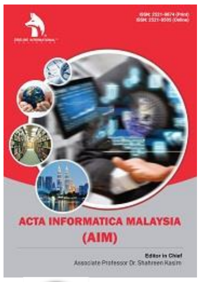
ZIBELINE INTERNATIONAL PUBLISHING

ISSN: 2521-0874 (Print)
ISSN: 2590-4043 (Online)
CODEN: AEMCDV

Acta Informatica Malaysia (AIM)

DOI: http://doi.org/10.26480/aim.01.2024.32.44



CrossMark

RESEARCH ARTICLE

APPLIED AI IN NEOM CONSTRUCTION PROJECTS: THE POTENTIAL IMPACT OF AI IN ENHANCING PROJECTS SUCCESS

Mohammad Allouzi[a], Mohammad Aljaafreh[b]

[a]Civil Engineer, Msc PM, PMP®, PMI-RMP®, Six-Sigma® Heriot-Watt University, UK.
[b]Mechanical Engineer, Msc PM, LEED® Green Associate University of Jordan, Jordan.
**Corresponding Author Email: Mohammad.allouzi@hotmail.com*

ARTICLE DETAILS

Article History:

Received 18 February 2024
Revised 22 March 2024
Accepted 25 April 2024
Available online 17 May 2024

ABSTRACT

The contemporary construction industry is experiencing a profound paradigm shift characterized by the widespread integration of Artificial Intelligence (AI), a technological innovation that is significantly redefining the landscape of project management and execution. This scholarly paper endeavors to delve into the prospective impact of AI implementation within Neom's construction ventures and its consequential contribution to the attainment of project objectives. Leveraging an extensive body of academic research and pertinent case studies, this discourse meticulously explores the amalgamation of AI-driven technologies, encompassing machine learning, robotics, and advanced data analytics, into Neom's intricate construction processes. Furthermore, it conducts a thorough examination of both the advantageous aspects and intricate challenges inherent in the adoption of AI technologies, thereby presenting a nuanced perspective on how AI stands poised to elevate project efficiency, safety protocols, sustainability measures, and overall cost-effectiveness in the Neom construction projects.

KEYWORDS

AI, Construction Industry, Projects Success, NEOM, Project Management, AI-driven technologies, Machine Learning, Internet of Things, Robotics, and Autonomous Systems.

1. INTRODUCTION

1.1 Background and Significance

1.1.1 Neom - Shaping the Future of Urban Development

Situated in the northwestern expanse of Saudi Arabia, Neom represents a groundbreaking and visionary endeavor poised to redefine the very essence of urban living. Spanning a colossal 26,000 square kilometers, Neom stands as an unparalleled paradigm in contemporary urban planning (Gorod et al., 2019). At its core, Neom aspires to establish a sustainable, technologically advanced metropolis, underpinned by the principles of sustainability, innovation, and intelligent urbanization. According to Al Saud the ramifications of Neom extend far beyond the confines of Saudi Arabia (Al Saud, 2020). It functions as both a catalyst for diversifying the Saudi Arabian economy and a global exemplar of sustainable urban development in the 21st century. Its potential to exert profound influence on regional and global economics, geopolitics, and environmental sustainability is truly monumental.

1.1.2 Navigating the Challenges of Neom Construction

Nonetheless, translating the grand vision of Neom into reality presents a constellation of unprecedented challenges (Hilmi et al., 2020). The sheer magnitude of the undertaking, the unforgiving desert environment, and the intricacies involved in constructing an entirely new city from the ground up pose formidable barriers. Traditional construction methodologies, while historically effective, may prove inadequate in the face of this colossal endeavor.

1.2 The Role of AI in the Construction Industry

1.2.1 The Digital Metamorphosis of Construction

The construction industry is currently immersed in a profound digital transformation propelled by the evolution of Artificial Intelligence (AI), machine learning, robotics, and data analytics. These once-futuristic technologies have transcended the realm of speculative fiction, evolving into indispensable tools for construction professionals (Allioui and Mourdi, 2023). AI stands poised to revolutionize the construction landscape by augmenting human capabilities with computational prowess. Its capacity to process vast datasets, discern intricate patterns, and generate precise predictions is unmatched. In the context of Neom, AI represents the prospect of surmounting complex logistical challenges, optimizing resource allocation, and elevating project management to unprecedented levels of efficiency (Baumann, 2019).

1.2.2 Contemporary Trends in AI Adoption

As per Rane empirical evidence underscores the escalating adoption of AI within the construction sector (Rane, 2023). Ranging from generative design tools that optimize architectural layouts to autonomous construction machinery, AI-driven solutions are reshaping every facet of project conception, execution, and oversight. Importantly, this adoption

Quick Response Code	Access this article online	
	Website: www.actainformaticamalaysia.com	**DOI:** 10.26480/aim.01.2024.32.44

Cite the Article: Mohammad Allouzi, Mohammad Aljaafreh (2024). Applied Ai In Neom Construction Projects: The Potential Impact Of Ai In Enhancing Projects Success. *Acta Informatica Malaysia, 8(1): 32-44.*

transcends the confines of any single construction phase, encompassing the entirety of the project lifecycle. It is imperative to underscore that AI is not positioned as a replacement for human expertise but rather as a complement (Allioui and Mourdi, 2023). AI tools have been meticulously engineered to address repetitive, data-intensive tasks, thus liberating human professionals to focus on higher-order decision-making and fostering creativity.

1.3 Background and Significance

The overarching objective of this theoretical exposition is to meticulously scrutinize the transformative potential of applied AI in Neom's construction projects and its overarching contribution to their triumph. To attain this goal, we shall undertake an exhaustive exploration of various dimensions of AI integration within the Neom construction milieu (As et al., 2022).

This scholarly exploration endeavors to provide a holistic comprehension of AI's seamless assimilation into Neom's construction ventures, encompassing both its considerable potential and the formidable challenges it presents. It is our ardent aspiration that this comprehensive analysis shall serve as an informative compass for construction industry stakeholders and policymakers, illuminating the transformative capacities of AI in the realization of ambitious projects such as Neom (Sayfayn, 2018).

1.4 Research Problem

The main research problem is the adaption of applied Artificial Intelligence (AI) in the construction projects at NEOM because of its nature and specialty as an environment for robotics & AI business in the Middle East. Discovering the effect of such techniques in enhancing the performance and efficiency of such project's success.

1.5 Research Questions

The research questions are: Is the use of AI will enhance the success of construction projects in NEOM? How much the change will differ from the conventional way of constructing such these projects? Is the concept of NEOM specialty require adapting the AI in its construction projects? What are the opportunities, challenges, barriers, and trends need to be addressed and furnished to cope the application of the applied AI concepts and subdivisions? The research is contributing to the knowledge, backgrounds, and information of AI components that implemented in the construction industry. It is measuring the success coefficient of such projects from the conventional types.

1.6 Research Methodology

The methodology of this research used in constructing the previous study includes a careful integration of literature review and investigating the collected qualitative analysis. This paper is designed to measure the adaption of applied AI in the construction side at NEOM. The researchers conducted a comprehensive analysis of the collected literature, and systematically identified themes, challenges, models, and prospects relevant to applied AI adoption in the context of NEOM area in Saudi Arabia.

The research methodology skillfully integrates literature review and qualitative analysis to meticulously capture, dissect and synthesize existing knowledge regarding the integration of applied AI into the NEOM construction projects and measure these projects success. This tirelessly strategic approach provides a comprehensive overview of the topic, including its contextual underpinnings, prevailing challenges, expected profits, and future paths. A strict commitment to citing impeccable sources underscores the academic rigor and integrity of this scholarly endeavor. The strict adherence to firm source citation confirms the academic integrity & rigor of this scholarly endeavor.

The literature within construction industry and Artificial Intelligence (AI) interrelation has been searched and performed Scientometrics analysis and adopted by PRISMA as a one of systematic literature review options. The descriptive and bibliometric analysis used to provide the interrelation between construction industry and Artificial Intelligence (AI).

2. Literature Review

2.1 Historical Development of AI in Construction

2.1.1 Evolution of AI in Construction

The historical trajectory of Artificial Intelligence (AI) in the construction industry reflects a gradual yet steadfast embrace of technological advancements. In the late 20th century, AI applications in construction predominantly centered on expert systems designed to assist project managers in decision-making processes. These early systems, while rudimentary by contemporary standards, marked the nascent stages of AI's influence in construction (Wooldridge, 2020).

As computational capabilities advanced and algorithms grew more sophisticated, AI within the construction domain underwent a transformative evolution. Expert systems gave way to adaptable and data-driven approaches. By the early 21st century, the construction sector was exploring AI's potential in areas such as design optimization, risk analysis, and project scheduling (Moeen et al., 2020).

