AI in Construction

A construction perspective on its use and challenges

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Executive Summary

The construction sector faces several significant challenges, including persistent labour shortages, cost overruns, safety concerns, material price volatility, and strict environmental regulations. These issues can delay project timelines, increase budgets, and compromise safety and sustainability.

However, the introduction of AI (artificial intelligence) offers promising solutions to these challenges. By streamlining processes and automating routine tasks, AI can potentially enhance productivity, ensuring projects are completed on time and within budget. In terms of safety, AI-powered systems can predict potential worksite hazards, and suggest preventive measures, significantly improving safety standards.

While the potential of AI is clear, the AEC sector generally is still at the starting line. This report aims to provide a better understanding of the current level of adoption, where companies foresee opportunities and threats, and where they identify their weaknesses and strengths. A survey among ENCORD members reveals varying levels of AI adoption, with most organizations trialling AI applications in test settings. The design and construction phases are identified as the areas where AI provides the most significant benefits. There is a strong consensus on the importance of AI implementation over the next five years.

A SWOT analysis conducted within the report highlights the strengths, opportunities, weaknesses, and threats associated with AI implementation in construction. Strengths include improved construction processes, more effective maintenance, assistance in decision-making, and improved structural and personal safety. Opportunities involve new business offerings, increased sector attractiveness and sustainability, and process optimization. Weaknesses are primarily related to data quality issues, lack of skills, an ill-purposed business model, and high implementation costs. Threats include recruitment problems, privacy and security concerns, fear of external disruption, and the potential loss of jobs due to AI.

The report includes several case studies from ENCORD members, demonstrating practical AI applications in construction. These case studies cover a range of innovations, from generative design and AI-enhanced climate calculations to AI-based material identification and computer vision for safety enhancements.

Finally, the report presents four possible future scenarios for AI adoption in construction: AI-Powered Innovation, Tech-Driven Resilience, Conservative Struggles, and Traditional Triumph. Each scenario highlights different aspects of AI adoption and market conditions, providing a view of potential future developments.

Foreword

ENCORD, European Network of Construction Companies for Research & Development, is a forum that invites its members to openly exchange ideas on topics and issues related to research, development, and innovation in the built environment. While most members are contractors, as the name ENCORD suggests, we recognize that the prevailing challenges in our industry—such as climate change mitigation and adaptation, CO2-neutrality, productivity, health and safety, and the efficient use of non-renewable primary materials—cannot be addressed if we follow traditional project-oriented business practices.

In this spirit of innovation and collaboration, we are excited to present our latest report on "AI in Construction." This report explores how artificial intelligence is transforming the construction industry, offering new solutions for efficiency, safety, and sustainability. By leveraging AI, we can optimize project management, enhance design and planning processes, and improve the overall quality and performance of our built environment. However, care regarding data quality, data biases, privacy, and security becomes even more important than before.

We are fortunate to have major players from across the supply chain within our association, contributing their expertise and insights to this report. Together, we are committed to driving forward the adoption of AI technologies in construction, ensuring that our industry remains at the forefront of innovation and sustainability. This report is the result of a concerted effort by the Council and the temporary working group "AI in Construction" during the time period November 2023 to December 2024.

This report does not aim to give a general overview of work that is currently available on AI in the built environment, particularly from academic institutions. However, our report aims to give ENCORD's perspective on the subject; an aim derived from an identified gap in the literature where most of the brown literature originates from management firms, consultancy, and architectural firms. The development and implementation of AI has an exponential rate, and this report can only give a snapshot. Nevertheless, we hope to be able to provide some insights and assist in the adoption of this technology.

Christina Claeson-Jonsson, WG leader

2025-01-20

1 Introduction

"Artificial intelligence is not a substitute for human intelligence; it is a tool to amplify human creativity and ingenuity." – Prof. Fei-Fei Li

The construction industry is on the cusp of a transformative era, with artificial intelligence (AI) playing a central role in reshaping its future. Despite being historically cautious about embracing technological change, the sector is now witnessing a paradigm shift, fuelled by rapid advancements in AI. This sets the scene for the multifaceted impact of AI on construction, indicating the broader implications for the industry.

1.1 The Evolution of AI in Construction

AI's integration into construction signifies a departure from traditional methodologies, bringing in a new age of efficiency and innovation. AI technologies, from predictive analytics and machine learning to robotics and computer vision, and of course, Large Language Models (LLM), are revolutionizing how projects are designed, planned, and executed. The exploration of AI in construction has moved beyond mere digitization and automation, offering sophisticated solutions that address complex industry challenges such as safety risks, labour shortages, and productivity issues. Successful pilots are also being scaled showing signs of efficiency, sustainability, and safety gains.

1.2 Surge in Investment and Technological Startups

The last few years have marked an unprecedented surge in investment in construction technology, with a significant focus on AI. The period from 2020 to 2022 alone saw an investment influx of around $50 billion worldwide into AEC technology[1], indicating a growing recognition of digital technologies' potential to redefine the industry. This financial boost has catalysed the growth of numerous startups, driving innovation and fostering a competitive technology landscape within the construction sector. Despite the maturation of the AEC tech industry, it still lags behind more established software markets such as logistics, manufacturing, and agriculture in terms of scale and sophistication.

1.3 Diverse Applications and Their Impact

AI's applications in construction are diverse and transformative. From leveraging drones for aerial surveys to employing AI for enhanced project scheduling and risk management, these technologies are setting new standards for efficiency and safety. Advanced AI applications, such as generative design software, are enabling architects and engineers to explore hundreds of design options quickly, optimizing for both aesthetics and functionality. Similarly, AI-driven project management tools are streamlining operations, facilitating better resource allocation, and reducing project delivery times. In Chapter 4, some current examples from ENCORD's members are presented.

1.4 Navigating the Path to Adoption: Challenges and Strategies

The journey toward widespread AI adoption in construction is fraught with challenges. The industry's fragmented nature, coupled with the high initial costs and a general hesitancy towards digital adoption, poses significant barriers. However, these obstacles can be overcome through strategic investment, a focus on developing scalable solutions, and fostering a culture of innovation within organizations. But the question arises: how do we get there, and what are the opportunities and threats? In the following chapter, we will explore these aspects using a SWOT analysis as a basis.

[1] https://www.mckinsey.com/industries/private-capital/our-insights/from-start-up-to-scale-up-accelerating-growth-in-construction-technology

2 Assessing the AI readiness of the European construction sector

2.1 SWOT Analysis for AI Implementation in Construction

A SWOT (Strengths, Opportunities, Weaknesses, Threats) analysis is a strategic planning tool used to evaluate a company's competitive positioning in the marketplace. In our context, it was used to assess the industry's positioning and as a basis for preparing the sector to successfully implement AI in construction.

During a workshop within the WG AI in Construction, attributes for the four key characteristics (Strengths, Opportunities, Weaknesses, Threats) were brainstormed. For each characteristic, the corresponding attributes were sorted into themes. These themes are presented in Figure 1. In the following sections, we will delve deeper into each characteristic.

Figure 1 The four quadrants with associated characteristics and theme groups

2.2 Strength and opportunities

Large European contractors are known for their technical expertise, innovation, sustainability efforts, and global reach. They have a strong financial position, a skilled workforce, and a commitment to quality and customer satisfaction. They also have robust risk management strategies and a deep understanding of regulatory compliance. Health and safety is a paramount concern for these contractors. They comply with stringent regulations, invest in training, use technology to improve safety, focus on accident prevention, and promote a strong safety culture. These strengths and competencies have established them as leaders in the global construction industry.

