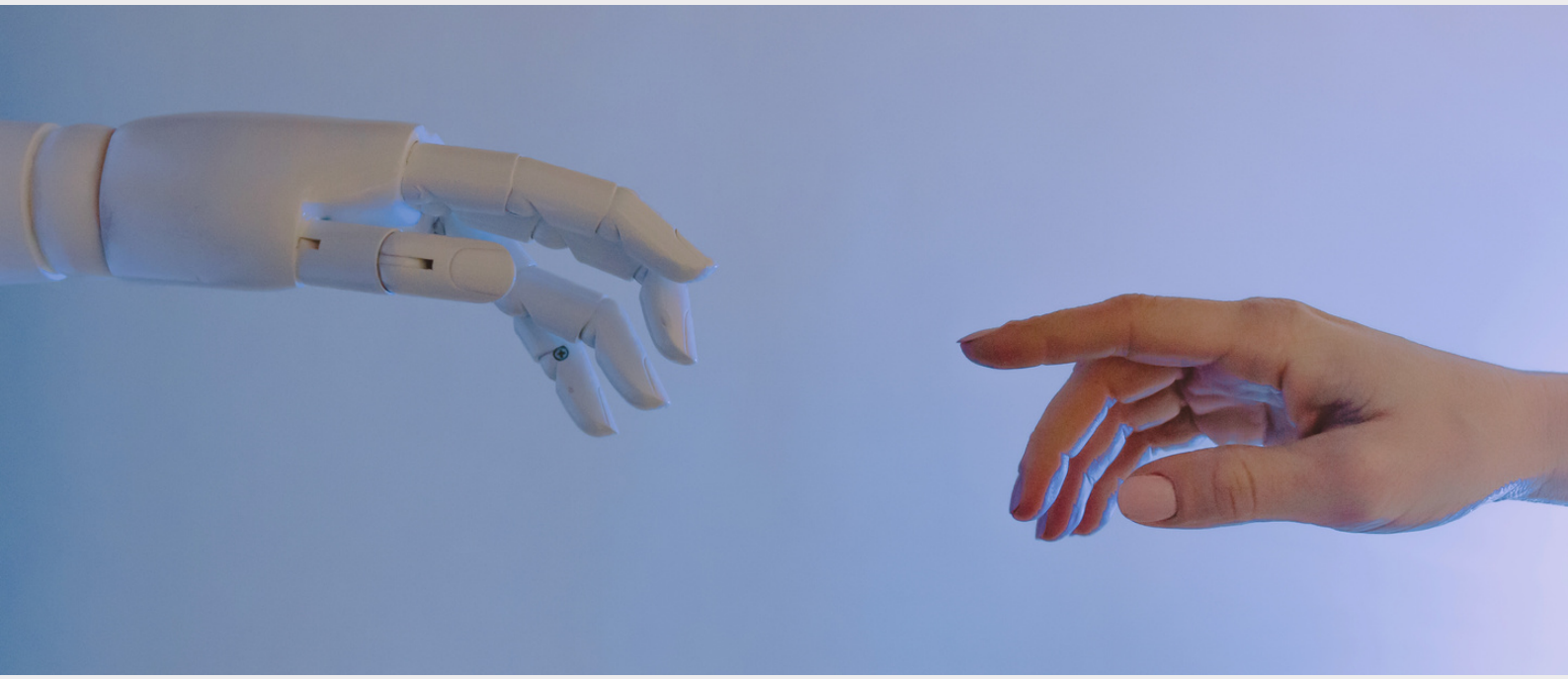
AI can scrutinise a multitude of data, including financial metrics, climate conditions, and performance data, to identify and present potential risks associated with each project. AI's strengths in thoroughness, precision, and impartiality make it an invaluable asset in this crucial stage.

AI can generate design alternatives, meet constraints, and mould ideal models through iterative learning and data expansion which can mitigate conflicts among teams.

The integration of AI and machine learning is prompting a paradigm shift in architectural design. Innovations like OpenAI's Point-E can generate 3D objects from simple text and simplify and enhance the construction industry's design and implementation processes.