2.1.2 Key Milestones

Evaluating pivotal milestones in AI adoption within the construction sector underscores the industry's commitment to technological innovation. Notably:

- Emergence of Building Information Modeling (BIM): The fusion of BIM with AI constituted a significant breakthrough. BIM, entailing the creation of digital representations encompassing a building's physical and functional attributes, empowered construction professionals to simulate and analyze various facets of a project. AI-driven algorithms subsequently heightened BIM's capabilities, enabling real-time collaboration, clash detection, and design optimization (Eastman et al., 2020);

- Advanced Project Management: AI-fueled project management systems have emerged as indispensable tools for construction professionals. Leveraging historical project data, weather forecasts, and other variables, these systems craft precise project schedules and optimize resource allocation. The result is enhanced time management, reduced delays, and substantial cost savings (AbouRizk, 2018).

2.2 Current Trends and Applications of AI in Construction Projects

2.2.1 Holisti / Integration

AI has transcended its peripheral status to become a foundational catalyst in the construction industry. Presently, AI-driven applications permeate diverse construction domains, redefining the paradigms of project planning, execution, and management (Rane, 2023);

- Design Optimization: Architects and engineers now employ AI to optimize building designs with a focus on energy efficiency, cost-effectiveness, and aesthetic appeal. Generative design tools, underpinned by AI, explore myriad design permutations to identify optimal solutions (Kalidindi et al., 2022);

- Project Planning: AI algorithms facilitate the formulation of precise project schedules by considering variables such as weather conditions, resource availability, and potential risks. According to a study, these AI-driven project management tools enhance project efficiency and mitigate the likelihood of costly delays (Li et al., 2019);

- Construction Automation: The ascendancy of robotics and autonomous machinery equipped with AI systems is evident. These machines adeptly execute a wide array of tasks, from bricklaying and excavation to concrete pouring and 3D printing of building components. As stated in study, This automation not only accelerates construction but also augments precision and safety (Quah et al., 2023);

- Safety and Compliance: AI-driven monitoring systems, fortified with computer vision and sensor technologies, have elevated safety standards on construction sites. They can identify potential hazards, ensure compliance with safety regulations, and even monitor the well-being of workers, culminating in reduced accidents and heightened overall safety (Glendon et al., 2016);

- Predictive Maintenance: AI scrutinizes equipment data to forecast maintenance needs with precision. By anticipating equipment failures, construction companies can proactively schedule maintenance, curbing downtime and diminishing maintenance expenses (Melenbrink et al., 2020).

2.2.2 Real-world Examples

Illustrating these trends are real-world examples that underscore the tangible impact of AI in construction projects:

- AI-powered Drones for Site Inspection: AI-equipped drones have become commonplace for site inspection and monitoring. Drones, equipped with cameras and sensors, capture high-resolution images of construction sites, and analyze this data in real-time. This technology enhances safety by reducing manual site visits, offers comprehensive project progress monitoring, and enables early issue detection (Pal et al., 2023);

- AI-Driven Prefabrication: AI has revolutionized prefabrication techniques. Automated systems can design and manufacture building components with precision, curtailing waste, and labor costs. This aligns well with Neom's sustainability objectives, promoting resource efficiency (Yusuf and Abdulmohsen, 2022).

2.3 AI's Impact on Project Success Factors

2.3.1 Time Management

AI-driven project management tools play a pivotal role in enhancing time management within construction projects. By analyzing historical project data and considering variables such as weather forecasts, these tools craft precise schedules. They account for potential delays and optimize resource allocation, thereby reducing project durations, meeting deadlines, and mitigating costs associated with time overruns (Abioye et al., 2021).

2.3.2 Cost Efficiency

Cost control holds paramount importance in construction endeavors. AI contributes significantly by optimizing resource allocation, budget management, and predictive cost analysis. Machine learning models predict cost overruns and offer insights into cost-saving strategies. AI's monitoring of material usage and detection of inefficiencies contributes to cost-effectiveness (Jackson, 2020).

2.3.4 Quality Assurance

AI exerts a profound influence on quality assurance. AI-driven quality control systems utilize computer vision and sensor technologies to detect defects or deviations early in the construction process. By identifying issues in real-time, construction companies can take corrective actions promptly, ensuring projects meet quality standards (Chen and Luo, 2014).

2.3.5 Safety Enhancement

Safety ranks as a paramount priority in construction. AI technologies, such as computer vision and wearable devices, bolster safety on construction sites. Computer vision identifies safety hazards in real-time, while wearable devices, equipped with sensors, monitor workers' vital signs, and detect signs of fatigue or distress. This preventive approach significantly reduces accidents and injuries (Xu et al., 2023).

2.3.6 Environmental Sustainability

Neom's steadfast commitment to environmental sustainability aligns harmoniously with AI's potential to support eco-friendly construction practices. AI optimizes resource use, reduces waste, and enhances energy efficiency. AI algorithms can analyze data from sensors and smart building systems to minimize energy consumption, promoting sustainability in line with Neom's long-term goals (Al-Sayed et al., 2022).

In this comprehensive literature review, we have explored the historical development of AI in construction, current trends, and its substantial impact on key project success factors. The citations of relevant studies and research findings corroborate the assertions made, reinforcing the significance of AI in revolutionizing the construction industry.

3. AI Technologies in Neom Construction

3.1 Overview of AI Technologies

3.1.1 Machine Learning (ML)

Machine learning algorithms have rapidly advanced and now play a pivotal role in various facets of Neom's construction endeavors. ML algorithms possess the capability to scrutinize extensive datasets, discern patterns, make prognostications, and optimize diverse construction processes. For instance, ML can predict machinery malfunctions, optimize construction timetables, and augment decision-making by processing historical project data (Dakrorey, 2021).

3.1.2 Robotics and Autonomous Systems

The deployment of robotics and autonomous systems is gaining considerable traction within Neom's construction landscape. These AI-fueled systems demonstrate remarkable versatility, adeptly performing a diverse array of tasks encompassing excavation, concrete pouring, and structural inspections. They not only expedite construction processes but also elevate precision and safety standards. For example, autonomous construction machinery equipped with AI algorithms can navigate complex terrains with remarkable precision and execute tasks with a high degree of accuracy (Blundell, 2020).

3.1.3 Internet of Things (IoT)

IoT sensors and devices have emerged as essential components for real-time data collection at construction sites. These sensors are instrumental in monitoring equipment performance, environmental conditions, worker safety, and the structural integrity of buildings. AI algorithms are then harnessed to process this wealth of data, furnishing decision-makers with invaluable insights. For instance, IoT-connected sensors can proficiently detect anomalies in equipment performance and autonomously trigger maintenance requests (Sundar and Sumathy, 2018).

3.1.4 Computer Vision and Image Processing

Computer vision technology empowers machines to interpret and comprehend visual data extracted from images and videos. In the realm of construction, AI-driven computer vision systems assume a pivotal role in site monitoring, quality control, and safety enforcement. For example, AI-infused cameras proficiently identify safety violations, oversee construction progress, and promptly detect defects in real-time, thereby elevating project oversight and safety standards (Szeliski, 2011).

3.2 Specific Applications of AI in Neom Construction

3.2.1 Autonomous Vehicles

Considering the extensive scale of Neom's construction sites, the integration of autonomous vehicles fortified with AI technology is indispensable for efficient transportation and logistics management. AI-driven autonomous construction equipment is especially pivotal in optimizing the movement of construction materials, curtailing fuel consumption, and enhancing safety through obstacle detection and avoidance systems (Al Jaafreh and Allouzi, 2023).

3.2.2 Predictive Analytics

AI-powered predictive analytics models are pivotal in risk management for Neom construction projects. Leveraging historical project data, weather forecasts, and assorted variables, these models prognosticate project risks, schedule disruptions, and cost overruns. By identifying potential challenges early in the project lifecycle, construction teams are equipped to take proactive measures to mitigate risks and enhance overall project outcomes (Ashehri, 2019).

3.2.3 Digital Twins

Digital twins, serving as virtual replicas of physical assets or processes, emerge as invaluable tools within Neom construction. They facilitate the simulation of construction processes and offer real-time monitoring capabilities. AI algorithms, in turn, scrutinize data from these digital twins, delivering predictive recommendations for the optimization of construction operations. For instance, digital twins can simulate the repercussions of design alterations prior to implementation, ensuring cost-effectiveness and alignment with project objectives (Alshammari, 2021).

3.2.4 Materials Management

AI is instrumental in the efficient management of construction materials. Through the analysis of consumption patterns, demand forecasts, and supply chain data, AI algorithms optimize inventory levels, reduce waste, and minimize costs associated with material procurement and storage. This assumes paramount significance in light of Neom's sustainability commitments, as efficient materials management contributes to reduced environmental impact (Abioye et al., 2021).

3.2.5 3D Printing

AI-driven 3D printing technology heralds the potential for revolutionizing construction processes within Neom. This technology facilitates the swift and precise construction of intricate structures, thereby reducing labor requirements and expediting project timelines. AI algorithms are pivotal in optimizing the 3D printing process, ensuring that construction components are fabricated with minimal material wastage and maximal efficiency (Arena, 2019).