The strength characteristic includes internal positives that provide a competitive advantage, such as product quality or effective processes. From the results of the workshop, five main themes were identified: Climate-friendly solutions, more effective maintenance, improved structural and personal safety, assistance in decision-making, and improved construction processes.

The opportunity characteristic includes external factors promising potential success, such as industry growth or positive customer feedback. Here we found the following themes: New business offerings, increased attractiveness to the sector (or company), increased sustainability, and optimization of the (value chain) processes including standardization.

2.3 Weaknesses and threats

Large European contractors face several challenges and weaknesses. They are grappling with a shortage of skilled labour and rising material costs, both of which can lead to project delays and increased costs. The impact of climate change, with more frequent extreme weather events, poses a significant risk to infrastructure projects. These companies are also highly dependent on economic cycles, and downturns can significantly impact their revenues and profitability. Regulatory changes can lead to increased costs or project delays, and the inherent risks of construction projects, such as delays, cost overruns, and quality issues, are constant challenges. Finally, the high level of competition in the construction industry, from both local and international companies, is a significant factor. These challenges need to be effectively managed for continued success in the global construction industry.

The weakness characteristic concerns adverse internal attributes that detract from strengths, like knowledge gaps or low-quality products. For this characteristic, we noted lack of quality data, lack of skills and counteractive mindset, ill-purposed business model, and high cost for implementation of AI to be the main problem areas.

The threat characteristics is influenced by external factors beyond your control that could negatively impact success, like future competitors or market trends. In this group, we find recruitment problems, trust issues, privacy and security issues, fear of external disruption, and the loss of jobs with the introduction of AI.

2.4 Additional reflections

When the results of the SWOT analysis were discussed within the group, we recognized some additional themes that should be added. One concerns ethics and biases where especially the latter can influence the results of an AI analysis as the European building sector is heavily overrepresented by male workers[2]. Other concerns lack or unclarity of AI data policies and standards and their interpretation and implementation. Finally, the risk of not including humans with domain knowledge in the loop was discussed.

[2] https://www.unesco.org/en/articles/generative-ai-unesco-study-reveals-alarming-evidence-regressive-gender-stereotypes

3 What is the current adoption of AI?

While many reports highlight the importance of implementing AI from a business perspective, the actual level of adoption and implementation of AI in the construction industry was unclear to us.

3.1 Survey method

To get a better understanding of the current status of adoption and implementation, the ENCORD members were asked to complete a web survey, created by the working group. From this selection, we received 21 anonymous answers. The majority of the answers were received from general contractors (14), followed by technology providers (5) and material suppliers (2). It is worth pointing out that some organizations may have provided several answers while others did not complete the survey. Nevertheless, it indicates the current status among the ENCORD members. A further limitation to the study is the fact that our network consists of mainly large actors whereas the status of SMEs is not included.

3.2 Survey results

In Figures 2-7, some of the results from the survey are presented. One of the indicators of AI maturity is if the organisation has established a team dedicated to AI applications. In this question of the survey, most respondents answered that they had while a few hadn't or did not know, see Figure 2. In Figure 3, the level of implementation in the organisations is explored. The results indicate that most of the respondents report AI applications being on trial in test settings while some have been implemented in some business units. However, no organization has fully implemented AI in all business areas. While AI can be used in all phases, with the question: "Where have you seen the most benefits?", we wanted to explore where we currently can see the main benefits. In Figure 4, we can see that the main benefits can be found in the design and construction phase. However, it is worth pointing out that most of the respondents represented a contractor and very few a material supplier which may explain the lower number in the manufacturing phase. Figures 5 and 6 present the results to the question: How important is the implementation of AI for your organization in the next 5 years? Here we have extracted the answers from the respondents representing a contractor and present these in Figure 5. As can be seen, a majority believes this is an important question. When presenting the results of the whole group, see Figure 6, most feel that the implementation of AI will be important or very important in the next five years while only a few take a neutral position. Clearly, AI is something that is one prioritized question for most organizations. Finally, in Figure 7, a word cloud presents the outcome to the question: In what areas do you think AI solutions will be the most useful? We note that many of these areas coincide with the areas that were mentioned in the SWOT analysis as opportunities.

Figure 2 The results of the survey question: Does your organisation have a team dedicated to AI applications?

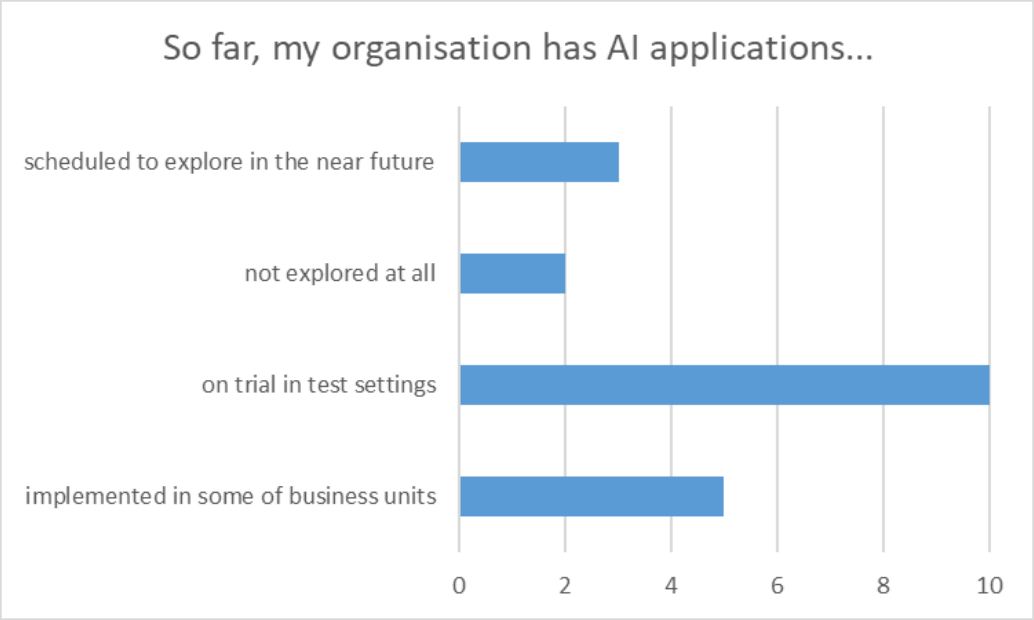

Figure 3 This survey question examines the level of implementation in the member organisations