Figure 4: Construction Process and AI use cases





AI Opportunities in Design Phase	Key use cases
Building Information Modelling (BIM)	• Remove design bottlenecks by automating repetitive tasks • Assist users with time-consuming and precision tasks • Augment level of detailing in designs
Internet of Things (IoT) SMARTSITE delivered by bre PROCORE CAIDIO	• Connect AI powered BIM with real-time data, enabling smarter construction processes. • IoT platforms like SmartSite, SiteSense, Indus.AI, and Caidio process data from every phase into valuable instructions
Generative Designs NETVIBES EXALEAD	• Streamline designs while considering constraints like comparing on-site planning documents • Use of Generative designs is restricted to large firms due to high license cost of the software
Computer integrated Construction (CIC)	• Augment data analysis, reduces uncertainties, and improves information sharing, giving stakeholders a clear project status overview at any stage
Clash Detection SPATIAL Accelerate 3D Innovation AUTODESK NAVISWORKS	• Simplify and expedite clash detection, for real-time clash identification.

Procurement Phase:
AI can enhance construction procurement efficiency and address supply chain disruptions, contractor reliability, and quality control challenges.

AI Opportunities in Procurement Phase	Key use cases
Supplier Selection and Qualification	• Scrutinise extensive supplier data, historical, quality and price
Risk assessment and mitigation	• Empowering procurement teams to make informed decisions.
Contract negotiation and management	• Automate contract negotiation and management
Quality Control and Compliance	• Automate adherence to quality standards
Supply Chain Management	• Minimise the impact of supply chain disruptions and prevents delays

Procure AI Bentley VIEWPOINT A TRIMBLE COMPANY PROCORE

Construction Phase:
AI has the potential to accelerate construction and safeguard against risks and hazards in the construction industry. Construction robots and automation can enhance existing plants, equipment, and task-specific robots.

AI Opportunities in Construction Phase	Key use cases
Monitoring	• Predict and estimate the compressive strength of concrete
Image processing	• Data collection on resources tracking and earthwork progress
Autonomous vehicles	• Autonomous vehicles can be used to assemble buildings • Ariel robots with digital twin can help in scheduling and planning of robots
Modular construction	• Automated offsite production of buildings offers a product-based approach.

AI Opportunities in Construction Phase	Key use cases
Auto Excavation	• Komatsu's Smart Construction integrates sensors and data analytics into machines and equipment to provide operators with real-time insights and guidance.
Task specific Robots	• Robots are being used to weld steel beams, paint walls, and inspect bridges. • Smart systems are being used to automate prefabrication of building components, such as walls and roofs. • Obayashi's Big Canopy system is being used to protect construction sites from typhoons and other severe weather events.
Wearables	• Wearable technologies can create an accessible information ecosystem on construction sites, with smartwatches delivering context-relevant information from a remote AI module to workers on-site.
Robotics	• Leading robotic companies such as SAM100, Ekso Bionics, and Piaggio Fast Forward, are using artificial intelligence (AI) to connect 3D design and manufacturing (CAD/CAM) data, schedules, and costs.
Virtual Reality (VR)	• VR technology assists in design constructibility verification, method selection based on space and accessibility, and resource allocation based on availability. • DAQRI and Nyfty.AI systems are helping engineering firms improve safety and communication with subcontractors through scheduling programs.

Post-Construction Phase:
AI has the potential to significantly improve the post-construction phase of building projects. By automating tasks, improving efficiency, and providing insights, AI can help to reduce costs, improve quality, and enhance customer experience.

AI Opportunities in Post Construction Phase	Key use cases
Defect management	• Automatically scan buildings and other structures for defects, such as cracks, misalignments, and leaks using image recognition technology, measuring the vibration, temperature and humidity inside the structure.
Ensuring efficient handovers	• Streamline the handover process by automating tasks such as document generation, checklist completion, and asset tracking.
Effective warranty management	• Track warranty claims and ensure that they are resolved quickly. The software can also be used to identify trends in warranty claims and make recommendations for improvements.