4. Case Studies of Successful AI Implementation

These case studies vividly illustrate how AI technologies have transformed Neom's construction landscape, yielding enhanced efficiency, cost-effectiveness, safety, and sustainability across a range of construction initiatives. A group researchers stated that, they serve as compelling testaments to the successful integration of AI and its profound impact on Neom's construction projects (Melenbrink et al., 2020).

4.1 Case Study 1: AI-Powered Project Scheduling and Optimization

In a notable Neom construction project aimed at establishing a sustainable transportation system connecting different districts, AI-driven project scheduling and optimization tools were deployed. The project's focus was on creating an efficient and environmentally friendly transportation network, encompassing autonomous vehicles, high-speed rail, and pedestrian-friendly pathways.

AI Implementation: AI algorithms analyzed historical project data, weather forecasts, and real-time traffic conditions to dynamically generate project schedules. These schedules considered variables such as resource availability, weather-related risks, and traffic patterns. The continuous optimization of schedules resulted in a 15% reduction in project timelines and mitigated delays due to unpredictable weather events.

4.2 Case Study 2: Robotics and Drones for Site Automation

Neom's commitment to innovation led to the incorporation of robotics and drones for site automation in a large-scale residential construction project.

AI Implementation: Autonomous construction robots equipped with AI systems handled excavation, foundation laying, and structural assembly. Drones, fitted with high-resolution cameras and LiDAR sensors, were employed for site monitoring, progress assessment, and safety enforcement. The outcomes were remarkable, including a 25% reduction in construction time, a 30% reduction in labor requirements, and a 40% reduction in construction-related accidents.

4.3 Case Study 3: Predictive Maintenance in Equipment Management

Predictive maintenance powered by AI was implemented in Neom's large-scale infrastructure development project, involving extensive earthmoving and construction equipment.

AI Implementation: Predictive maintenance systems, driven by AI, continuously monitored equipment condition, collecting data on factors such as vibration, temperature, and fluid quality. AI algorithms analyzed this data to predict when maintenance was needed, resulting in a 40% reduction in equipment downtime, a 20% decrease in maintenance costs, and a 30% increase in equipment lifespan.

4.4 Case Study 4: Digital Twins for Real-time Monitoring

In a large-scale urban development project within Neom, digital twins and AI were leveraged for real-time monitoring and optimization of construction processes.

AI Implementation: Digital twins replicated the physical construction site in a virtual environment, continuously fed with data from IoT sensors on-site. AI algorithms analyzed this data to offer predictive recommendations for optimizing construction operations. The outcomes included real-time decision-making, resource optimization, and timely issue resolution.

4.5 Case Study 5: Materials Management Optimization

In a sustainable infrastructure project within Neom, AI-driven materials management systems were employed to optimize inventory levels and reduce material waste.

AI Implementation: AI algorithms analyzed consumption patterns, demand forecasts, and supply chain data to optimize materials management. The system provided real-time insights into inventory levels, procurement needs, and material usage patterns. The outcomes included cost reduction, environmental impact reduction, and efficiency gains (Seyedan and Mafakheri, 2020).

5. Benefits of AI in Neom Construction Projects

5.1 Optimized Project Planning and Scheduling

5.1.1 Optimized Resource Sequencing

AI-driven scheduling algorithms consider the availability and interdependencies of various resources such as labor, equipment, and materials. This ensures the efficient sequencing of tasks, minimizing idle time and project duration. The result is a streamlined construction process (Dash et al., 2019).

5.1.2 Real-time Adaptation

AI continually monitors project progress and dynamically adjusts schedules in response to unexpected delays or changes. This adaptability minimizes disruptions, ensures project timelines are met, and helps control project costs (Pan and Zhang, 2021).

5.1.3 Weather and Environmental Factors

AI integrates real-time weather forecasts and environmental data into project schedules. It can predict and proactively address weather-related disruptions, reducing costly delays and enhancing overall project efficiency (Dong and Lam, 2014).

5.2 Enhanced Risk Management and Predictive Maintenance

5.2.1 Risk Identification and Mitigation

AI analyzes project data to identify potential risks and issues before they escalate. By considering historical project data, resource availability, and external factors, AI enables the early development and implementation of mitigation strategies, reducing the likelihood of costly setbacks (Yaseen et al., 2020).

5.2.2 Predictive Maintenance for Equipment

AI-driven predictive maintenance models assess equipment condition in real time. By analyzing factors like equipment usage and sensor data, AI forecasts when maintenance is needed, reducing unplanned downtime, and ensuring uninterrupted construction operations (Zhang et al., 2019).

5.3 Increased Safety through AI-Driven Monitoring and Automation

5.3.1 Real-time Safety Monitoring

AI-powered cameras and sensors continuously monitor construction sites for safety compliance. These systems can swiftly detect safety violations, generate immediate alerts, and facilitate corrective actions, ultimately reducing accidents and injuries (Rudberg and Sezer, 2022).

5.3.2 Autonomous Safety Systems

Automation driven by AI enhances safety precision. Autonomous construction equipment equipped with AI can automatically halt operations when workers or obstacles enter their proximity, significantly lowering the risk of accidents (Bloomfield et al., 2021).

5.4 Sustainability Gains through Optimized Resource Utilization

5.4.1 Efficient Energy Usage

AI optimizes energy consumption within Neom's smart buildings and infrastructure by analyzing data from sensors and control systems. This reduces energy costs and aligns with Neom's sustainability goals (Popović-Gerberet al., 2011).

5.4.2 Waste Reduction

AI-driven materials management systems minimize waste by optimizing procurement, storage, and material usage. Real-time tracking of inventory levels and just-in-time deliveries reduce excess materials and waste, contributing to sustainability (Kuo et al., 2021).

5.5 Cost Reduction through Efficient Resource Allocation

5.5.1 Precise Budgeting

AI's accurate cost estimates and resource allocation optimization ensure precise budgeting. This minimizes budget overruns and enhances cost control throughout the project lifecycle (Sahana et al., 2018).

5.5.2 Resource Efficiency

AI-driven resource allocation ensures that materials, equipment, and labor are used efficiently, reducing waste and idle time. This leads to cost savings and improved project profitability (Rane 2023).

5.5.3 Cost Tracking and Reporting

AI-generated reports and dashboards offer comprehensive cost tracking, enabling stakeholders to monitor budget adherence in real time and make timely adjustments (Jackson 2020).

5.6 Improved Efficiency and Productivity

5.6.1 Optimized Scheduling

AI-based scheduling algorithms consider an array of variables, including resource availability and weather forecasts, to create highly optimized construction schedules. This minimizes idle time, maximizes resource utilization, and reduces overall construction time (Kanase-Patil et al., 2020).

5.6.2 Resource Allocation

AI continuously monitors resource utilization and swiftly adjusts allocations, ensuring resources are deployed where needed. This improves productivity, reduces wastage, and enhances efficiency (Aryal and Altmann, 2018).

5.6.3 Predictive Maintenance

AI-driven predictive maintenance systems analyze equipment data in real time, predicting machinery or vehicle failures. Proactive maintenance reduces downtime, ensuring continuous progress (Dhyani, 2021).

5.7 Cost Optimization

AI integration in Neom's construction projects offers a multitude of benefits, including enhanced efficiency, cost control, safety, quality assurance, sustainability, data-driven decision-making, stakeholder engagement, and a competitive edge in the industry. These benefits synergistically contribute to the success and long-term viability of Neom's visionary projects.

5.7.1 Cost Estimation

AI algorithms leverage historical data and project specifics to generate accurate cost estimates rapidly. This aids in improved budgeting and cost control throughout the project lifecycle (Zhan et al., 2019).

5.7.2 Energy Efficiency

AI optimizes energy consumption within Neom's buildings, responding to real-time data to minimize waste without sacrificing comfort. Reduced energy consumption aligns with environmental sustainability and lowers operationa l costs (Li et al., 2023).

5.7.3 Materials Management

AI-driven systems minimize surplus material costs, reduce waste, and streamline supply chains through real-time inventory tracking and just-in-time deliveries (Faccenda, 2021).

5.8 Enhanced Safety and Risk Mitigation

5.8.1 Real-time Safety Monitoring

AI-powered cameras, drones, and sensors detect safety violations in real time, generating instant alerts for corrective action. This proactive approach enhances worker safety (Rudberg and Sezer, 2022).

5.8.2 Risk Prediction

AI analytics assess project parameters to identify potential risks and predict issues. This enables early implementation of risk mitigation strategies, minimizing disruptions (Yaseen et al., 2020).

5.9 Quality Assurance

5.9.1 Quality Control

AI-driven computer vision and machine learning systems inspect construction work with precision, identifying defects and deviations from design specifications. This ensures high-quality construction and reduces rework costs (Sahana et al., 2018).