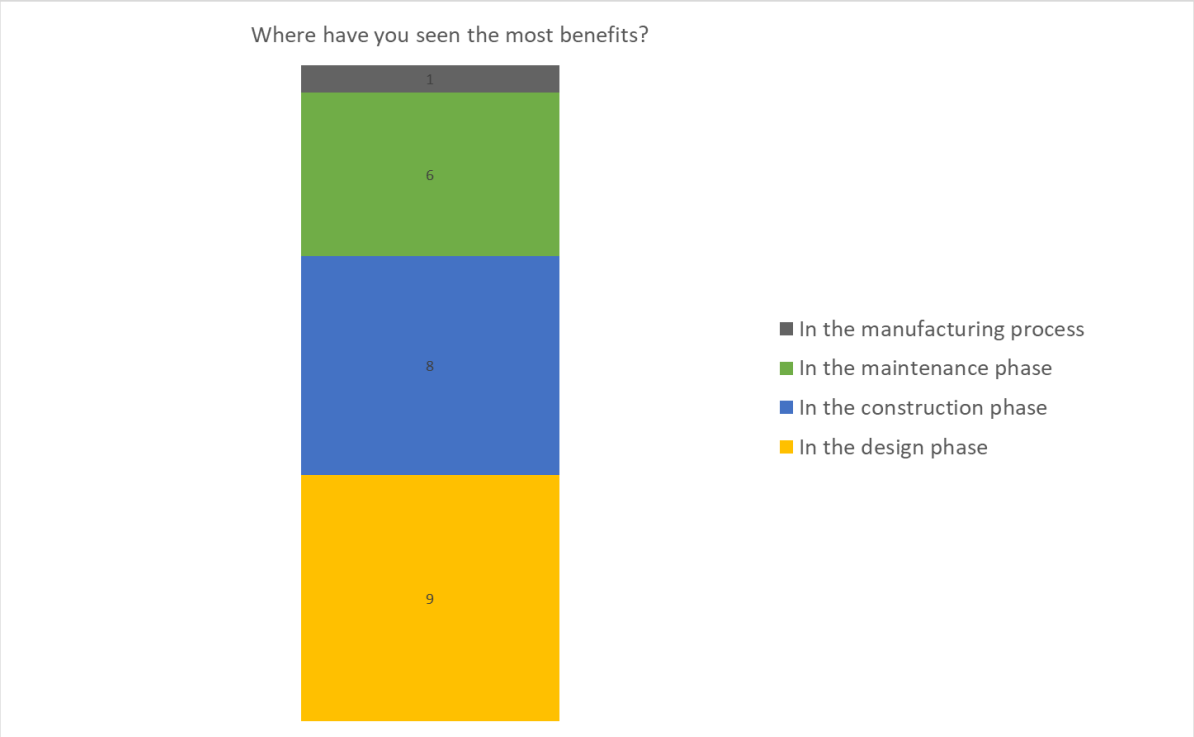

Figure 4 Results to the question: "Where have you seen the most benefits?".

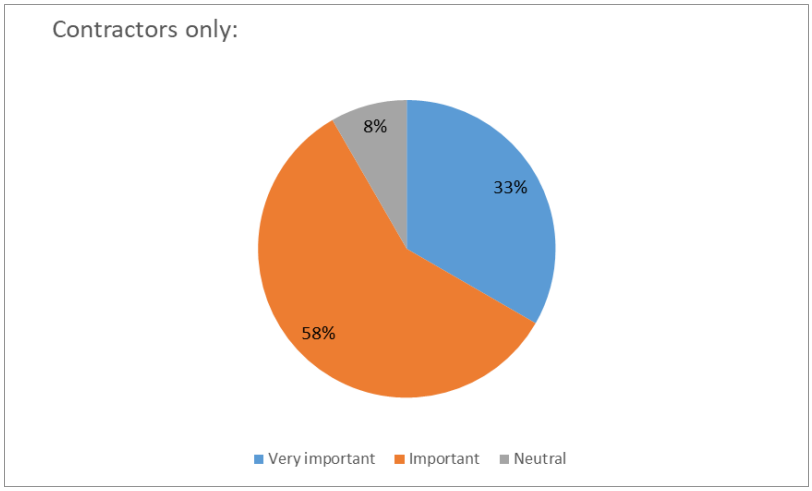

Figure 5 Importance of implementation of AI on a five year perspective as of the general contractors

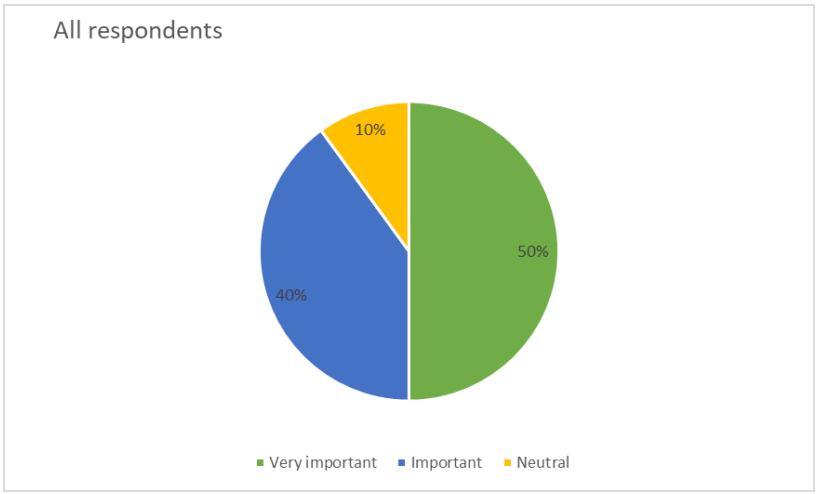

Figure 6 Importance of implementation of AI on a five year perspective visualized based on all respondents' answers

Figure 7 A word cloud (77 words) summarizing where the respondents foresee the most benefits of using AI in the future

4 Applications of AI in construction, examples from ENCORD members

Next, we asked ENCORD members to provide us with examples from their businesses. These examples have also been selected to represent different fields and aspects rather than highlighting the same topics.

4.1 The Smart (de)design: Generative Design in Project Development (Strabag)

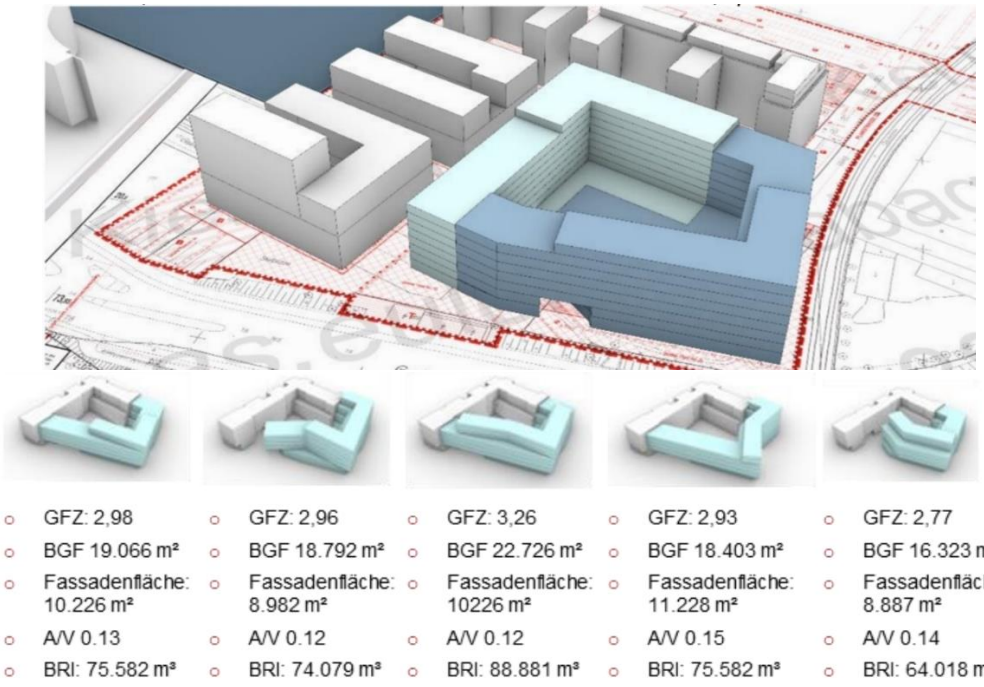

Figure 8 Selection of the five "best" of over 1,400 variants in this project (Source: Strabag).