AI Adoption in the Construction Industry

From 2014 to 2019, the global construction industry increased its investment in engineering and construction technologies, including AI, to USD 26 billion, which is three times the earlier investments in AI, in the previous five years. However, despite this rise in spending on construction technologies, the construction industry has not altered its core construction processes in the last few decades.

Currently, the industry may have limited AI skills, restricted business models, and knowledge of AI. As a result, the use of AI in construction remains a time-consuming, expensive, and error-prone endeavour, which hinders the rapid adoption of AI in construction process.

A significant challenge in the construction industry arises from the abundance of unstructured data on construction sites, which hinders the effective functioning of many platforms.

To harness the full potential of data, it is crucial to establish standardised data collection and tracking procedures across the organisation and throughout the project lifecycle.

The global construction sector has recently begun to embrace research and development in digital technologies. Companies are increasingly recognising the advantages of these technologies in terms of operational efficiency and productivity.

AI can enhance data analysis accuracy and develop more effective strategies and boost efficiency, and competitiveness of construction companies. Given the temporary, multi-organisational nature of construction projects, which heavily rely on planning and scheduling models, the construction industry stands to gain more from AI technology integration. It can empower the construction industry to shift towards more evidence-based practices and diminish its reliance on tacit knowledge, ultimately mitigating unforeseen disruptions to project timelines and budgets.

Common AI Technologies in the Construction Industry

AI Technologies	Key use cases
Big data and data analytics	• Risk detection and assessment that can predict incidents and issue early warnings. • Data gathering using smartwatch for analytical purposes. • Resolving potential on-site problems and innovative solutions • Decision making and strategy building using data analytics

AI Technologies	Key use cases
Robotics and automation	• Specialised tasks such as bricklaying, painting, and loading etc. • Minimising time and effort to repetitive tasks and enhancing worker safety in hazardous building environments • Aerial drones for site surveys can enable data collection that empowers surveyors to create detailed 3D models of buildings.
Data and system integration	• Digital automation combined with virtual reality can enhance safety management by improving education, planning, and inspection processes and ensuring real-time personnel safety
Mobility and wearable	• Wearables can monitor workers' movements, spatio-temporal activities, and thoracic posture, delivering real-time on-site data to minimise the potential for accidents involving workers and heavy machinery

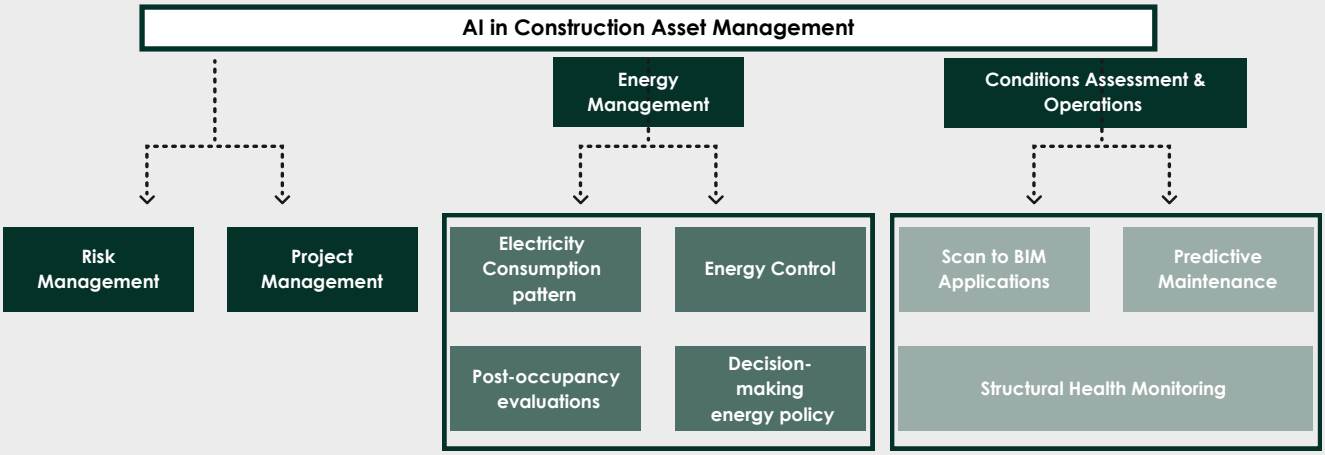
Opportunities for AI Applications in the Industry