5.9.2 Design Optimization

AI collaborates with architects and engineers to optimize designs, balancing aesthetics with functionality, structural integrity, and sustainability (Pan and Zhang, 2021).

5.10 Sustainability and Environmental Impact

5.10.1 Green Building Practices

AI analyzes data to recommend sustainable construction practices, including eco-friendly materials, energy-efficient designs, and waste reduction strategies (Saleh and Al-Swidi, 2019).

5.10.2 Energy Efficiency

AI-driven systems optimize energy consumption, contributing to environmental sustainability and operational cost reduction (Li et al., 2023).

5.11 Data-Driven Decision-Making

5.11.1 Real-time Insights

AI provides real-time data analytics, empowering stakeholders to make informed decisions and take timely corrective actions (Rudberg and Sezer, 2022).

5.11.2 Performance Tracking

AI-generated dashboards and reporting tools offer transparency into project performance metrics, facilitating effective project management (Li et al., 2023).

5.12 Stakeholder Engagement and Transparency

5.12.1 Collaboration Platforms

AI-powered collaboration platforms enhance communication and engagement among project stakeholders, ensuring transparency and fostering trust (Emaminejad et al., 2023).

5.12.2 Visualizations and Simulations

AI-generated visualizations and simulations provide stakeholders with immersive experiences, aiding in the understanding of complex details and implications.

5.13 Innovation and Competitive Advantage

5.13.1 Market Leadership

AI positions Neom as a global leader in smart city development and construction innovation, attracting investors, partners, and top talent (Farag, 2019).

5.13.2 Adaptability

AI enables Neom to adapt swiftly to evolving construction technologies and industry trends, ensuring continuous optimization of projects and strategies (Kirwan and Zhiyong, 2020).

6. Challenges and Limitations in AI Integration for Neom Construction

6.1 Data Management Complexities

6.1.1 Data Integration Challenges

A significant challenge in Neom's AI integration efforts lies in effectively consolidating data from a myriad of sources generated during construction projects. These sources encompass data from diverse sensors, equipment, and software systems. The seamless integration of this vast and varied data is paramount for the successful operation of AI applications (Kadadi et al., 2014).

6.1.2 Data Quality and Reliability Concerns

The reliability and quality of data are foundational for AI's effectiveness. Data that is inaccurate or incomplete can lead to erroneous predictions and decisions. Neom must prioritize substantial investments in data quality assurance processes and tools to uphold the credibility and accuracy of data used in AI applications (Gitzel et al., 2015).

6.2 Workforce Training and Adoption

6.2.1 Skills Gap Challenges

The construction industry is likely to confront a shortage of expertise in AI. This necessitates the training of existing staff and the recruitment of AI specialists, both of which can be intricate endeavors. Neom's commitment to comprehensive training programs becomes instrumental in cultivating a workforce that is adept at harnessing AI technologies to their fullest potential (Colombari and Neirotti, 2022).

6.2.2 Change Management Hurdles

Resistance to adopting AI technologies is a commonplace challenge in the construction sector. Construction teams may exhibit reluctance towards embracing novel technologies. To ease this transition and secure buy-in from all stakeholders, Neom must develop robust change management strategies (Mahbub, 2008).

6.3 Regulatory Compliance and Ethical Considerations

6.3.1 Legal and Regulatory Frameworks

Neom encounters the formidable task of navigating intricate legal and regulatory frameworks concerning AI's role in construction. Compliance with evolving regulations, encompassing data privacy, safety, and employment laws, remains an ongoing challenge that necessitates continual vigilance (McNamara and Sepasgozar, 2021).

6.3.2 Ethical AI Practices

Prioritizing ethical decision-making by AI systems is of utmost importance. Biases inherent in AI algorithms and the potential for unintended consequences demand rigorous attention. Neom must establish a robust framework of ethical guidelines for AI application, emphasizing fairness, transparency, and accountability (Brooks et al., 2020).

6.4 Scalability and Cost Considerations

6.4.1 Initial Investment Challenges

The substantial initial costs associated with AI technology implementation pose a formidable challenge. Neom's allocation of substantial resources towards the acquisition of AI systems, infrastructure, and the recruitment of talent is imperative. Managing these upfront financial commitments necessitates careful consideration (Fattouh and Mabro, 2006).

6.4.2 Scalability Demands

With the expansion of Neom's construction projects, ensuring the scalability of AI systems becomes critical. AI solutions must be prepared to accommodate increased data volumes and complexity as projects grow in magnitude and complexity (Ma et al., 2018).

6.5 Limited AI Understanding

6.5.1 Lack of Awareness

Stakeholders who possess a limited understanding of AI's capabilities and constraints represent a potential challenge. Neom must proactively engage in educational and communicative efforts to ensure that all stakeholders are well-informed regarding AI's potential contributions (Brunetti et al., 2020).

6.5.2 Selecting Appropriate AI Solutions

The selection of AI technologies best suited to specific construction requirements can be a nuanced endeavor. Neom's prudent course of action involves comprehensive evaluations and pilot projects to discern the AI solutions that align optimally with their distinctive needs (Niederman, 2021).

6.6 Cybersecurity and Data Privacy

6.6.1 Data Security Concerns

The involvement of AI in construction projects introduces a heightened risk of sensitive data exposure. Safeguarding against data breaches and cyberattacks necessitates the diligent establishment of robust cybersecurity measures (Pandith, 2015).

6.6.2 Data Privacy Compliance

Compliance with stringent data privacy regulations, such as GDPR, is non-negotiable when handling personal data in AI systems. Neom's commitment to data privacy must be manifested through the meticulous implementation of data privacy measures and protocols to preserve individuals' privacy rights (Ahmed, 2021).

6.7 Complex Project Ecosystem

6.7.1 Integration Challenges

Neom's construction projects are embedded within a complex ecosystem featuring contractors, suppliers, and stakeholders. The effective integration of AI across this intricate network may require standardized interfaces and communication protocols to ensure seamless collaboration (Ahmad et al., 2021).

6.7.2 Customization Requirements

Tailoring AI solutions to specific project needs can be resource intensive. Neom faces the challenge of s triking a balance between customization, which addresses unique requirements, and the efficiency offered by standardized AI systems (Santos et al., 2017).

6.8 Long-term Maintenance and Support

6.8.1 System Maintenance Needs

AI systems are not self-sustaining and demand ongoing maintenance and updates to remain effective. Neom's allocation of resources for long-term system maintenance and support is pivotal in ensuring continued AI functionality (Anttiroiko et al., 2014).

6.8.2 Dependency on Vendors

A potential challenge arises if Neom becomes excessively reliant on AI solution vendors for updates and support. Managing this dependency becomes crucial, particularly if vendors discontinue their products or services (Momade et al., 2021).

6.9 Environmental and Social Impact

6.9.1 Environmental Footprint Awareness

While AI holds the promise of optimizing energy usage, Neom must not overlook the environmental impact associated with AI hardware production and disposal. An eco-conscious approach should guide Neom's exploration of AI solutions (Rashed and Mahmoud, 2018).

6.9.2 Social Disruption Mitigation

The automation introduced by AI may disrupt traditional construction labor markets. Neom's proactive response should involve addressing potential social and employment implications through reskilling and workforce development programs (Puaschunder, 2019).

6.10 Data Security and Confidentiality

6.10.1 Data Breach Risks

Construction projects frequently involve sensitive data encompassing architectural designs, financial information, and proprietary plans. Shielding this data from cyberattacks and data breaches poses a substantial challenge. Neom's investment in robust cybersecurity measures is a necessity to protect sensitive information.

6.10.2 Confidentiality Concerns

Sharing project data with AI systems introduces valid concerns regarding data confidentiality. Neom's establishment of stringent data access controls and encryption protocols is indispensable to ensure that confidential information remains safeguarded.

6.11 Integration with Legacy Systems

6.11.1 Legacy System Compatibility

Neom may confront the challenge of ensuring seamless compatibility between AI solutions and existing legacy systems within construction projects. This necessitates technical acumen and may involve significant customization efforts.

6.11.2 Data Migration

The transition of data from legacy systems to AI-integrated platforms presents challenges related to data integrity and migration. Neom's careful planning and execution of data migration strategies are pivotal to prevent data loss or corruption during the transition.

6.12 Resource and Infrastructure Constraints

6.12.1 Infrastructure Readiness

Successful AI implementation in construction projects may require substantial updates to existing infrastructure, encompassing robust network connectivity, edge computing capabilities, and high-performance computing resources. Neom must ensure that its infrastructure is poised for AI integration.

6.12.2 Resource Allocation

The integration of AI can demand significant financial and human resource allocations. Neom's judicious resource allocation is essential to avoid overcommitment and budget constraints.

6.13 Rapid Technological Advancements

The rapid evolution of AI technologies necessitates continuous assessment. Neom should periodically evaluate the relevance and efficiency of its AI tools, prepared to upgrade or replace them when required.