Case background and relevance

Early recognition of property potential is vital for competitive advantage in project development. Generative design helps explore and assess the optimal use of a property before purchase.

Problem: How to know the full potential of your property

Assessing the optimal use of a property before purchase is challenging and requires detailed analysis.

Solution: Analyse potential quickly, automatically, and based on data

Strabag uses generative design to analyze and evaluate property development options, providing valuable insights early in the process. This tool generates and compares numerous building variants to determine the best economic and sustainable use of a property.

Outlook: Valuable data-driven insights

Generative design will enhance project development by providing data-driven insights and optimizing sustainability and economic aspects. This tool generates and compares numerous building variants to determine the best economic and sustainable use of a property.

4.2 AI to Reduce Carbon in the Built Environment (Autodesk)

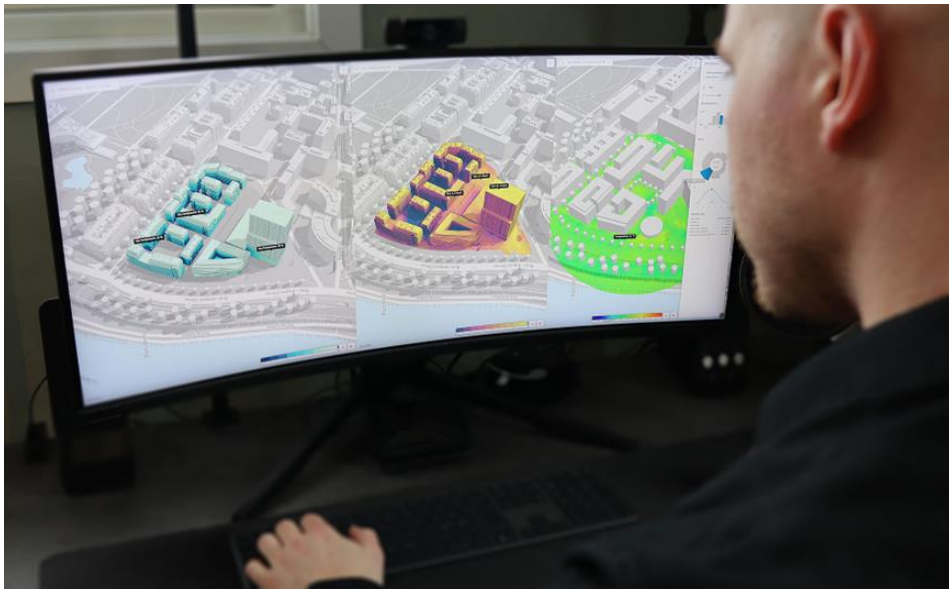

Figure 9 AI-Enhanced energy and microclimate calculations (Source: Autodesk)

Case background and relevance

Calculating carbon emissions, as well as anticipating solar radiation, heat islands, wind, and noise impact late in the design process limits the ability to make impactful changes. Early integration of microclimate, weather, and carbon calculations is necessary for sustainable building design.

Problem: Energy and weather-related calculations timing

Determining solar radiation, heat islands, wind and noise impact, embodied and operational carbon too late in the design process prevents meaningful adjustments.

Solution: AI-enhanced energy and microclimate calculations

Autodesk's AI-based tool, Forma, allows for early-stage solar radiation, heat islands, wind, and noise impact, as well as carbon analysis, enabling more efficient and accurate calculations. This tool reduces reliance on manual applications and extensive Excel spreadsheets.

Outlook: Real-time design feedback

AI-enhanced solar radiation, heat islands, wind and noise impact as well as carbon analysis supports sustainable building design by providing real-time feedback and enabling adjustments throughout the design process. This approach contributes to reducing the built environment's carbon impact.

4.3 Optimizing Construction Logistics through Intelligent Identification and Counting of Materials (Doka)

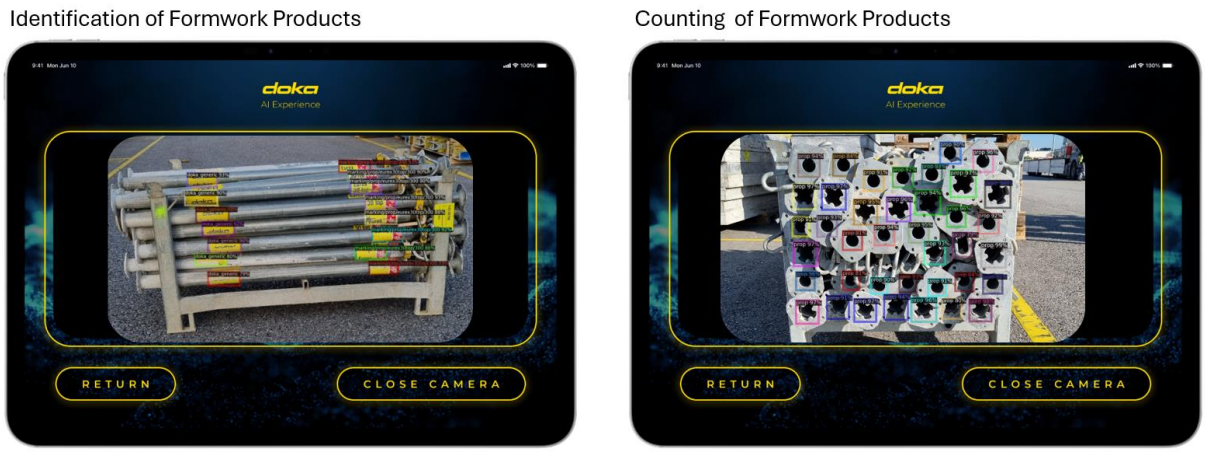

Figure 10 Identification and Counting of Formwork Products (Source: Doka)

Case background and relevance

Efficient logistics are crucial for operational excellence and cost management on construction sites. Doka delivers large quantities of materials worldwide and aims to streamline the process of ordering, receiving, using, and returning formwork materials. A key component is the identification and counting of these materials on-site.

Problem: How to quickly and precisely identify and count Doka's formwork products on construction sites

Extracting real-time information on the exact type and amount of formwork material stored in a specific location is a challenge, particularly concerning the many similar product shapes and sizes. Traditional methods like barcodes and RFID face constraints in large inventories.

Solution: AI-based computer vision models extract information from on-site pictures

Doka is developing AI-based computer vision models to extract information from on-site pictures, improving the accuracy and speed of material identification and counting. A Proof of Concept (PoC) has shown promising results, and further tests will include more product types and images from construction sites.

Outlook: Computer vision is an essential technological component of construction digitalization

AI-based computer vision will play a significant role in construction digitalization, enhancing operational efficiency and enabling better material management. This technology can also be applied to other use cases, such as assessing material damages and tracking construction progress.

