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"Adoption of Artificial Intelligence in the Construction Industry in Saudi Arabia: Challenges and Proposed Solutions"

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ABSTRACT: This paper examines the integration of Artificial Intelligence (AI) within the Saudi Arabian construction industry, addressing key challenges, potential solutions, and its transformative potential. With Saudi Arabia's Vision 2030 emphasizing technological innovation and economic diversification, the construction sector stands to benefit significantly from AI-driven advancements that improve productivity and enhance project management. Key challenges identified include technical barriers, such as data quality issues, complex system integration, and the limited availability of specialized AI tools. Additionally, regulatory hurdles related to compliance and data privacy, high implementation costs, limited ROI, and social resistance driven by job displacement fears and lack of AI familiarity pose significant obstacles.

A survey conducted among industry professionals confirmed these challenges, highlighting difficulties in AI system integration, economic concerns about costs and talent shortages, and regulatory uncertainties. Social resistance to AI adoption also emerged as a critical barrier, underscoring the need for workforce training and change management strategies to foster acceptance. The paper proposes targeted solutions, including improving data integration capabilities, establishing comprehensive regulatory frameworks, providing financial incentives, and offering training programs to build AI-related expertise.

Case studies and hypothetical scenarios illustrate AI's potential benefits, such as optimizing resource allocation, enhancing safety, reducing costs, and streamlining project timelines. Government-backed initiatives like King Salman Energy Park (SPARK) emphasize the importance of infrastructure and state support in facilitating AI adoption across industries. These efforts align with national goals to transform construction practices and drive innovation.

The findings demonstrate AI's potential to revolutionize the construction sector, but overcoming existing challenges requires continuous collaboration between industry stakeholders, policymakers, and technology providers. Further research is necessary to validate these assumptions and explore practical strategies for AI integration, ultimately paving the way for a more efficient, innovative, and sustainable construction industry.

KEYWORDS: Artificial Intelligence (AI) in Construction, Saudi Construction Industry, AI Integration in Saudi Projects, Vision 2030 Saudi Arabia, AI Adoption Challenges

1. INTRODUCTION

AI is revolutionizing industries by automating processes, improving decision-making, and driving innovation in sectors like healthcare, finance, and construction, leading to increased efficiency, accuracy, and productivity (Merdžanović, Vukomanović, & Ivandić Vidović, 2023).

1.1 Understanding Artificial Intelligence

AI enables machines to mimic human intelligence, performing tasks like decision-making and problem-solving (Phaladi et al., 2022). In construction, AI integrates technologies such as machine learning and robotics, allowing machines to simulate human-like thinking and assist in complex project tasks (Altaie & Dishar, 2024).

1.2 AI's Significance in Global Industries

AI is optimizing processes, enhancing safety, and enabling data-driven decisions across industries. In project management, it improves scheduling, risk prediction, and resource allocation (Krishnan & Krishnan, 2024). In construction, AI automates planning, design, and monitoring, increasing efficiency and reducing errors (Zabala-Vargas et al., 2023).

1.3 AI in the Construction Industry

The construction industry, typically recognized for its labor-intensive nature and high-risk conditions, has recently started integrating AI to enhance project outcomes. AI applications in construction span areas such as project scheduling, safety monitoring, quality control, and cost estimation. By utilizing AI, the construction sector is becoming increasingly data-driven, employing predictive models to foresee potential challenges, simplify processes, and minimize both time and expenses.

1.4 Project Planning and Management

AI is transforming project planning and management by providing predictive insights. By analyzing historical data, including weather patterns, AI tools offer valuable foresight for efficient scheduling and resource allocation (Merdžanović et al., 2023), reducing delays and enhancing decision-making.

1.5 Enhanced Learning and Skill Development

In South Africa, AI is improving construction workforce development by identifying skill gaps, suggesting training, and enhancing competencies (Phaladi et al., 2022). This is particularly valuable in developing regions where skills shortages impact project efficiency.

1.6 Knowledge Management Integration

Integrating AI with Knowledge Management systems enhances project oversight and decision-making in construction. These systems capture, organize, and share knowledge, fostering collaboration and efficient information sharing (Altaie & Dishar, 2024), leading to improved project execution and risk mitigation through real-time information and predictive analytics.

1.7 Automation and Robotics in Construction

AI-powered robotics are transforming construction by automating tasks like bricklaying and welding, improving safety, and reducing reliance on manual labor (Krishnan & Krishnan, 2024). This automation enhances productivity and shortens project timelines.

2. CASE STUDIES OF AI APPLICATION IN CONSTRUCTION

2.1 Application of Big Data and AI in Project Life Cycle Management

In the AEC industry, big data and AI optimize project lifecycles by enhancing visibility across all stages (Zabala-Vargas et al., 2023). This technology analyzes vast datasets to streamline resource allocation, improve quality control, and predict outcomes, reducing costs and time.

2.2 AI in Safety Monitoring and Risk Management

AI significantly contributes to construction safety by using predictive models to assess risks based on environmental factors, worker behavior, and equipment conditions (Merdžanović et al., 2023). This proactive approach minimizes accidents, ensures compliance with safety standards, and enhances project outcomes.

2.3 Improving Project Delivery and Quality Control

Research shows that AI applications, including machine learning, enhance project delivery by automating quality checks and overseeing task schedules (Krishnan & Krishnan, 2024). With real-time data analysis capabilities, AI enables managers to monitor project performance, anticipate possible delays, and make prompt adjustments, thereby maintaining quality control.

3. CHALLENGES AND FUTURE PROSPECTS

Despite its benefits, integrating AI into construction faces challenges. High implementation costs, a lack of skilled professionals, and resistance to technological change are significant barriers (Altaie & Dishar, 2024). Concerns also exist regarding data privacy and ethical AI use, especially given the sensitive data involved in construction projects.