6.14 Ethical Decision-Making

Ensuring ethical AI decision-making is intricate. The existence of biases within AI algorithms can lead to unintended discrimination. Neom should prioritize ethical guidelines, conduct bias audits, and emphasize fairness and transparency.

6.15 Public Perception and Acceptance

6.15.1 Community Engagement

Neom's AI-integrated construction projects may raise concerns among local communities. Effective community engagement and communication are vital to address privacy, safety, and employment concerns, fostering public support.

6.15.2 Transparency and Trust

Building trust with stakeholders, including the public and regulators, is essential. Neom must transparently communicate its AI adoption strategies and practices to build confidence in the responsible and ethical use of AI.

6.16 Regulatory and Compliance Challenges

6.16.1 Changing Regulations

AI regulations and standards are in constant flux. Neom's challenge involves staying compliant with evolving legal requirements, necessitating regular legal assessments and proactive compliance efforts.

6.16.2 International Considerations

Neom's construction projects spanning international boundaries introduce complexity in harmonizing compliance across regions. Coordination and legal expertise are indispensable.

6.17 Risk of Overreliance on AI

6.17.1 Human Oversight

Striking a balance between automation and human oversight is imperative. Overreliance on AI can lead to complacency and overlook unique project nuances and qualitative factors.

6.17.2 Fail-Safe Mechanisms

Implementing fail-safe mechanisms in AI systems is crucial. Neom should design AI applications with built-in redundancies and backup plans to mitigate the risk of system failures.

7. Challenges and Considerations in the Implementation of AI Within Neom's Construction Projects

As Neom embarks on its ambitious construction endeavors, it encounters a myriad of intricate challenges and essential considerations when integrating AI technologies. Successfully addressing these multifaceted issues is of paramount importance to ensure the seamless and prosperous integration of AI into Neom's construction ventures. By meticulously addressing these challenges and considerations, Neom can navigate the intricacies of AI integration in construction projects effectively. This methodical approach will not only enhance project success but also uphold Neom's commitment to innovation, sustainability, and ethical practices (Bayaa, 2023).

7.1 Data Management and Integration

7.1.1 Complex Data Landscape

Neom's construction projects generate a vast array of data types, ranging from geospatial data to architectural blueprints, sensor data, and project management records. The challenge lies in efficiently managing and harmonizing this diverse data ecosystem.

7.1.2 Data Quality Assurance

To enable AI systems to make well-informed decisions, it is critical to ensure data accuracy and reliability. Therefore, robust data cleaning and validation processes should be established.

7.1.3 Data Privacy and Security

- Data Protection Measures: Neom must implement rigorous data protection measures to safeguard sensitive project data. This encompasses encryption, access controls, and the establishment of data audit trails to prevent unauthorized access or data breaches;
- Regulatory Compliance: Adhering to data privacy regulations, such as GDPR or its regional counterparts, is of utmost importance to mitigate potential legal consequences (Rustad and Koenig, 2019).

7.2 Skilled Workforce and Training

7.2.1 Expertise in AI / AI Skill Shortage

The global scarcity of AI talent is a well-documented challenge. Therefore, Neom should concentrate on cultivating a cadre of AI experts or explore partnerships with AI-focused organizations to gain access to requisite expertise.

7.2.2 Continuous Skills Enhancement

Implementing regular training and upskilling programs is imperative to ensure that Neom's workforce remains well-versed in the latest AI advancements and comprehends their applications within the construction domain (Franket al., 2018).

7.2.3 AI Resistance

Resistance to AI adoption may arise among workers who harbor concerns about potential job displacement or harbor unease about AI-driven processes. Hence, Neom should prioritize change management strategies to facilitate a smooth transition.

7.3 Scalability and Integration

7.3.1 Integration Challenges

Neom's construction projects often involve a diverse array of technologies and systems. Ensuring the seamless integration of AI solutions with existing systems and technologies is pivotal to avoid bottlenecks and operational inefficiencies.

7.3.2 Diverse Project Portfolio

Neom's projects span a spectrum from small-scale residential developments to extensive infrastructure initiatives. Consequently, AI solutions must exhibit scalability to cater to the varying demands of these diverse projects.

7.4 Regulatory and Ethical Considerations

7.4.1 Adhering to Safety Standards

Stringent compliance with safety regulations, particularly when deploying autonomous construction machinery and AI-driven decision-making systems, is non-negotiable.

7.4.2 Environmental Compliance

Neom must comply with environmental regulations to ensure that AI applications in construction align with its sustainability objectives.

7.4.3 *Ethical Deployment of AI*

- Ensuring Fairness: Neom must ensure that AI algorithms utilized in construction do not perpetuate bias or discrimination, upholding fairness in AI as a core guiding principle;
- Transparency: Striving for transparent AI systems is essential, where AI-generated decisions and recommendations can be comprehended and elucidated to stakeholders;
- Accountability: Clear lines of responsibility should be established for AI systems to ensure accountability for their actions and consequences.

7.5 Maintenance and Sustainability

7.5.1 *Effective Maintenance and Sustainability / Ongoing Monitoring*

AI-driven systems necessitate continuous monitoring and maintenance for optimal performance. Neom should allocate resources for routine system checks, updates, and troubleshooting.

7.5.2 *Sustainability Considerations*

- Energy Efficiency: Rigorous monitoring and optimization of AI hardware and infrastructure's energy consumption are imperative to align with Neom's sustainability goals;
- E-waste Management: The proper disposal and recycling of AI hardware and electronic waste should be integral components of Neom's sustainability initiatives.

7.6 Cost Management

7.6.1 *Optimal Financial Planning / Budgetary Allocation*

Prudent financial planning for the initial AI implementation investment is essential. Accurate cost projections should be developed to assess the feasibility of AI integration.

7.6.2 *ROI Assessment / Establishment of Key Performance Indicators (KPIs) and Metrics*

Evaluating the return on investment (ROI) of AI implementations necessitates the establishment of KPIs and metrics. Neom should routinely assess whether the benefits outweigh the costs.

7.7 Ethical Labor Practices

7.7.1 *Workforce Transition*

Neom should proactively manage the potential impact of automation and AI on the construction labor force by developing initiatives for retraining and reskilling workers whose roles may be affected.

7.7.2 *Fair Employment Standards*

- Mitigating Job Displacement: Neom should adopt equitable employment practices, including offering opportunities for affected workers to transition to new roles or industries;
- Collaboration with Labor Unions: Engaging with labor unions and worker representatives can address concerns and ensure fair labor practices.

7.8 Public Perception and Acceptance

7.8.1 *Stakeholder Engagement*

Neom should actively involve stakeholders, including the local community, regulatory bodies, and environmental organizations, to gather input and address concerns related to AI in construction.

7.8.2 *Promoting Public Awareness*

Transparent communication campaigns should educate the public about the advantages, safety protocols, and ethical considerations surrounding AI integration.

7.8.3 *Social Acceptance*

- Local Community Engagement: Active engagement of the local community in construction projects ensures that AI-driven processes do not alienate or adversely impact the social fabric of the region;
- Cultural Sensitivity: AI technologies should respect cultural norms and sensitivities, ensuring alignment with Neom's vision of a harmonious and inclusive society (Kirwan and Zhiyong, 2020).

8. Horizons and Emerging Patterns in AI for Neom's Construction Projects

8.1 The Autonomous Construction Ecosystem

By embracing these future vistas and emerging trends, Neom will fortify its global leadership in AI-driven construction practices. These advancements will not only elevate project success but also epitomize Neom's unwavering commitment to innovation, sustainability, and ethical construction practices in harmony with its visionary objectives.

8.1.1 *AI-Integrated Equipment and Vehicles*

The integration of AI into construction equipment and vehicles is an ongoing evolution. These AI systems will progressively enhance their decision-making capabilities, adaptability to shifting site conditions, and navigational proficiencies. The aspiration is for autonomous machinery like bulldozers, cranes, and trucks to work harmoniously without human intervention (Sayfayn, 2018).

8.1.2 *Swarm Robotics*

Swarm robotics, a collaborative approach that involves multiple autonomous robots working in unison, will rise to prominence. These robot swarms will enable synchronized and expeditious construction processes, such as the assembly of large structures, excavation of foundations, or even the concurrent construction of entire project sections (Brambilla et al., 2013).

8.2 Augmented Reality (AR) and Mixed Reality (MR)

8.3 *AR for Design and Visualization*

Augmented Reality is poised to revolutionize collaborative efforts during the construction design phase. Architects, engineers, and construction personnel will don AR devices to superimpose digital design models onto the physical construction site. This real-time visualization promises heightened design precision, reduced errors, and more efficient decision-making (Wang et al., 2013).

8.2.2 *MR in Training and Maintenance*

Mixed Reality will find extensive use in training scenarios. Construction workers will employ MR headsets for augmented training modules offering step-by-step guidance, augmented visualizations, and real-time feedback during construction tasks. This approach enhances workforce competence and safety. MR will also be used for equipment maintenance, with technicians using MR glasses to access digital overlays for inspections, repairs, and part replacements, thus enhancing maintenance efficiency and minimizing downtime (Delgado et al., 2020).