4.4 Reality Capture for Progress Monitoring and Quality Control (Hexagon)

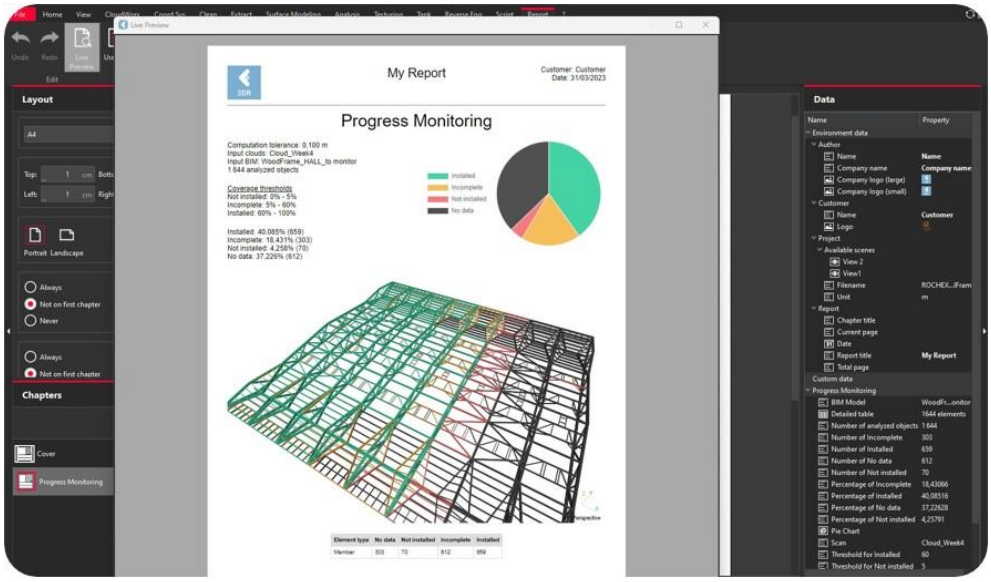

Figure 11 Progress monitoring of construction sites by an AI-enabled comparison of as-built point cloud data and BIM design (Source: Hexagon)

Case background and relevance

The construction industry faces challenges like demographic changes, environmental concerns, and inflation. Hexagon's autonomous solutions aim to enhance productivity, sustainability, and profitability by leveraging AI-driven autonomy for better decision-making, safety, and efficiency.

Problem: How to monitor complex construction sites and remain competitive

Monitoring complex construction sites to ensure quality, schedule, cost, and sustainability is challenging and often perceived as expensive and time-consuming. Traditional surveying methods are often seen as expensive and time-consuming, leading to inaccuracies and reduced competitiveness.

Solution: Combine reality capture mature solutions with AI technology to get accurate data analysis and support quick decisions

Hexagon combines Reality Capture solutions with AI technology to provide accurate data analysis and support quick decisions. Their 3D laser scanners and software like Leica Cyclone 3DR offer automated and precise progress monitoring and quality control. The BLKARC sensor, for example, can scan construction sites with minimal human intervention, while AI enables efficient processing of data and delivery of accurate results to decision makers.

Outlook: AI-boosted digital reality drives the construction industry to efficiency

AI-boosted digital reality is essential for the construction industry to achieve efficiency and sustainability. Hexagon's AI ecosystem is driving this trend, helping construction firms adopt full digital reality methods.

4.5 Machine Learning for TBM Performance Optimization (ACCIONA)

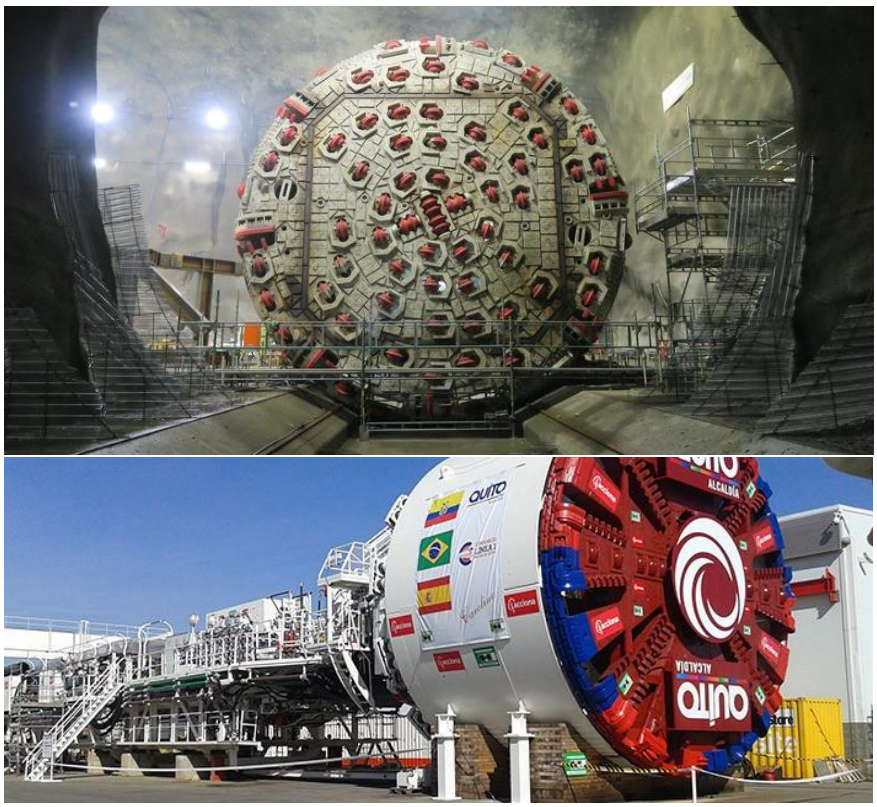

Figure 12 Tunnel Boring Machines (TBMs) are crucial for tunnel construction but represent a high capital investment. Optimizing their performance is essential for cost efficiency. (Source: Acciona)

Case background and relevance

Tunnel Boring Machines (TBMs) are crucial for tunnel construction but represent a high capital investment. Optimizing their performance is essential for cost efficiency. Optimizing their performance is essential for cost efficiency and project success.

Problem: Improve TBM performance and reduce geological uncertainties

Improving TBM performance and reducing geological uncertainties that lead to cost overruns and delays is a major challenge.

Solution: Machine learning algorithms development

ACCIONA uses machine learning algorithms to analyze data from TBMs, predicting forward speed, detecting anomalies, and optimizing tunneling phases. Their proprietary TBM Data Management System collects and processes information from numerous sensors to control the machine's progress and deliver key performance indicators.

Outlook: AI opens a new field for data-based decision-making

AI and machine learning are transforming tunnel construction by enabling data-driven decision-making and improving safety and efficiency. This project highlights the importance of using data to enhance performance and sustainability.

4.6 Advanced Robotics for Construction (Ballast Nedam)

Case background and relevance

Ballast Nedam explores advanced robotics to address the shortage of skilled masons and improve construction efficiency. The Ropax bricklaying robot is a key example of this innovation.

Problem: Shortage of skilled masons

The shortage of skilled masons affects the quality and speed of masonry work, leading to delays and increased costs.

Solution: Using robotics

The Ropax bricklaying robot can lay bricks faster, more accurately, and more safely than human workers. It handles different types of bricks and mortar, adapting to various wall designs and dimensions. The robot increases productivity, improves quality, and enhances safety for workers.

Outlook: Significant benefits to be expected

Robotics will play a significant role in the construction industry, enhancing efficiency, quality, safety, and sustainability. Ballast Nedam plans to continue exploring and experimenting with different types of robotics and integrating them with other digital technologies.