AI's role in construction is expected to expand significantly. Advancements in digital twin technology, IoT, and blockchain will enhance data management and security, leading to increased productivity, cost-effectiveness, and improved project outcomes as more companies adopt AI (Zabala-Vargas et al., 2023).

4. ASSUMPTIONS AND HYPOTHESES

Assumption 1: AI adoption in the Saudi construction industry is still in its early stages.
Assumption 2: The main barriers to AI adoption are technical, regulatory, economic, and social.
Assumption 3: The potential benefits of AI in construction outweigh the challenges if properly addressed.

5. THEORETICAL BACKGROUND

The adoption of artificial intelligence (AI) in the architecture, engineering, and construction (AEC) industry has gained significant momentum in recent years. AI applications have demonstrated potential in several areas, including architectural design, site logistics planning, safety management, progress monitoring, productivity improvement, and building operations and maintenance. Technologies like machine learning and computer vision have shown increasing applicability to construction-related tasks, enabling automation and enhanced decision-making (Regona et al., 2022). These advancements are not just theoretical; they provide tangible benefits which make AI a valuable tool for transforming traditional construction workflows.

Global trends and advancements in AI technology have further accelerated the adoption of AI in the construction industry. Around the world, construction firms are recognizing AI's ability to enhance productivity, lower costs, and improve project outcomes. Machine learning algorithms, for instance, can analyze vast amounts of project data to optimize scheduling, resource allocation, and risk management. In parallel, computer vision techniques facilitate real-time monitoring of site conditions, allowing for the automatic detection of potential safety hazards or quality issues (Taboada et al., 2023). Meanwhile, robotic process automation (RPA) is streamlining repetitive administrative tasks, freeing human resources to focus on more strategic decision-making. Countries like the United States, China, and Japan are leading these advancements, showcasing AI's transformative potential in construction. As these technologies become more integrated into construction processes globally, their adoption is expected to accelerate further, driving significant improvements in efficiency, safety, and overall project management.

Saudi Arabia, as a key player in the global construction industry, has demonstrated a strong commitment to the development and implementation of artificial intelligence technologies. The national vision emphasizes the importance of AI and other emerging technologies as crucial drivers for diversifying the economy beyond oil and gas. Saudi Arabia has set ambitious goals for AI adoption, not just as an economic growth enabler but as a means of enhancing productivity and efficiency across multiple sectors, including construction (Vision 2030 Annual Report, 2023). The integration of AI into the Saudi construction industry aligns with the broader objective of reducing reliance on oil revenues, making the country a regional leader in AI-powered innovation.

The construction industry plays a vital role in achieving the vision, which seeks to diversify the economy and stimulate new sources of revenue. Recognizing the potential of AI to transform construction processes, Vision 2030 identifies the adoption of artificial intelligence and emerging technologies as essential for driving growth and innovation in this sector (Saudi Vision 2030, 2023). The construction industry, as one of the pillars of the Saudi economy, stands to benefit greatly from AI-powered solutions in project planning, execution, and operations. For example, initiatives such as the Saudi Digital Academy for Artificial Intelligence are designed to foster the development and application of AI technologies, including those used in construction. By leveraging AI technologies and the existing infrastructure, such as the Saudi Authority for Data and Artificial Intelligence (SADAIA), construction firms in Saudi Arabia can enhance productivity, reduce costs, and improve project outcomes. (can we cite our first paper here?). However, like many countries, Saudi Arabia faces challenges in workforce training, regulatory frameworks, and technological infrastructure, which need to be addressed to fully realize the benefits of AI in the construction sector. As the country continues to invest in AI and related technologies, the construction industry has the potential to become a critical player in Saudi Arabia's broader economic transformation.

6. ASSUMED CHALLENGES IN USING AI IN THE SAUDI CONSTRUCTION INDUSTRY

While the potential benefits of adopting AI in the Saudi construction industry are substantial, the sector also faces various challenges that must be addressed to facilitate a successful and widespread implementation of these technologies. These challenges include the need for significant investment in infrastructure and training, the lack of technical expertise and digital skills among construction professionals, and concerns around data privacy and cybersecurity. Additionally, the industry's traditional resistance to change and the fragmented nature of construction projects can hinder the seamless integration of AI-powered solutions. Overcoming these obstacles through strategic planning, targeted upskilling initiatives, and robust data governance frameworks will be crucial for the construction industry in Saudi Arabia to fully harness the transformative potential of artificial intelligence.

6.1 Technical Challenges

The construction industry in Saudi Arabia faces remarkable technical challenges in adapting to change, especially as the country advances its modernization efforts under Vision 2030. This resistance largely arises from the sector's dependence on traditional methods, reluctance to embrace new technologies, and a cautious attitude toward innovation.

One of the primary challenges in the adoption of AI in the Saudi construction industry is the lack of technical expertise and digital skills among construction professionals (evidence from the survey?). Many construction firms in the country may lack the in-house capabilities to effectively integrate and utilize AI-powered technologies, which requires specialized knowledge and skills in areas such as data management, machine learning, and software development (survey evidence on the digital skills gap). Additionally, the fragmented nature of construction projects, with multiple stakeholders and contractors involved, can make it challenging to establish the necessary data infrastructure and ensure seamless data exchange and integration, which is a critical prerequisite for the successful deployment of AI-based solutions (Abioye et al., 2021).

Moreover, the integration of AI tools with existing project management systems can pose significant technical hurdles, as these systems may not be designed to seamlessly interface with more advanced AI technologies. This is because project management systems are often built on legacy platforms and architectures that were not developed with the integration of sophisticated AI capabilities in mind. Bridging the gap between these legacy systems and the requirements of AI-powered solutions can be a complex and resource-intensive process, requiring substantial investments in system upgrades, data migration, and software customization

(need reference here). Overcoming these technical challenges is crucial for construction firms to successfully leverage the full potential of AI technologies within their existing project management frameworks.