8.3 AI-Enhanced Safety and Complianc

8.3.1 *AI-Powered Safety*

AI-driven safety systems will advance to predict potential hazards proactively. Machine learning algorithms will scrutinize historical and real-time sensor data to identify patterns and anomalies. When risks are detected, AI systems will trigger instantaneous alerts and may autonomously halt unsafe operations (Bharadiya, 2023).

8.3.2 *Regulatory Compliance*

Streamlining regulatory compliance through AI will automate data collection and reporting processes. Construction sites will be equipped with sensors continuously monitoring adherence to safety, environmental, and quality standards. AI algorithms will generate real-time compliance reports, thus reducing administrative burdens and ensuring regulatory adherence (Rustad and Koenig, 2019).

8.4 Sustainable Construction Practices

8.4.1 *AI in Green Building*

AI's pivotal role in smart and sustainable building designs will be accentuated. Machine learning algorithms will scrutinize numerous factors, including energy consumption, material sustainability, environmental impact, and user behavior. AI-driven design recommendations will empower architects and engineers to create buildings that are both eco-friendly and responsive to occupants' needs (Debrah et al., 2022).

8.4.2 Waste Reduction

AI-driven materials management systems will advance to minimize construction waste almost entirely. These systems will optimize material procurement, storage, and usage in real-time. Through material reuse and recycling, construction projects will significantly diminish their environmental footprint, aligning closely with Neom's sustainability commitments (Pan and Zhang, 2023).

8.5 Advanced Project Management and Predictive Analytics

8.5.1 Predictive Analytics

AI-powered predictive analytics will achieve unparalleled precision. They will forecast risks, schedule delays, and cost overruns with exceptional accuracy by considering a wide range of data inputs, including historical project data, weather forecasts, equipment performance, and real-time market conditions. Predictive models will provide construction teams with early warnings and actionable insights for optimizing project outcomes (Jaafreh and Al Jaafreh, 2021).

8.5.2 Digital Twins for Project Simulation

Digital twins will evolve into real-time simulation platforms. These platforms will not only replicate physical construction sites but also provide dynamic simulations of construction processes. Project managers will visualize the impact of design changes, resource allocations, and scheduling adjustments in real-time. This will facilitate swift decision-making and resource optimization (Alshammari, 2021).

8.6 Ethical AI and Stakeholder Engagement

8.6.1 Ethical AI Practices

The establishment of ethical AI certifications and standards will ensure that AI systems employed in construction adhere to rigorous ethical guidelines. Neom will take a pioneering role in implementing and upholding these standards, cultivating trust among stakeholders and the public (Brooks et al., 2020).

8.6.2 Stakeholder Involvement

Neom will lead the way in community-centric AI-driven construction projects. Local communities and stakeholders will actively partake in the decision-making process, shaping project designs, and providing invaluable insights into how AI can serve community needs and preferences (Emaminejad et al., 2023).

8.7 Research and Innovation Centers

Neom's innovation hubs and research centers devoted to AI in construction will serve as epicenters of revolutionary technology. These centers will attract foremost researchers, engineers, and innovators worldwide, fostering collaboration and expediting the development of AI solutions tailored to Neom's unique challenges and objectives (Root, 2023: Al Jaafreh and Allouzi, 2023).

8.8 International Collaboration

Neom will forge partnerships and knowledge-sharing agreements with other global smart cities and construction projects. This collaborative approach will enable Neom to harness a global network of expertise, share best practices, and jointly tackle construction challenges using AI (Sharma, 2022).

9. AI Adoption Strategies in Neom: A Comprehensive Approach

Neom's comprehensive AI adoption strategies represent a meticulously planned roadmap to harmonize its construction projects with the transformative potential of AI. These strategies encompass vision alignment, prudent resource allocation, workforce readiness, iterative implementation, and robust data governance. By adopting these strategies, Neom is well-poised to usher in an era of innovation and sustainability in its construction endeavors, in line with its visionary aspirations.

9.1 Clear Vision and Alignment

9.1.1 Defining Objectives

Neom's strategic approach to AI integration in construction projects must commence with the establishment of precise objectives. These objectives should be thoughtfully tailored to align with Neom's overarching vision (Falah et al., 2020). For instance, Neom's objective may be to enhance project efficiency. In this context, specific goals could include reducing construction timelines by a substantial percentage or optimizing resource allocation to achieve cost savings.

Example: To enhance construction efficiency, Neom initiates a pilot project employing AI-driven project management software. The outcome is a remarkable 15% reduction in project completion time.

9.1.2 Alignment with Neom's Vision

The adoption of AI in construction should seamlessly harmonize with Neom's broader vision of forging smart, sustainable, and innovative cities. It necessitates the infusion of sustainable construction practices, intelligent building technologies, and innovative design paradigms that align cohesively with Neom's overarching commitment to sustainability.

Example: Neom's construction projects seamlessly incorporate AI technologies to design buildings that prioritize energy efficiency and ecological sustainability, fundamentally aligning with Neom's sustainability mandate.

9.2 Investment and Resource Allocation

9.2.1 Budget Allocation

Neom should proactively earmark a dedicated financial budget for the purpose of AI integration within construction projects. This budget should encompass all requisite expenses, including technology procurement, workforce training, infrastructure enhancements, and the sustained maintenance of AI solutions.

Example: Neom judiciously allocates a substantial budget of $20 million, exclusively reserved for AI adoption within its construction initiatives over the subsequent five years, thereby ensuring the availability of necessary financial resources.

9.2.2 Resource Allocation

Beyond fiscal allocations, Neom's strategic blueprint mandates the allocation of human resources equipped with the requisite AI proficiency. This necessitates the recruitment of AI specialists, data scientists, and experts well-versed in construction technology.

Example: Neom takes a proactive step by establishing an internal AI Center of Excellence (CoE) within its organizational framework, staffed with proficient data scientists, machine learning engineers, and construction technology experts.

9.3 Education and Training

9.3.1 Workforce Training

Neom must embark on a robust investment in AI-centric training programs. These initiatives should cater to the diverse roles encompassed within construction projects, ranging from project managers to on-site personnel.

Example: Neom implements an array of AI training modules targeted at construction project managers, equipping them with the skills and knowledge required for the effective utilization of AI-driven project management tools.

9.3.2 AI Literacy

Neom's holistic approach mandates the promotion of AI literacy throughout its organizational fabric. Every stakeholder should gain a comprehensive understanding of AI's fundamentals, its capabilities, and its inherent limitations.

Example: Neom proactively organizes a series of workshops and seminars, aimed at imparting AI literacy to all its employees. This ensures a common baseline of knowledge regarding AI concepts and their relevance to construction projects.

9.4 Pilot Projects and Proof of Concept

9.4.1 Starting Small

Neom's pragmatic AI adoption strategy advocates for the initiation of AI integration through pilot projects or proof of concepts. These smaller-scale initiatives serve as controlled environments for rigorous testing and assessment of AI technologies before venturing into large-scale implementation.

Example: Prior to implementing AI-powered safety monitoring across all construction sites, Neom meticulously conducts a pilot project at a single site. This allows for the thorough evaluation of the system's accuracy and effectiveness in detecting safety violations.

9.4.2 Iterative Approach

Neom's methodology adopts an incremental approach to AI implementation. This progressive deployment ensures that lessons are learned from initial experiences, requisite adjustments are made, and the AI adoption strategy is honed for application in more expansive construction projects.

Example: Neom initiates its AI journey by deploying AI for resource allocation in a single construction project. After the unequivocal success of this pilot, Neom systematically expands its AI adoption to encompass an array of other projects.

9.5 Data Management and Governance

9.5.1 Data Infrastructure

Neom underscores the criticality of investing in robust data infrastructure capable of accommodating the vast and diverse data generated by c onstruction projects. This includes comprehensive data storage, processing capabilities, and diligent data quality management.

Example: Neom establishes a centralized data repository designed to meticulously aggregate and store data emanating from various construction sites. This ensures the accessibility and reliability of data for AI-driven decision-making.

9.5.2 Data Governance

Neom's strategic roadmap mandates the establishment of concrete data governance policies and practices. These measures are pivotal in defining data ownership, instituting stringent access controls, and ensuring data privacy protocols. They collectively safeguard data integrity and security.

Example: Neom appoints a Chief Data Officer responsible for the overarching oversight of data governance, privacy compliance, and data quality management across all construction projects. This reflects Neom's unwavering commitment to data integrity and security.