Use Case	Purpose
Automated scheduling	• Analyse and optimise the most efficient construction path based on comparable projects for improved project preparation
Supply chain	• Enhance predictability of materials arrival, reducing manufacturing downtime, project costs
Digital Twins	• Digital twin tech offers real-time data for comparing progress with initial designs, aiding productivity

Use Case	Purpose
Inventory location	• Digital maps can display material and machine locations, saving time searching for specific items
Robotics and modularisation	• Robotic technology, including bricklaying and welding robots, self-driving heavy machinery, and wearable robotics, enhances construction safety. Additionally, modular construction can transform 2D/3D designs into prefabricated building components.
Analytics	• Analytical platforms can use sensor data to understand patterns, deploy real-time solutions, reduce costs, mitigate risks, and prevent downtime.
Automated image recognition	• Identification of unsafe behaviours and safety education, detection of unregistered individuals can be aggregated using on-site video data collection
Predictive AI algorithms	• Predict project risks, structural stability, and inform decision-making on technical solutions. Predictive AI enhances profit margins, reduces uncertainties, and detects hazards early

AI Adoption in Asset Management

The application of AI in construction asset management includes areas such as Energy management, Condition assessment and Operations, Risk management and Project management.



AI Application	Use Cases	Purpose
Energy Management at present buildings consume 30-45% of global energy, therefore the focus needs to be in achieving energy-efficient, cost-effective, and environmentally friendly operations.	Electricity Consumption pattern	AI can be used for predicting electricity and HVAC pricing and load. It can also help in better electricity scheduling, and setting disaster recovery, and demand and response criteria.
	Energy Control	Predict weather, occupancy, and energy use to optimise building operations. Can also enable controllers to learn from building data, adapt to changes, and update parameters.
	Post-occupancy evaluations	Enable facility manager to better manage Indoor air quality (IAQ), indoor environmental quality, occupant health and safety, occupant comfort, and occupant complaints in office and large buildings
	Decision-making energy policy	Augment the retrofit analysis process for better decision making and forecast post-retrofit energy savings
Condition Assessment and Operations AI powered Condition Inspection and Monitoring (CIM) can help predict the durability of colours and materials used	Structural Health Monitoring	Detecting structural fault and cracks
	Predictive Maintenance	Early failure detection of sensors, and reducing unnecessary maintenance
	Scan to BIM Applications	Augmenting maintenance of MEP (Mechanical, Electrical, Plumbing) assets in the building environment
Risk Management	Identify and mitigate project risks, especially in the early stages.	
Project Management	Augment compliance, predict construction labour productivity, predicting litigation in site condition disputes. Predict time and cost claims, bid/no bid decision making, classifying construction waste material and Forecast material prices.	

Future Trends in Construction technology Powered by AI

AI will continue to make the entire construction process smarter and more efficient, and cost-effective.

Digital Twins
Digital Twins are virtual representations of physical assets, systems, and processes in a controlled environment. They can be used to simulate the behaviour of the assets in real time, and to predict how they will respond to different conditions.

Digital twins enhance the capabilities of BIM by seamlessly integrating data and processes, allowing for real-time, two-way information management. Although digital twins can operate on their own, their maximum potential is realised when seamlessly integrated with BIM's workflows and information exchange, making it more efficient to initiate this synergy through BIM.

Use of Digital Twins in the Construction Process
Design and planning: Digital twins can be used to create virtual prototypes of buildings and other structures. This can help to identify and resolve potential problems before construction begins.

Construction: Digital twins can be used to track the progress of construction projects in real time. This can help to identify potential delays and problems early on, and to ensure that projects are completed on time and on budget.

Operation and maintenance: Digital twins can be used to monitor the performance of buildings and other infrastructure assets in real time. This can help to identify potential problems early on, and to schedule maintenance and repairs accordingly.