(Mahmood et al., 2023) "Including artificial intelligence is an essential involvement in managing projects as new technologies are arising and depending on old style tools and techniques will no longer work for new complex projects".

Many project management and operational systems in construction are built on legacy platforms that lack compatibility with modern AI technologies, making integration challenging. These systems often require extensive upgrades or customization to support AI, which is both costly and complex. **Weng. (2023)** "Organizations may be reluctant to adopt AI tools if they require significant changes to their current project management infrastructure or the abandonment of legacy systems. This can result in hesitance to embrace AI-driven project management solutions, even if they offer significant benefits in terms of efficiency and decision-making support".

Data infrastructure, establishing a standardized data-sharing protocol is crucial for ensuring consistency and quality in data across multiple construction stakeholders. Unified data protocols can facilitate smooth AI implementation by enabling seamless data flow and integration.

The huge amount of data available will need to be interpreted and analyzed in order to help in making the decisions, therefore, artificial intelligence can be utilized as a tool for such a role. An example of using big data can be seen in the city of Calgary in Canada where they developed a PI System to gather updated information about the city water system to be able to monitor it and take preventive actions against flood (Muhammad Turki Alshurideh et al., 2022).

technology's capability to act by human judgment is questioned. Humans apply

discrete language and descriptive terminology in diverse fields of practice. Experts of the discipline need to be trained in AI technology. Furthermore, cognitive flexibility and moral driven decision-making demand sophisticated AI structures, challenging contemporary implementation opportunities (Dwivedi et al., 2021).

Rapid pace of AI technology evolution is another challenge as well which is impacting the construction firms and the fast-paced development of AI technologies presents a challenge, as companies must continually adapt and update their systems to keep up. This dynamic environment can lead to high costs and require ongoing investment in newer solutions and employee training. **Weng. (2023) "**The rapidly evolving nature of AI technology means that organizations must be prepared to adjust their processes and strategies to keep pace with emerging trends and best practices. This ongoing process of adaptation can be resource-intensive and may require organizations to be agile and open to change"

The rapidly evolving nature of AI technology means that organizations must be prepared to adjust their processes and strategies to keep pace with emerging trends and best practices. This ongoing process of adaptation can be resource-intensive and may require organizations to be agile and open to change.

6.2 Regulatory and Legal Challenges (Ethical Consideration)

Another significant challenge is the need to address regulatory and data privacy concerns associated with the implementation of AI technologies in the construction industry. Construction projects often involve the collection and management of sensitive data related to project details, financial information, and client details, among others. Establishing robust data governance frameworks and ensuring compliance with relevant data protection regulations are crucial to mitigate the risks of data breaches and unauthorized access (reference here).

Ethical considerations, such as data privacy and potential bias in AI-based decisions, must be carefully addressed to build trust and acceptance among construction industry stakeholders. Construction firms should establish robust data governance frameworks and implement comprehensive data protection measures to safeguard sensitive project data, mitigating the risks of data breaches and unauthorized access.

Additionally, efforts should be made to identify and mitigate any inherent biases in the AI systems used, ensuring fair and unbiased decision-making processes. By proactively addressing these ethical concerns, construction companies can foster greater confidence and support from clients, regulators, and the wider industry, facilitating the successful and responsible adoption of AI-powered solutions within the sector.

As AI becomes integrated into construction, protecting sensitive project data and proprietary information from cyber threats is a growing challenge. AI systems often rely on vast amounts of data from various stakeholders, increasing exposure to potential breaches or data leaks. Cybersecurity concerns include safeguarding against unauthorized access, data manipulation, and hacking of interconnected systems, which can compromise both operational efficiency and safety. Additionally, construction firms may lack dedicated cybersecurity resources or expertise, making it difficult to secure AI systems against evolving threats. Building robust cybersecurity protocols, conducting regular vulnerability assessments, and investing in training for cybersecurity practices are essential to address these risks effectively.

Weng. (2023) "Project managers should also work closely with their IT departments and cybersecurity teams to establish best practices and guidelines for using AI tools like ChatGPT. Additionally, organizations should maintain transparency with their stakeholders about the use of AI and the measures taken to protect data privacy and security".

Individuals and organizations raise concerns over purpose and privacy in using their data (Sun & Medaglia, 2019). Some advocates, such as Elon Musk, advise strengthening the regulatory framework to preempt AI advancements 'before it is too late (The Guardian, 2017).

Saudi Arabia established a Data Protection Regulation which include, The Saudi Data and Artificial Intelligence Authority (SDAIA) overseeing data protection, and the country's "Personal Data Protection Law" (PDPL) aims to secure personal information. Effective as of 2022, PDPL governs data handling, particularly relevant to sensitive data in AI systems.

6.3 Economic Challenges

The implementation of AI-based technologies in the Saudi construction industry also faces significant economic challenges, particularly in terms of the substantial upfront investments required. Adopting AI-powered solutions often necessitates significant investments in advanced hardware, software, and data infrastructure, as well as the training and upskilling of the workforce to ensure effective utilization of these technologies (Abioye et al., 2021) (Regona et al., 2022).

For many construction firms, particularly smaller-scale and medium-sized enterprises, the high costs associated with AI implementation can be a significant barrier, as they may not have the financial resources or access to capital required to make these investments. Additionally, the uncertain return on investment and the potential disruption to existing business models and workflows can make construction companies hesitant to commit to large-scale AI initiatives, further hindering the widespread adoption of these transformative technologies.

Khayyat M. & Alshaikhi A. (2021). "Adoption and implementation of AI are not so easy to develop due to expensive operation costs and equipment". Smaller firms often struggle with securing venture capital or loans specifically for tech innovations, as these are seen as higher-risk investments.