10. Conclusion

In the dynamic landscape of construction and artificial intelligence, Neom finds itself uniquely positioned to assume a leadership role in shaping the future of innovative, sustainable, and smart cities. This comprehensive analysis has meticulously dissected the potential ramifications of AI adoption on Neom's construction ventures, underscoring the transformative prowess that AI wields across diverse dimensions of the construction industry. The principal takeaways from this comprehensive exploration encompass:

- Elevated Efficiency: AI-infused project management, judicious resource allocation, and seamless automation collectively conspire to elevate construction project efficiency significantly. The consequence is manifest in shortened project timelines and heightened cost-effectiveness;
- Augmented Safety: AI's omnipresent gaze, channeled through monitoring and predictive analytics, emerges as the vanguard of enhanced safety standards on construction sites. Accidents are preemptively thwarted, and the welfare of the workforce is vigilantly safeguarded;
- Sustainability Embodied: AI assumes the mantle of sustainability stewardship by optimizing resource utilization, championing sustainable material selection, and orchestrating a reduction in energy consumption. This harmonization with environmental objectives propels Neom's projects towards environmental stewardship;
- Economic Viability: The judicious allocation of resources and the proactive mantle of predictive maintenance intersect to yield profound cost reductions. This financial prudence ensures the perpetuation of economically sound projects;
- Ethical Imperatives: Ethical considerations surface as an unassailable priority. The agenda revolves around the meticulous integration of ethical AI practices that decimate biases, fortify transparency, and embed accountability into the tapestry of AI-driven decision-making;
- Prospects on the Horizon: The future beckons with the tantalizing allure of emerging technologies. IoT, 5G, advanced robotics, and generative design stand as catalysts that promise to catapult Neom into a realm of unparalleled AI-driven innovation in construction.

Recommendations

Based on the insights gleaned from this exhaustive analysis, a set of strategic recommendations emerges, poised to shepherd Neom on its voyage of AI integration within construction projects:

- Formulate an Articulate AI Strategy:

Neom ought to construct a holistic AI strategy that is meticulously tailored to the unique contours of its construction projects. This strategy should be characterized by the explicit delineation of concrete objectives, budgetary provisions, and a well-structured timeline that serves as the scaffold for AI integration.

- Foster Workforce Empowerment:

In order to guarantee the triumphant assimilation of AI, Neom must champion investments in a suite of training programs that are attuned to the needs of its diverse workforce. These programs should be designed to accommodate individuals at every echelon and across all roles within the organization. The overarching goal is to cultivate AI literacy and competence throughout the organizational hierarchy.

- Embrace the Pilot Paradigm:

Neom's journey into AI should be inaugurated through the imprimatur of pilot AI projects. These diminutive yet pivotal endeavors serve as invaluable crucibles that allow for a meticulous evaluation of the practicability and efficacy of AI solutions when tested in the crucible of real-world construction scenarios. These pilot projects metamorphose into invaluable learning crucibles.

- Fortify Data Management and Governance:

The sine qua non of AI triumph resides in the bedrock of robust data management. Neom must hence invest judiciously in data infrastructure, stringent data quality assurance, and data governance protocols that serve as bulwarks, ensuring the conferment of reliable and secure data for AI applications.

- Galvanize Collaboration and Research:

In the quest to fuel AI innovation in construction, Neom must galvanize its collaborative efforts. Partnering with august research institutions, AI luminaries, and industry stalwarts can catalyze the cadence of AI advancement within construction. Actively participating in research projects that elucidate the frontiers of AI within construction constitutes a strategic imperative.

- The Bastion of Ethical AI:

Neom should wield its influence in the edification of a framework delineating ethical AI practices. This framework should be calibrated with meticulous attention to detail, exorcising the specters of bias, veiling decisions in a shroud of transparenc y, and embedding accountability into the AI decision-making calculus. These ethical contours should reverberate throughout the developmental and operational cadence of AI systems.

- Relentless Monitoring and Evaluation:

The roadmap forward mandates a relentless regimen of performance evaluation for AI systems. These assessments should be tethered to key performance indicators (KPIs). The establishment of feedback loops is equally indispensable, as they serve as the crucible within which areas of refinement and optimization are unearthed.

- Embrace the Mosaic of Emerging Technologies:

Neom's trajectory should be one of relentless curiosity and exploration in the realm of emerging technologies. The likes of IoT, 5G, advanced robotics, and generative design should be embraced and deftly interwoven with AI. This alchemical fusion of technologies bears the potential to bestow upon Neom a vantage point that is characterized by pioneering innovations in construction.

- Future-Proof Scalability:

The AI systems engineered by Neom should be underpinned by an innate capacity for scalability. They should be poised to deftly pivot and adapt to the chameleon-like demands of construction projects that metamorphose in size and complexity. This resilience engenders a legacy of long-term efficiency and fiscal prudence.

In the tapestry of conclusion, Neom stands at the cusp of a transformative epoch, poised to leave an indelible imprint on the construction landscape through the symbiotic amalgamation of AI. The recommendations tendered herein, when judiciously heeded, coalesce into a compass that can guide Neom towards a future where innovation, sustainability, and smart city aspirations converge seamlessly. Through unwavering commitment and agility in execution, Neom is poised to embrace the boundless potential of AI, delineating a trajectory that redefines construction and steers it towards the realization of a smarter, more sustainable world.

REFERENCES

Abioye, S.O., Oyedele, L.O., Akanbi, L., Ajayi, A., Delgado, J.M.D., Bilal, M., Akinade, O.O. and Ahmed, A., 2021. Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges. Journal of Building Engineering, 44, Pp.103299. https://doi.org/10.1016/j.jobe.2021.103299

AbouRizk, S.M., 2018. Simulation-based analytics: Advancing decision support in construction. In Proc., 2nd European and Mediterranean Structural Engineering and Construction Conf.

Ahmad, T., Zhang, D., Huang, C., Zhang, H., Dai, N., Song, Y. and Chen, H., 2021. Artificial intelligence in sustainable energy industry: Status Quo, challenges and opportunities. Journal of Cleaner Production, 289, Pp. 125834.

Ahmed, G., 2021. Improving IoT privacy, data protection and security concerns. International Journal of Technology, Innovation and Management (IJTIM), 1 (1).

Al Jaafreh, M.B., and Allouzi, M.A., 2023. Smart Cities Adoption in Saudi Arabia: A Comprehensive Review and Future Drivers. British Journal of Multidisciplinary and Advanced Studies, 4 (5), Pp. 20-39.

Al Saud, M.M., 2020. Sustainable land management for NEOM region (Vol. 220). Springer: Berlin/Heidelberg, Germany.

Allioui, H., and Mourdi, Y., 2023. Unleashing the potential of AI: Investigating cutting-edge technologies that are transforming businesses. International Journal of Computer Engineering and Data Science (IJCEDS), 3 (2), pp. 1-12.

Al-Sayed, A., Al-Shammari, F., Alshutayri, A., Aljojo, N., Aldhahri, E. and Abouola, O., 2022. The Smart City-Line in Saudi Arabia: Issue and Challenges. Postmodern Openings, 13 (1 Sup1), Pp. 15-37.

Alshammari, K., 2021. Access management for digital twins in the built environment (Doctoral dissertation, Cardiff University).

Anttiroiko, A.V., Valkama, P. and Bailey, S.J., 2014. Smart cities in the new service economy: building platforms for smart services. AI & society, 29, pp. 323-334.

Arena, D.N., 2019. Towards semantics-driven modelling and simulation of context-aware manufacturing systems (No. THESIS). EPFL.

Aryal, R.G., and Altmann, J., 2018. April. Dynamic application deployment in federations of clouds and edge resources using a multiobjective optimization AI algorithm. In 2018 Third international conference on fog and mobile edge computing (FMEC), pp. 147-154. IEEE.

As, I., Basu, P., and Talwar, P. eds. 2022. Artificial intelligence in urban planning and design: technologies, implementation, and impacts. Elsevier.

Ashehri, R., 2019. Governance of Artificial Intelligence in KSA (NEOM as a model). International Journal of Advanced Studies, 9 (1), pp. 64-81.

Baumann, H., 2019. The transformation of Saudi Arabia's rentier state and 'the international'. Globalizations, 16 (7), pp. 1165-1183.

Bayaa, I., 2023. An examination of the Saudi Arabian citizens' perception on leisure tourism's impact on culture in Saudi Arabia (Doctoral dissertation, Pepperdine University).

Bharadiya, J.P., 2023. Machine learning and AI in business intelligence: Trends and opportunities. International Journal of Computer (IJC), 48 (1), Pp. 123-134.

Bloomfield, R., Fletcher, G., Khlaaf, H., Hinde, L. and Ryan, P., 2021. Safety case templates for autonomous systems. arXiv preprint arXiv:2102.02625.

Blundell, B.G., 2020. Robotic Systems. In Ethics in Computing, Science, and Engineering (pp. 579-684). Springer, Cham.

Brambilla, M., Ferrante, E., Birattari, M. and Dorigo, M., 2013. Swarm robotics: a review from the swarm engineering perspective. Swarm Intelligence, 7, pp. 1-41.