Sustainability: Digital twin technology can enhance project sustainability. Through a project's digital twin, designers and planners can simulate multiple sustainability scenarios and experiment with different strategies for sustainability.

Digital twins have the potential to revolutionise the construction industry by making it more efficient, safer, and more sustainable. The Digital Twin technology is expected to grow from USD 9.9 Billion in 2021 to USD 60 Billion by 2027.

Digital Twin in Action

AI Companies	Digital Twin Usage
Skanska	Skanska has collaborated with the UK's Met Office to create a digital twin of their weather balloon facility with the help of BIM. The digital twin was developed in two stages: first, they created a precise 3D model replica by incorporating laser scans of the physical facility, and later, they integrated operational and maintenance data.
Bentley systems with Microsoft	In collaboration with Bentley and Microsoft, the city of Dublin, Ireland, initiated the development of an extensive digital twin as a part of its urban planning endeavours.
AECOM	To construct the world's longest sea bridge, the Hong Kong-Zhuhai-Macau Bridge, AECOM harnessed a digital twin for design optimization, construction process simulation, and early issue detection.
Cityzenith	Amaravati, Andhra Pradesh's capital city, is using a digital twin that combines over 1,000 data sets for permit management, construction monitoring, and evaluating design plans in the city's challenging climate.
Dassault Systemes	Singapore has developed a virtual digital twin of the entire city to simulate the testing of innovative solutions.

AI assisted 3D Printing

3D printing is revolutionising the construction industry, enabling better planning, issue detection, and cost savings. 3D printing technology is now applied to large-scale construction projects. Construction companies can create project models, detect issues early, and save time and money with custom parts.

AI can help with customisation of 3D designs. Style2Fab, an AI-powered tool developed by MIT researchers that can allow users to personalise 3D models with natural language prompts. It simplifies the design process by automatically separating aesthetic and functional elements. Style2Fab is a promising new tool that has the potential to revolutionise the way that buildings and other structures are designed and constructed.

In the construction industry, the tool has broad use cases such as customising 3D-printed bridges, building components, and construction prototypes. It enables design personalisation for railings, supports, and more, offers unique building components not available commercially, and aids in testing new construction project designs and visualisations.

Virtual Reality and Wearables
AI-assisted VR and wearables are transforming the construction industry with benefits like enhanced safety through VR training and wearables monitoring vital signs, increased efficiency by visualising and planning projects, and reduced costs. VR solutions such as STRIVR for machinery training, Trimble for project visualisation, and RealWear's wearable headset for real-time feedback can accelerate construction processes.

Wearable devices in construction offer real-time environmental monitoring, enhancing safety and productivity. They also contribute to emotional well-being, fostering trust, morale, and teamwork between employees and managers. This technology not only improves job conditions but also job satisfaction and overall employee satisfaction in the construction industry.

Wrapping up

Bridging the data gap between humans and technology is crucial, especially in labour-intensive construction sites. A systemic approach, incorporating current technology and new AI applications, will drive industry transformation. Advancements in robotics, mixed reality, and AI will improve efficiency, safety, and project management. AI is a mainstream technology of the Fourth Industrial Revolution or Industry 4.0 and will continue to find more use cases in the construction industry. While large companies may initially have an advantage due to data needs, smaller ones will also adopt AI for cost and time benefits. AI is a driving force for efficiency, safety, and cost reduction in the construction industry, with its full potential unfolding in the coming years.

About the Authors

Dr. Pradeep K. Mukherji
Managing Partner
pk.mukherji@tauranadvisors.com

Alok Ranjan
Partner
alokr@tauranadvisors.com

If you have questions regarding this white paper or would like to discuss AI in the Construction Industry, reach out to us at connect@tauranadvisors.com

The authors duly acknowledge the information obtained from various sources and discussions with industry leaders.

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Registered HQ:
163 Rajapark Building, 18th Floor Sukhumvit Soi 21 (Asoke), Wattana Bangkok 10110,Thailand

Mumbai:
5A/1401,
New Mhada Lokhandwala Andheri (West) Mumbai– 400053 India

USA:
2920 N. Paulina Street Chicago, IL- 60657, USA