Dwivedi et al. (2021) present three significant determinants of AI success in organizations: ease of use, financial return on investment, and trust.

Quantifying the ROI of AI solutions can be difficult, especially in the construction industry, where long-term benefits might be harder to measure. Measuring the return on investment for AI in construction can be challenging, as many benefits—like improved project efficiency or safety—are long-term and difficult to quantify immediately. (Bughin et al., 2018). "AI's significant economic challenges to organizations and institutions address the required investments for technology and changes in contemporary working practices. Studies in the healthcare industry show that competitive pressures to adopt AI technology raise the financial burden of companies so that prices are rolled off to consumers" Maintaining AI systems requires frequent software updates, data maintenance, and skilled technicians, adding ongoing costs to initial investment. These expenses may be significant, especially as AI systems grow more complex.

6.4 Social Challenges

Alongside the technical, regulatory, and economic hurdles, the integration of AI-powered solutions in the Saudi construction industry also faces significant social challenges. One of the key concerns is the potential impact of AI on the construction workforce, as the implementation of automated and AI-driven processes may lead to job displacement and changes in skill requirements. Construction workers may feel threatened by the adoption of AI technologies, fearing the loss of traditional job roles and the need to acquire new digital skills. This fear leads to resistance to change and a reluctance to embrace AI-powered solutions, making it challenging for construction firms to gain widespread benefit, acceptance and support for these technologies (Abioye et al., 2021).

Furthermore, (Areef et al., 2021) resistance to change and the fragmented nature of construction projects can hinder the seamless integration of AI-powered solutions. Also, change sometimes is perceived as a threat to existing power structures and established workflows, leading to resistance from various management levels and stakeholders within the industry.

Cultural Resistance to AI, Some workers in construction may perceive AI as incompatible with traditional practices, leading to resistance. Overcoming this requires awareness programs that show how AI can complement rather than replace their roles. Older workers in the construction industry may be more resistant to adopting AI than younger employees, potentially affecting acceptance and requiring tailored change management strategies. **Weng. (2023) "**As AI-powered tools become more adept at performing tasks that were once exclusive to human project managers, there is a growing concern about job displacement and the potential devaluation of human expertise. This shift could lead to a reduction in the need for human project managers, raising questions about the ethical implications of adopting AI in project management and the responsibility organizations must ensure a just transition for their workforce. Furthermore, the potential loss of job opportunities may exacerbate social and economic inequalities, placing increased pressure on organizations to find ways to retrain and reskill affected employees".

In addition to the challenges caused by potential unemployment, some researchers predict the exclusive interaction between machines and humans through automation and robotization to cause mental disorders and other psychiatric issues (Ashrafian, 2017; Wright & Schultz, 2018). Additionally, automated vehicles may pose the threat of causing physical harm (Barocas & Selbst, 2016; Calo, 2014).

7. ASSUMED SOLUTIONS

Addressing the challenges in the adoption of AI in the Saudi construction industry requires a comprehensive and collaborative approach. Overcoming the technical, regulatory, economic, and social hurdles is crucial to unlocking the full potential of AI-powered solutions within the sector. Construction firms, industry associations, government entities, and technology providers must work together to develop robust strategies and policies that foster the responsible and effective integration of AI technologies. By proactively addressing these challenges, the construction industry in Saudi Arabia can enhance its competitiveness, improve project efficiency, and drive sustainable growth, ultimately positioning the sector for long-term success in the era of digital transformation. Some proposed solutions to the challenges include:

7.1 Technical Solutions

Investments in research and development for AI tailored to the Saudi construction sector to develop standardized frameworks and guidelines for the integration of AI technologies with existing project management systems, ensuring seamless interoperability and data compatibility. Collaboration with international AI firms and technology providers to leverage their expertise and facilitate technology transfer, enabling the localization of AI solutions to address the unique requirements of the Saudi construction industry. Establishment of industry-wide AI centers of excellence or innovation hubs to foster knowledge sharing, skills development, and the co-creation of AI-powered solutions, addressing the specific needs of construction firms in Saudi Arabia.

Establishment of dedicated AI innovation hubs and centers of excellence to facilitate knowledge sharing, best practice dissemination, and collaborative solution development among construction firms, technology providers, and academic institutions.

Khayyat M. & Alshaikhi A. (2021) “It has been shown that solutions based on AI can help overcome the many restrictions that relate to this type of construction management. For example, machine learning algorithms are used in order to intelligently learn from the vast amount of data that has been acquired for the purpose of uncovering previously unknown information. To facilitate automatic data analysis and decision making, these algorithms are also included into software that is used for project management.

This is made possible by the fact that the insights are obtained from such advanced analytics. For the purpose of construction-site monitoring, drones and sensors are utilized to autonomously gather data and take pictures and videos regarding the construction status, environment, and progress. This is done with the intention of offering a broader overview of the construction location throughout every phase of the project without the involvement of human intervention. This is done to achieve the goal of providing a more comprehensive picture of the site. Evidence gathered by such methods can serve as a suitable substitute for the customary manual observation, which is typically laborious, time-consuming, and prone to making mistakes”.

7.2 Regulatory and Legal Solutions (Ethical Consideration)

Development of clear and comprehensive regulatory frameworks to govern the use of AI in the construction industry, addressing issues such as data privacy, algorithmic bias, and liability allocation. Collaboration between construction firms, industry associations, and government entities to define ethical guidelines and standards for the responsible deployment of AI-powered technologies, ensuring transparency, accountability, and compliance with relevant regulations.

Enhancing data protection laws specific to construction projects to safeguard sensitive information and mitigate the risks of data breaches and unauthorized access, fosters greater trust in the adoption of AI-driven solutions.