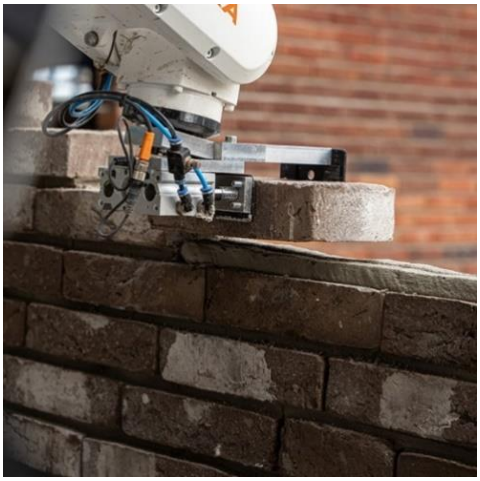

Figure 13 The Ropax robot for bricklaying (Source: Ballast Nedam)

4.7 Supporting Health & Safety work on the Construction Sites using AI (NCC)

Case background and relevance

The construction industry has a high incidence of accidents, particularly in crane lifting operations. Enhancing safety in these areas is critical.

Problem: How to enhance safety in crane lifting using computer vision

Identifying unauthorized workers under suspended crane loads to prevent accidents is a significant challenge.

Solution: Computer vision to analyse real-time video feeds

NCC used computer vision technology to analyze real-time video feeds, detecting workers in restricted zones and alerting crane operators to take action. This system can enhance safety by preventing potential accidents and ensuring compliance with safety protocols.

Outlook: Computer vision will be a valuable tool to increase safety on the construction sites

Computer vision can significantly improve safety on construction sites by providing real-time insights and enabling proactive risk management. This technology helps site management maintain a comprehensive overview of safety and progress.

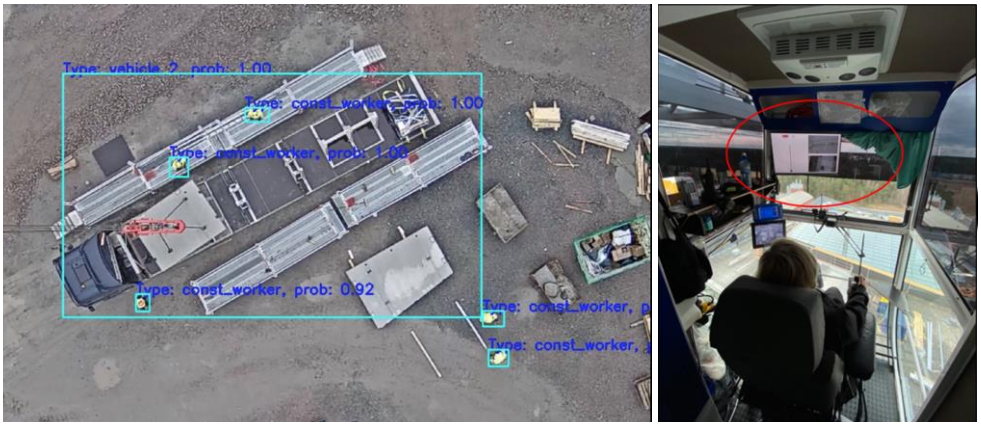

Figure 14 Identifying possible hazard situations and giving the crane driver more insights (Source: NCC)

4.8 AI in Road Management and Maintenance (BAM)

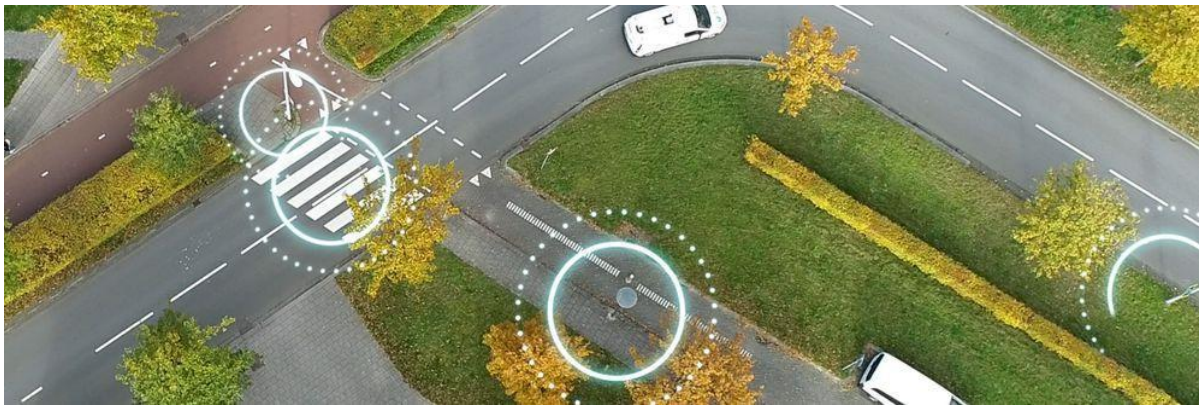

Figure 15 Collecting and understanding data with the BAM ADAPT Wegen (Source: BAM)

Case background and relevance

BAM Infra Nederland uses AI to gain insights into road conditions and maintenance needs. Efficient road management is crucial for safety and smooth traffic flow.

Problem: How to increase safety on roads

Efficiently assessing the condition of roads and road furniture is challenging and time-consuming.

Solution: Data, technology, and domain knowledge

BAM's ADAPT Wegen tool combines data, technology, and domain knowledge to provide accurate road condition assessments using AI. A scan car equipped with a Lidar scanner and camera collects data, which is then analyzed to create a complete overview of road assets.

Outlook: Saving time and more insight

AI-driven road management tools will save time and provide detailed insights, improving maintenance planning and execution. This technology enhances the efficiency and accuracy of road condition assessments.

4.9 Machine Learning in Facility Management and Maintenance (TEIXEIRA DUARTE)

Case background and relevance

Facility Management (FM) and Maintenance companies need to innovate to increase efficiency and competitiveness. AI algorithms applied to traditional Enterprise Asset Management (EAM) Software are crucial for managing and analyzing collected data.

Problem: Data quality

Ensuring data quality for predictive maintenance models is a significant challenge.

Solution: Machine Learning - Natural Language Processing (NLP)

TEIXEIRA DUARTE uses NLP to dynamically classify and catalog historical work orders, enabling condition-based predictive maintenance. This approach improves data quality and supports decision-making.

Outlook: Condition-based predictive maintenance – a prescriptive approach

AI will support younger workers and improve asset management, making FM and maintenance more efficient and effective. The company aims to develop a prescriptive maintenance methodology using AI resources.

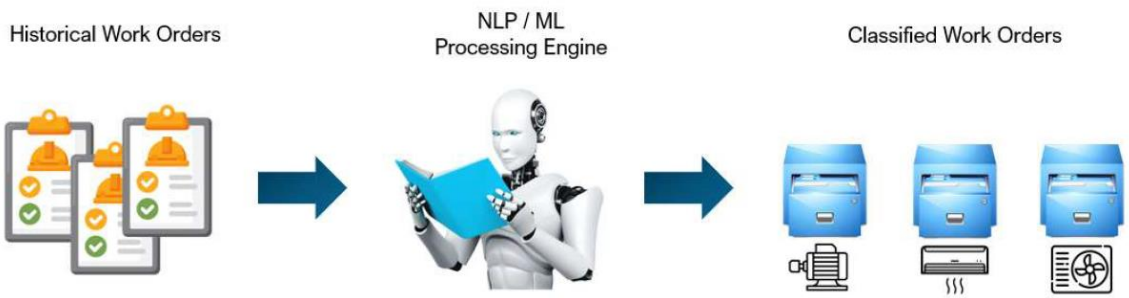

Figure 16 Work Orders pipeline (Source: Teixeira Duarte)

4.10 AI Summarizing Survey Results (Implenia)

Case background and relevance

Implenia uses AI to analyze large amounts of data generated by various systems to optimize business practices. AI is becoming indispensable for interpreting, understanding, and utilizing this data effectively.