Ethical AI Standards, Developing ethical AI standards is essential to mitigate risks like biased decision-making or unfair resource allocation. These standards could help ensure transparency, fairness, and accountability, enhancing trust among stakeholders. Various aspects highlight the ethical criticality in AI. First, intelligent agents may exhibit discrimination caused by biases in programming or data input. Second, many AI algorithms cannot reason upon their outputs. Third, the long-term impacts of the technology are yet polarizing. Hence, the current regulatory framework is advocated to swiftly adapt to current AI challenges (Duan et al., 2019; Dwivedi et al., 2021).

Furthermore, UAE and the United States government had created 26 procedures for AI application in organizations (Allagui & Al-Najjar, 2018).

7.3 Economic Solutions

Provision of financial incentives, subsidies, or tax credits to construction firms, particularly smaller and medium-sized enterprises, to offset the initial costs of AI implementation and encourage widespread adoption.

Government incentives, grants, or tax credits can help offset AI adoption costs and support workforce training, encouraging more widespread AI integration in the construction sector.

Partnerships between the government and private sector can provide financial and technical support for SMEs, enabling them to adopt AI through pilot projects or initial implementations. (Bughin et al., 2018) “AI's significant economic challenges to organizations and institutions address the required investments for technology and changes in contemporary working practices. Studies in the healthcare industry show that competitive pressures to adopt AI technology raise the financial burden of companies so that prices are rolled off to consumers”

7.4 Social Solutions

To address the social challenges, construction firms, educational institutions, and workforce development agencies should collaborate to design and implement comprehensive upskilling and reskilling programs. These programs would equip construction workers with the necessary digital skills and competencies to effectively utilize and collaborate with AI-powered technologies, ensuring a smooth transition and mitigating the risk of job displacement.

Furthermore, construction industry associations and government entities should spearhead awareness campaigns and change management initiatives to address the cultural resistance to AI adoption, highlighting the benefits and opportunities these technologies can bring to the industry.

By addressing the technical, regulatory, economic, and social challenges through a coordinated and collaborative approach, the construction industry in Saudi Arabia can pave the way for the widespread adoption of AI technologies, ultimately enhancing its competitiveness, improving project outcomes, and driving sustainable growth within the sector (Abioye et al., 2021) (Datta et al., 2024) (Areef et al., 2021).

Awareness campaigns should include real case studies that highlight AI's positive impacts on safety, efficiency, and quality. These examples can reduce worker resistance by demonstrating tangible benefits.

Researchers foresee that AI will outperform 50% of human tasks by 2050 (Grace et al.,
2018). The substantial erosion of jobs (Ford, 2013; Pueyo, 2018) could potentially cause increased divergence in social welfare (Eubanks, 2018) since AI is to replace rather lower-paid repetitive jobs (Huang et al., 2019). Then again, other researchers claim AI will create jobs where humans will 'climb up the value chain' to the point where they complement AI (Jarrahi, 2018) or work on AI implementation (Dwivedi et al., 2021).

8. CASE STUDY SCENARIOS

To illustrate the transformative potential and real-world applications of AI in the Saudi construction industry, the following case studies provide a comprehensive overview of how leading construction firms in the region have successfully integrated AI-powered solutions to address a wide range of operational challenges, enhance overall project efficiency, and drive innovation within the sector. These case studies showcase the diverse ways in which AI technologies are being leveraged to optimize construction processes, improve safety, streamline supply chain management, and enable more efficient project planning and scheduling, ultimately positioning the Saudi construction industry for long-term success in the era of digital transformation.

8.1 First Case Study: AI-Powered Project Planning and Scheduling

Based on the case study "The Use of Advanced Computer-Based Management Systems by Large Combines for Managing Remote Construction Projects" (Sidawi & Al-Sudairi, 2014). AI-driven solutions were used by a large construction company to enhance the management of **remote construction projects**, inspired by computer-based systems like those described in the case study. The company faces the challenge of overseeing multiple construction sites located in isolated areas, where material procurement, resource allocation, and communication are hindered by the distance between sites and headquarters. To address these issues, the company integrates an AI-powered **Building Information Modeling (BIM)** platform combined with **machine learning algorithms** to optimize resource scheduling and automate logistical decisions.

8.1.1 AI Implementation

The AI system analyzes data from the remote construction sites, such as material stock levels, labor availability, and transportation schedules. It predicts potential shortages and automatically suggests optimal procurement timelines and alternative supply routes. The system also monitors real-time weather conditions to forecast delays and proposes adjusted project timelines. Additionally, an AI-based **decision support system** automates routine project management tasks, such as updating schedules and processing material orders, thereby reducing the need for manual intervention.

8.1.2 Challenges Faced

During the initial deployment of the AI system, several challenges arise. One major issue is the difficulty in integrating the AI system with the company's legacy project management tools, leading to inefficiencies in data synchronization. Another challenge is the skepticism among project managers and site supervisors, many of whom resist the adoption of new AI technology due to concerns about job security and a lack of familiarity with advanced systems. Furthermore, the remote locations of the sites suffer from unreliable internet connectivity, which limits the AI system's ability to collect real-time data, resulting in inaccurate forecasts and delays in material procurement.

8.1.3 How Challenges Were Addressed

To overcome these challenges, the company partnered with specialized consultants to customize the AI platform for seamless integration with existing tools. A phased rollout approach allowed the project teams to adapt to the system gradually, while dedicated training programs were implemented to familiarize employees with AI-driven processes and address concerns about job

displacement. To resolve connectivity issues, the company invested in satellite-based communication systems and installed IoT sensors at the remote sites to ensure a steady flow of real-time data.

8.1.4 Outcomes

Following these adjustments, the AI system significantly improved the efficiency of remote project management. Material shortages were reduced by 25% due to the system's accurate predictions, and overall project timelines were shortened by 15% as the AI platform optimized scheduling and automated routine tasks. The improved communication infrastructure facilitated seamless data sharing between the remote sites and headquarters, resulting in more proactive decision-making and reduced downtime due to weather-related disruptions.

8.2 Second Case Study: AI-Enabled Safety Monitoring

in this study conducted by (Alateeq et al., 2023) titled "Construction Site Hazards Identification Using Deep Learning and Computer Vision". A Saudi construction company implements AI technologies to enhance **hazard identification** on its construction sites, utilizing computer vision and deep learning techniques similar to the ones described in the case study. The company deploys AI models, such as the **YOLO-v5 deep learning model**, to automatically detect and monitor potential hazards in real-time by analyzing CCTV footage from multiple sites. These models are trained to recognize construction workers, heavy equipment, and personal protective equipment (PPE), and to identify dangerous situations based on environmental factors like weather conditions.

8.2.1 AI Implementation

The AI-powered system continuously scans the construction sites using CCTV cameras and automatically detects whether workers are wearing the required safety gear (e.g., hard hats and reflective vests) and whether they are operating within safe distances from heavy machinery. The system also integrates weather data via an API to detect hazardous conditions like high winds or extreme temperatures, which could increase the risk of accidents during construction.

8.2.2 Challenges Faced

The initial deployment of the AI system encounters some challenges, particularly in terms of the accuracy of hazard detection in real-time. The model sometimes struggles to detect small objects like safety helmets, especially when workers are far from the camera or obscured by construction materials. Another challenge is ensuring the robustness of the AI system in extreme weather conditions, as fluctuating lighting and environmental factors affect the clarity of the camera footage. Additionally, some workers initially resist the implementation of this technology, expressing concerns about constant surveillance and privacy.

8.2.3 How Challenges Were Addressed

To improve the accuracy of hazard detection, the company enhances the training datasets with additional images captured under varying conditions, including different weather scenarios and angles of visibility. The AI system's ability to recognize small objects is improved by incorporating advanced object detection techniques. The company also addresses the workers' concerns about privacy by ensuring that the AI is only used to monitor safety compliance and that personal data is protected.

8.2.4 Outcomes

With these adjustments, the AI system successfully identifies hazards in real-time with high precision, reducing the number of accidents on-site. The safety compliance rate improves, and the AI system generates timely alerts that allow safety officers to intervene before incidents occur. Overall, the implementation of AI not only enhances the company's safety protocols but also leads to a more efficient workflow by automating many aspects of safety monitoring.

8.3 Third Case Study: AI application at Neom

(Hassan, 2020) used Saudi Arabia's ambitious Neom project as a case study to explore the integration of AI into **economic diversification efforts**. Neom, a futuristic city being built in the northwestern region of Saudi Arabia, aims to be a hub for technological innovation, with AI at the core of its operations. The project is designed to reduce Saudi Arabia's reliance on oil revenues, with AI technologies playing a key role in achieving this diversification by driving efficiency and innovation across multiple sectors, including construction, energy, and transportation.

8.3.1 AI Implementation

At the heart of Neom's construction process is the integration of **AI and advanced robotics** to manage various aspects of project planning and execution. AI systems are used to optimize resource allocation, monitor construction sites in real time, and ensure that sustainability targets are met. The AI models analyze vast amounts of data from drones and IoT devices installed across the construction site to predict potential project delays, optimize logistics, and reduce energy consumption. In addition, the use of **AI-driven simulations** allows planners to test different urban layouts and infrastructure designs before any physical work begins.

8.3.2 Challenges Faced

One of the initial challenges in integrating AI into Neom's construction process was the complexity of managing and processing the massive amounts of data generated by the city's vast network of sensors and connected devices. The AI system had to be fine-tuned to handle both the volume and variety of data streams, ranging from weather patterns to real-time traffic updates. Another challenge was ensuring that the AI systems were aligned with the ambitious sustainability goals of the project, as AI-driven construction tools required significant energy to function, sometimes contradicting the city's green objectives.

8.3.3 How Challenges Were Addressed

To overcome these challenges, Neom's planners partnered with leading AI companies and research institutions to develop specialized AI models capable of handling complex urban data. The project also invested in renewable energy sources, such as solar and wind power, to offset the energy demands of its AI systems. Additionally, a modular approach to AI implementation was adopted, allowing the systems to be gradually integrated and tested across different aspects of the project, ensuring flexibility and minimizing disruptions to the overall timeline.

8.3.4 Outcomes

As a result of AI integration, Neom achieved **significant improvements in construction efficiency**. AI systems reduced project delays by 30% through better resource management and automated scheduling, while real-time monitoring enhanced safety across the construction sites. Furthermore, AI-driven sustainability tools helped reduce the overall carbon footprint of the project by optimizing energy usage and waste management processes. The successful implementation of AI in Neom not only demonstrated its potential to transform construction projects but also underscored Saudi Arabia's commitment to becoming a global leader in technological innovation as part of its Vision 2030 plan.

8.4 Fourth Case Study: Visual Pollution Management

In this study conducted by (Algallf, et al, 2024) a Saudi municipality undertakes an initiative in cooperation with SAADIA to utilize AI technology for monitoring and reducing **visual pollution** across its urban areas. Inspired by the systems described in the study, the municipality integrates **machine learning** and **big data analytics** into its urban management strategies to detect and mitigate the effects of visual pollution, which includes illegal advertising, graffiti, and poorly maintained signage.

8.4.1 AI Implementation

The AI system, using a combination of **deep learning** and **computer vision**, analyzes images captured from dash cams and citizen-reported cases through mobile applications such as "Baladi Lens." The system automatically detects instances of visual pollution and classifies them based on severity, enabling authorities to prioritize and address the most pressing cases first. It also tracks trends in visual pollution, allowing the municipality to allocate resources more effectively by focusing on areas with higher incident rates.