Problem: To identify critical success factors by analysing interviews using AI

Identifying critical success factors from survey data to improve training content and methods is a time-consuming and tedious process.

Solution: Using Natural Language Processing

Implenia uses Natural Language Processing (NLP) technology to process and analyze survey data quickly and accurately, reducing analysis time and eliminating bias. This approach supports incremental process optimization and ensures findings are not distorted by expectations.

Outlook: The potential is great

AI-driven data analysis will continue to enhance business practices, making Implenia more data-driven and efficient. Implenia company plans to explore further potential use cases and the limits of AI technology.

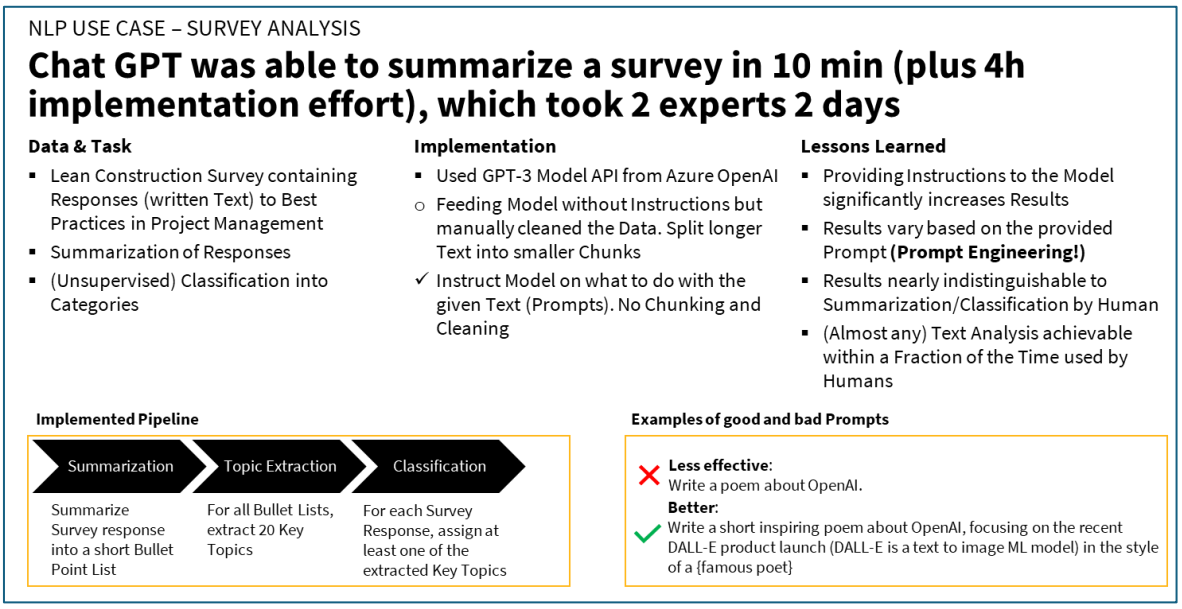

Figure 17 Summary of the NLP use case of Implenia (Source: Implenia)

5 Future of AI in Construction

5.1 The Road Ahead: Future Prospects and Innovations

The future of AI in construction promises even greater innovations and efficiency gains. The next frontier includes the seamless integration of AI with other emerging technologies such as the Internet of Things (IoT), blockchain, and augmented reality (AR), enhancing interoperability and data exchange across various platforms. Furthermore, the development of more intuitive, user-friendly AI tools will be crucial in democratizing technology access and facilitating wider adoption across the industry. As AI continues to evolve, its potential to drive sustainability, improve safety, and reduce the environmental impact of construction projects becomes increasingly apparent.

5.2 Industry Collaboration and Policy Support

Realizing the full potential of AI in construction requires concerted efforts from all industry stakeholders, including construction firms, technology providers, academia, and policymakers. Collaboration across these sectors can accelerate the development of standards and best practices for AI implementation, ensuring ethical considerations and worker safety are prioritized. Additionally, policy support, in the form of investment incentives and regulatory frameworks, can play a pivotal role in encouraging innovation and facilitating the integration of AI technologies into mainstream construction practices.

5.3 Responsible AI

In today's construction landscape, companies are faced with an urgent need to comprehend and harness their synergies for a positive impact on the built environment, while effectively managing the associated risks. The increasing integration of AI in the construction industry may complicate this process by introducing risks such as personal integrity, cybersecurity, data fairness and biases, and ethical considerations. A framework to guide responsible AI practices in the context of ESG is needed for assessment, monitoring, and evaluation. The white paper "AI's Impact on Our Sustainable Future: A Guiding Framework for Responsible AI Integration Into ESG Paradigms[3]" offers a roadmap for integrating AI to support and enhance ESG commitments. It also offers guiding questions to enable organizations and stakeholders to make responsible decisions related to their AI projects and investments.

5.4 EU Data and AI acts

Applying artificial intelligence in construction often requires excessive amounts of high-quality data for the training and validation of machine learning models and neural networks. Collecting, aggregating, and analysing data generated by humans, IoT devices, construction machines, and sensors across a building's and civil engineering structure's (henceforth asset) life cycle provides several challenges. Primarily data ownership and accessibility pose crucial barriers for leveraging data in assets' construction and operational processes.

The EU Data Act[4] provides a legislative framework regulating rights to access and use data. Granting users of connected devices, e.g. construction machinery, access to data generated under "fair, reasonable and non-discriminatory terms and conditions and in a transparent manner" is complemented by removing obstacles of switching data processing providers, e.g. cloud service

[3] https://20965052.fs1.hubspotusercontent-na1.net/hubfs/20965052/AIs%20Impact%20on%20Our%20Sustainable%20Future%20White%20Paper%20V1.pdf

[4] Data Act | Shaping Europe's digital future (europa.eu)

providers. The resulting data accessibility provides unprecedented opportunities for construction process documentation, e.g. built-as-planned, and subsequent process automation, e.g. invoicing. Moreover, data obtained from connected construction devices can be leveraged to furnish digital twin enabling cost-efficient operation and management. Finally, accessibility to construction process data allows for detailed process monitoring, AI-enhanced optimization, and thus unprecedented efficiency gains across the asset's life cycle. In addition, gaining an in-depth understanding of assets' construction and operation processes due to data accessibility provides opportunities to improve design and planning by leveraging generative design methods.

Applying AI in asset design and leveraging AI-powered construction machinery requires compliance with the EU AI Act[5]. AI-assisted design aids of streets, rails, bridges, and other critical infrastructure construction projects may be attributed as a high-risk level according to the AI Act and thus might be subject to assessments before deployment. Similarly, AI-powered construction machinery certainly requires advanced certifications under the EU's product safety legislation before being used on live construction sites. Consequently, keeping regulatory requirements in mind when developing AI-power construction aids will be critical for delivering added-value and industry-wide deployment.

At the same time, construction principals are entitled to obtain access to the connected devices deployed in their assets. Since assets' sensor layout design and integration is certainly subject to the design and construction process, integrating systems that provide a unified means to access and collect data can become a specification in future tenders. Consequently, construction industry suppliers as well as general contractors might want to team up for the development and standardization of data interfaces that allow for a seamless integration.