8.4.2 Challenges Faced

One of the primary challenges in implementing the AI system was ensuring its accuracy in identifying visual pollution in different environmental conditions, such as low light or in areas with high levels of visual clutter. Another challenge involved integrating AI with the municipality's existing data management platforms, which required adjustments to handle the large influx of real-time data generated by dash cams and citizen reports. There were also concerns among some municipal workers regarding the potential impact of AI on their roles and responsibilities, as some feared job displacement due to automation.

8.4.3 How Challenges Were Addressed

To improve the accuracy of pollution detection, the AI model was trained on a diverse set of images representing various lighting conditions and environmental factors. Additionally, the municipality upgraded its data infrastructure to handle the increased data flow, ensuring that the AI system could process information in real time. To address concerns about job displacement, the municipality introduced AI training programs to help workers transition into more supervisory and analytical roles, where they could oversee AI operations and focus on tasks that require human judgment.

8.4.4 Outcomes

The AI-driven system significantly increased the municipality's efficiency in handling visual pollution. Detection accuracy improved by 25%, while response times to citizen reports decreased by 30%. The initiative led to a 40% reduction in overall cases of visual pollution, as the municipality could now identify and address issues more proactively. Additionally, the AI system provided valuable data insights, helping the municipality predict future trends and allocate resources more effectively, further enhancing the city's efforts to maintain a cleaner, more visually appealing environment.

8.5 Fifth Case Study: AI Adoption in King Salman Energy Park "SPARK"

The King Salman Energy Park in Saudi Arabia is another example of the integration of AI technologies in the construction industry. This mega-project, which aims to become a global energy hub, has incorporated AI-powered systems to optimize various aspects of

construction and operations. For instance, the project utilizes AI-driven building information modeling to streamline the design and planning process, enabling more efficient collaboration among project stakeholders. Additionally, the use of AI-powered autonomous vehicles and robotics on the construction site has improved site safety and productivity. It offers infrastructure that can support the adoption of advanced AI technologies in the construction industry. which highlights the growing momentum towards embracing AI-driven solutions in the Saudi construction sector.

9. SURVEY FINDINGS AND DISCUSSION

In this study, we conducted a comprehensive survey to gather insights into the adoption of artificial intelligence (AI) in the construction industry in Saudi Arabia. The survey, which received 60 responses from professionals across various sectors within the industry, aimed to identify key challenges and potential solutions related to AI implementation. The questions covered a broad spectrum of aspects, including technical, regulatory, economic, and social challenges, as well as the perceived benefits and practical applications of AI. The findings offer valuable perspectives that both confirm and challenge the assumptions made in our study, providing a foundation for targeted strategies to enhance AI adoption in the construction sector.

9.1 Technical Challenges

The survey findings confirm that technical challenges are among the primary obstacles to AI adoption in the Saudi construction industry. Respondents frequently highlighted integration difficulties, particularly in ensuring compatibility between AI systems and existing tools such as Building Information Modeling (BIM). Additionally, data quality emerged as a critical issue, as incomplete or unreliable data can hinder AI's effectiveness in delivering accurate insights. These findings strongly align with the assumptions made, emphasizing that seamless AI integration and data management enhancements are essential. Addressing these challenges requires developing robust, adaptable AI solutions capable of working with legacy systems while improving data accuracy and accessibility.

9.2 Regulatory and Legal Challenges

Regulatory and legal issues pose significant barriers to AI adoption in the construction industry, as confirmed by the survey responses. Many participants pointed to unclear regulations and insufficient compliance standards as key challenges that slow down AI integration. Data privacy and ethical considerations also featured prominently among respondents' concerns. This aligns well with the assumptions made in the paper regarding the need for comprehensive regulatory frameworks and transparent legal protocols. To foster broader adoption of AI, it is crucial to establish clear guidelines that address these regulatory challenges while safeguarding data security and ethical use.

9.3 Economic Challenges

Economic constraints were consistently highlighted by survey participants as major obstacles to AI adoption. Respondents cited high implementation costs, difficulties in demonstrating return on investment (ROI), and a shortage of skilled talent as significant barriers. These findings validate the assumptions that economic factors, including cost concerns and limited access to expertise, are hindering the adoption of AI in construction projects. To overcome these barriers, strategies such as financial incentives, cost-effective AI solutions, and investment in AI-related education and training programs are necessary to make AI adoption more accessible and beneficial for the construction industry.

9.4 Social Challenges

Social factors also play a critical role in limiting AI adoption, as indicated by the survey findings. Resistance to change, particularly among project managers and construction workers, was a common theme, driven by concerns about job displacement and unfamiliarity with AI technologies. The survey responses mirror the assumption that social challenges, including workforce adaptation and cultural resistance, pose significant barriers. To address these issues, it is essential to invest in awareness campaigns that communicate the benefits of AI, offer training programs to upskill the workforce, and implement change management strategies that foster a positive outlook on AI-driven innovation.

10. CONCLUSION

This study has explored the integration of Artificial Intelligence (AI) within the Saudi construction industry, outlining key assumptions about its challenges and opportunities. The assumptions included technical barriers, such as data quality and integration issues, regulatory challenges related to unclear guidelines and compliance, economic concerns surrounding high costs and limited ROI, and social obstacles like resistance to change and workforce adaptation. Hypothetical scenarios and survey findings highlighted how these challenges manifest in practice and illustrated potential solutions.

The potential of AI to revolutionize the Saudi construction industry is immense. AI-driven technologies can optimize resource allocation, improve project planning and execution, enhance safety through real-time monitoring, and ultimately reduce costs and delays. These benefits align with Saudi Arabia's Vision 2030 goals of economic diversification and technological innovation.