The EU Data Act and AI Act provide a foundation for the development and application of AI-powered construction processes. Nevertheless, the rate of technology adoption in the sector certainly depends on collaborative efforts across the ecosystem to collect, exchange, share and learn from a growing body of data generated in assets' construction and operational processes. A unified means to exchange data across devices is pivotal for the digital transformation of the built environment and thus a high research priority for the construction sector.

[5] Artificial intelligence act | Think Tank | European Parliament (europa.eu)

5.5 Four possible scenario narratives on AI in construction

Based on the outcomes of the workshop as well as the survey, a small exercise was conducted where AI adoption and the market situation were analysed. While by no means including all factors, it can highlight some of the things that construction companies need to consider to be better prepared for the future.

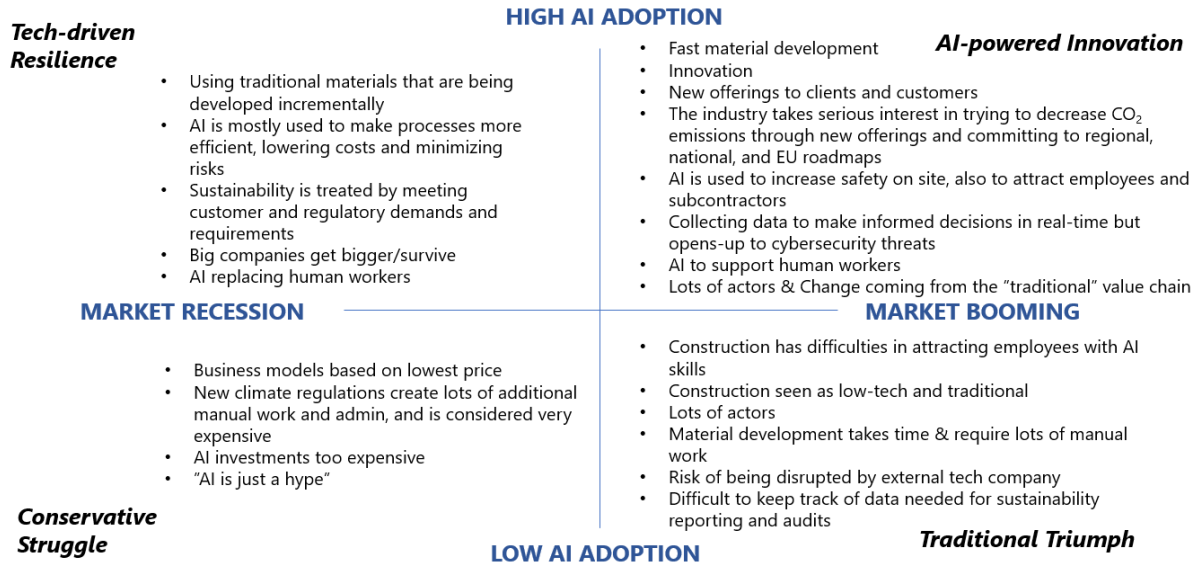

Figure 18 The AI adoption willingness versus the market situation

From Figure 18, four scenario narratives can be crystallised. These are shortly presented below.

AI-Powered Innovation

Image: AI generated

In the bustling metropolis of tomorrow, **AI-Powered Innovation** reigns supreme. Skyscrapers adorned with shimmering digital displays tower over the city, each a testament to the rapid advancements in

technology and future faith. Autonomous vehicles glide effortlessly through the streets, while drones zip overhead, delivering goods with precision and speed.

At the heart of this thriving urban landscape, AI-driven innovations are the lifeblood of progress. Factories hum with the synchronized dance of robotic arms, producing goods at an unprecedented pace. In retail, smart stores analyse customer preferences in real-time, offering personalized shopping experiences that delight and surprise.

The construction industry, once seen as traditional, has embraced AI to revolutionize safety and efficiency on-site. Workers collaborate seamlessly with intelligent machines, ensuring projects are completed faster and with greater precision. Sustainability is no longer a mere regulatory requirement but a core value, with AI optimizing energy use and minimizing waste.

In this era of **AI-Powered Innovation**, construction businesses flourish by leveraging cutting-edge technology to stay ahead of the curve. Innovation is not just encouraged; it is the driving force behind every decision. The city pulses with the energy of endless possibilities, where AI and human ingenuity combine to create a future that is both prosperous and sustainable.

Tech-Driven Resilience

Image: AI generated

In a world facing economic downturn, **Tech-Driven Resilience** emerges as a beacon of hope. Despite the challenging market conditions, the construction companies that have embraced AI stand strong. The cityscape is dotted with smart infrastructure, where AI optimizes every aspect of urban life, from energy consumption to traffic management.

Construction sites, though fewer in number, are marvels of efficiency. AI-powered robots and drones handle the bulk of the labour, ensuring projects are completed on time and within budget. The workforce, though smaller, is highly skilled, working alongside intelligent machines to achieve

remarkable feats. However, investments in new technologies are not for all, and in this scenario, big is the key to survival.

While the world faces the consequences of global warming, companies are merely meeting the demands of their clients and not trying to exceed expectations. Sustainability is still seen as driving costs and no new circular business model has been adopted.

In this era of Tech-Driven Resilience, innovation is crucial. Companies that leverage AI to streamline operations and cut costs are the ones that thrive. The city may face economic challenges, but its spirit remains unbroken, driven by the relentless pursuit of technological advancement.

Conservative Struggles

In the midst of an economic recession, **Conservative Struggles** paints a picture of businesses grappling with the challenges of a tough market. Construction projects are few and far between, and the lowest price is the only criterion when clients evaluate bids. The industry is seen as low-tech and traditional, making it difficult to compete with more innovative sectors for talents.

Many construction companies face an uphill battle, with new climate regulations adding to their workload and costs. AI investments are deemed too expensive, and many businesses view AI as just a passing trend. Material development is slow and labour-intensive, further hampering progress. Sustainability reporting and audits become a burden, with companies finding it hard to keep track of the necessary data. The risk of disruption by external tech companies looms large, as traditional businesses struggle to adapt to the changing landscape.

In this era of **Conservative Struggles**, the market's challenges are met with resilience and determination. Companies may face significant hurdles, but they continue to push forward, relying on their experience and grit to navigate the difficult times.

Traditional Triumph

Image: Vilius Kukanauskas, Pixabay

In a booming market, **Traditional Triumph** celebrates the success of conventional methods. The city is alive with the hustle and bustle of thriving businesses, many of which rely on tried-and-true practices rather than cutting-edge technology. Construction sites are busy with workers using traditional tools and techniques, building structures that stand as testaments to human craftsmanship.

Innovation is cautious, with companies preferring incremental improvements over risky ventures. AI is viewed with scepticism and seen as an expensive and unnecessary hype. Instead, businesses invest in their workforce and traditional methods, confident in their ability to succeed without relying on advanced technology.

In this era of **Traditional Triumph**, the market's prosperity is driven by the strength of conventional practices. Companies thrive by sticking to what they know best, proving that sometimes, the old ways are still the best ways.

6 Conclusions

The integration of AI into the construction industry represents a significant leap forward, offering solutions to longstanding challenges and opening up new avenues for innovation and growth. While the path to widespread adoption is complex, the benefits of AI — ranging from operational efficiency and safety enhancements to environmental sustainability — underscore the importance of this technological shift. As the industry continues to evolve, the collective efforts of stakeholders to embrace and advance AI technologies will be instrumental in shaping a more efficient, safe, and sustainable future for construction.

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