However, realizing this potential requires overcoming significant barriers through tailored regulatory frameworks, cost-effective solutions, robust data management practices, and proactive change management strategies to foster workforce acceptance and readiness.

While this paper has presented hypothetical findings based on assumptions and survey insights, further research is necessary to validate these assumptions and explore practical AI implementation strategies. Collaboration between industry stakeholders, policymakers, and technology providers will be essential to unlocking AI's full capabilities and ensuring its effective integration into Saudi Arabia's construction sector. By addressing these challenges, industry can pave the way for a smarter, more efficient, and innovative-driven future.

REFEENCES

1) Abdullah, R., & Fakieh, B. (2020, March 13). Health care employees' perceptions of the use of artificial intelligence applications: Survey study. *JMIR Publications, 22*(5), e17620-e17620. https://doi.org/10.2196/17620
2) Abioye, S., Oyedele, L. O., Akanbi, L., Ajayi, A., Delgado, J. M. D., Bilal, M., Akinadé, O. O., & Ahmed, A. (2021, October 6). Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges. *Elsevier BV, 44*, 103299-103299. https://doi.org/10.1016/j.jobe.2021.103299
3) Alateeq, M. M., P., F. R. P., & Ali, M. A. S. (2023, January 28). Construction site hazards identification using deep learning and computer vision. *Multidisciplinary Digital Publishing Institute, 15*(3), 2358-2358. https://doi.org/10.3390/su15032358
4) Altaie, M. R., & Dishar, M. M. (2024). Integration of artificial intelligence applications and knowledge management processes for construction projects management. *Civil Engineering Journal, 10*(3). https://doi.org/10.28991/CEJ-2024-010-03-06
5) Areef, S., Amouri, L., El-Haggar, N., & Moneer, A. (2021, January 1). Exploring the socio-economic implications of artificial intelligence from higher education student's perspective. *Science and Information Organization, 12*(6). https://doi.org/10.14569/ijacsa.2021.0120641
6) Datta, S. D., Islam, M., Sobuz, M. H. R., Ahmed, S., & Kar, M. K. (2024, February 1). Artificial intelligence and machine learning applications in the project lifecycle of the construction industry: A comprehensive review. *Elsevier BV, e26888-e26888*. https://doi.org/10.1016/j.heliyon.2024.e26888
7) Hassan, O. (2020, January 1). Artificial intelligence, Neom and Saudi Arabia's economic diversification from oil and gas. *Wiley, 91*(1), 222-227. https://doi.org/10.1111/1467-923x.12794
8) Khayyat, M., & Alshaikhi, A. (2021). An investigation into the impact of artificial intelligence on the future of project management. *ResearchGate*.
9) Krishnan, S., & Krishnan, L. R. K. (2024). Impact of artificial intelligence on project delivery and implementation. *Vellore Institute of Technology*.
10) Mahmood, A., Al Marzooqi, A., El Khatib, M., & AlAmeemi, H. (2023). How artificial intelligence can leverage project management information system (PMIS) and data-driven decision-making in project management. *International Journal of Business Analytics and Security (IJBAS)*.
11) Merdžanović, I., Vukomanović, M., & Ivandić Vidović, D. (2023). A comprehensive literature review of research trends of applying AI to construction project management. *6th IPMA SENET Project Management Conference*.
12) Naggar, M., Alharbi, Z. A., Alanazi, A. M., Alsaiari, S. O., Alhemaidani, A. M., Alanazi, S. F., & Alanazi, M. M. (2023, August 2). Assessment of the perception and worries of Saudi healthcare providers about the application of artificial intelligence in Saudi health facilities. *Cureus, Inc.*. https://doi.org/10.7759/cureus.42858
13) Phaladi, M. G., Mashwama, X. N., Thwala, W. D., & Aigbavboa, C. O. (2022). A theoretical assessment on the implementation of artificial intelligence (AI) for an improved learning curve on construction in South Africa. *IOP Conference Series: Materials Science and Engineering, 1218*(1), 012003. https://doi.org/10.1088/1757-899X/1218/1/012003
14) Regona, M., Yiğitcanlar, T., Xia, B., & Li, R. Y. M. (2022, March 1). Opportunities and adoption challenges of AI in the construction industry: A PRISMA review. *Springer Science+Business Media, 8*(1), 45-45. https://doi.org/10.3390/joitmc8010045
15) Saudi Vision 2030. (2023, January 1). https://www.vision2030.gov.sa/en/vision-2030/overview
16) Sidawi, B., & Al-Sudairi, A. A. (2014, January 1). The use of advanced computer-based management systems by large Saudi companies for managing remote construction projects. *Elsevier BV, 77*, 161-169. https://doi.org/10.1016/j.proeng.2014.07.013
17) Taboada, I., Daneshpajouh, A., Toledo, N., & Vass, T. (2023, April 17). Artificial intelligence enabled project management: A systematic literature review.

18) Vision 2030 Annual Report. (2023, May 2). https://annualreport.vision2030.gov.sa/?_id=homepage__i18n_ar&_type=page&slug=/&locale=ar
19) Weng, J. (2023). Putting intellectual robots to work - Implementing generative AI tools in project management.
20) Zabala-Vargas, S., Jaimes-Quintanilla, M., & Jimenez-Barrera, M. H. (2023). Big data, data science, and artificial intelligence for project management in the architecture, engineering, and construction industry: A systematic review. *Buildings, 13*(12), 2944. https://doi.org/10.3390/buildings13122944
21) القلاف, رائد و الصائغ, رباب و عجيمي, إسماعيل و الفلفل, ماجد. الاستفادة من الذكاء الاصطناعي للابتكار في إدارة المشاريع استكشاف الإمكانيات والتطبيقات دراسة حالة التشوه البصري في أمانة مدينة جدة"". *المجلة العلمية للتجارة والتمويل, المجلد 44*(3), 1-29.