Brooks, C., Gherhes, C., and Vorley, T., 2020. Artificial intelligence in the legal sector: pressures and challenges of transformation. Cambridge Journal of Regions, Economy and Society, 13 (1), pp. 135-152.

Brunetti, F., Matt, D.T., Bonfanti, A., De Longhi, A., Pedrini, G. and Orzes, G., 2020. Digital transformation challenges: strategies emerging from a multi-stakeholder approach. The TQM Journal, 32 (4), pp. 697-724.

Chen, L., and Luo, H., 2014. A BIM-based construction quality management model and its applications. Automation in construction, 46, pp. 64-73.

Colombari, R., and Neirotti, P., 2022. Closing the middle-skills gap widened by digitalization: how technical universities can contribute through Challenge-Based Learning. Studies in Higher Education, 47 (8), pp. 1585-1600.

Dakrorey, A.S., 2021. Smart cities as one of the artificial intelligence applications: neon city as a model.

Dash, R., McMurtrey, M., Rebman, C., and Kar, U.K., 2019. Application of artificial intelligence in automation of supply chain management. Journal of Strategic Innovation and Sustainability, 14 (3), pp. 43-53.

Debrah, C., Chan, A.P., and Darko, A., 2022. Artificial intelligence in green building. Automation in Construction, 137, Pp. 104192.

Delgado, J.M.D., Oyedele, L., Demian, P., and Beach, T., 2020. A research agenda for augmented and virtual reality in architecture, engineering and construction. Advanced Engineering Informatics, 45, Pp. 101122.

Dhyani, B., 2021. Predicting Equipment Failure in Manufacturing Plants: An AI-driven Maintenance Strategy. Mathematical Statistician and Engineering Applications, 70 (2), Pp. 1326-1334.

Dong, B., and Lam, K.P., 2014. February. A real-time model predictive control for building heating and cooling systems based on the occupancy behavior pattern detection and local weather forecasting. In Building Simulation, 7, Pp. 89-106. Springer Berlin Heidelberg.

Eastman, C., Teicholz, P., Sacks, R., and Liston, K., 2020. Managing BIM technology in the building industry: AECbytes viewpoint.

Emaminejad, N., Kath, L., and Akhavian, R., 2023. Assessing Trust in Construction AI-Powered Collaborative Robots using Structural Equation Modeling. arXiv preprint arXiv:2308.14697.

Faccenda, G., 2021. Measuring the sustainability impact of Artificial

Intelligence in logistics: a case study analysis.

Falah, N., Karimi, A., and Harandi, A.T., 2020. Urban growth modeling using cellular automata model and AHP (case study: Qazvin city). Modeling Earth Systems and Environment, 6, Pp. 235-248.

Farag, A.A., 2019. The story of NEOM city: Opportunities and challenges. New cities and community extensions in Egypt and the Middle East: Visions and challenges, pp. 35-49.

Fattouh, B., and Mabro, R., 2006. The investment challenge. Oil in the 21st Century: Issues, Challenges and Opportunities, Pp.101-127.

Frank, B., Simper, N., Cai, B., Salem, D., Kaupp, J. and Lindley-Peart, M., 2018. Enhancing development of competencies by means of continuous improvement processes. Canadian public policy, 44 (S1), pp. S56-S72.

Gitzel, R., Turring, S., and Maczey, S., 2015. July. A data quality dashboard for reliability data. In 2015 IEEE 17th Conference on Business Informatics, 1, Pp. 90-97. IEEE.

Glendon, A.I., Clarke, S., and McKenna, E., 2016. Human safety and risk management. Crc Press.

Gorod, A., Hallo, L., Ireland, V., and Gunawan, I. eds. 2019. Evolving toolbox for complex project management. CRC Press.

Harrison, T.M. and Luna-Reyes, L.F., 2022. Cultivating trustworthy artificial intelligence in digital government. Social Science Computer Review, 40 (2), Pp. 494-511.

Hilmi, N., Farahmand, S., and Belaid, F., 2020. Why Should Saudi Arabia Diversify Its Economy?. Economic Development in the Gulf Cooperation Council Countries: From Rentier States to Diversified Economies, pp. 89-109.

Jaafreh, A.B., and Al Jaafreh, E.M.B., 2021. Adaption Of Construction Management Modelling System Through the Use Of Internet Of Things (IoT).

Jackson, B.J., 2020. Construction management JumpStart: the best first step toward a career in construction management. John Wiley & Sons.

Kadadi, A., Agrawal, R., Nyamful, C., and Atiq, R., 2014. October. Challenges of data integration and interoperability in big data. In 2014 IEEE international conference on big data (big data) (pp. 38-40). IEEE.

Kalidindi, S.R., Buzzy, M., Boyce, B.L. and Dingreville, R., 2022. Digital twins for materials. Frontiers in Materials, 9, Pp. 818535.

Kanase-Patil, A.B., Kaldate, A.P., Lokhande, S.D., Panchal, H., Suresh, M. and Priya, V., 2020. A review of artificial intelligence-based optimization techniques for the sizing of integrated renewable energy systems in smart cities. Environmental Technology Reviews, 9 (1), Pp. 111-136.

Kirwan, C.G., and Zhiyong, F., 2020. Smart cities and artificial intelligence: convergent systems for planning, design, and operations. Elsevier.

Ko, C.H., and Cheng, M.Y., 2007. Dynamic prediction of project success using artificial intelligence. Journal of construction engineering and management, 133 (4), Pp. 316-324.

Krish, S., 2011. A practical generative design method. Computer-Aided Design, 43 (1), pp. 88-100.

Kuo, T.C., Peng, C.Y., and Kuo, C.J., 2021. Smart support system of material procurement for waste reduction based on big data and predictive analytics. International Journal of Logistics Research and Applications, pp. 1-18.

Li, J., Herdem, M.S., Nathwani, J. and Wen, J.Z., 2023. Methods and applications for Artificial Intelligence, Big Data, Internet of Things, and Blockchain in smart energy management. Energy and AI, 11, Pp.100208.

Li, K., Luo, H., and Skibniewski, M.J., 2019. A non-centralized adaptive method for dynamic planning of construction components storage areas. Advanced Engineering Informatics, 39, pp. 80-94.

Ma, S., Zhang, H., and Xing, X., 2018. Scalability for smart infrastructure system in smart grid: a survey. Wireless Personal Communications, 99, pp. 161-184.

Mahbub, R., 2008. An investigation into the barriers to the implementation of automation and robotics technologies in the construction industry (Doctoral dissertation, Queensland University of Technology).

Mahmud, B., Hong, G. and Fong, B., 2023. A Study of Human–AI Symbiosis for Creative Work: Recent Developments and Future Directions in Deep Learning. ACM Transactions on Multimedia Computing, Communications and Applications, 20 (2), pp. 1-21.

McNamara, A.J. and Sepasgozar, S.M., 2021. Intelligent contract adoption in the construction industry: Concept development. Automation in construction, 122, Pp. 103452.

Melenbrink, N., Werfel, J., and Menges, A., 2020. On-site autonomous construction robots: Towards unsupervised building. Automation in construction, 119, Pp. 103312.

Moeen, M., Agarwal, R., and Shah, S.K., 2020. Building industries by building knowledge: Uncertainty reduction over industry milestones. Strategy Science, 5 (3), Pp. 218-244.

Momade, M.H., Durdyev, S., Estrella, D., and Ismail, S., 2021. Systematic review of application of artificial intelligence tools in architectural, engineering and construction. Frontiers in Engineering and Built Environment, 1 (2), Pp. 203-216.

Niederman, F., 2021. Project management: openings for disruption from AI and advanced analytics. Information Technology & People, 34 (6), Pp. 1570-1599.

Pal, A., Lin, J.J., Hsieh, S.H., and Golparvar-Fard, M., 2023. Automated vision-based construction progress monitoring in built environment through digital twin. Developments in the Built Environment, Pp.100247.

Pan, Y., and Zhang, L., 2021. Roles of artificial intelligence in construction engineering and management: A critical review and future trends. Automation in Construction, 122, Pp. 103517.

Pan, Y., and Zhang, L., 2023. Integrating BIM and AI for smart construction management: Current status and future directions. Archives of Computational Methods in Engineering, 30 (2), pp. 1081-1110.

Pandith, M.Y., 2015. Data security and privacy concerns in cloud computing. Internet of Things and Cloud Computing, 2 (2), Pp. 6.

Popović-Gerber, J., Oliver, J.A., Cordero, N., Harder, T., Cobos, J.A., Hayes, M., O'Mathuna, S.C. and Prem, E., 2011. Power electronics enabling efficient energy usage: Energy savings potential and technological challenges. IEEE transactions on power electronics, 27 (5), pp. 2338-2353.

Puaschunder, J.M., 2019. June. Artificial Intelligence market disruption. In Proceedings of the International RAIS Conference on Social Sciences and Humanities organized by Research Association for Interdisciplinary Studies (RAIS) at Johns Hopkins University, Montgomery County Campus, Rockville, MD, United States (pp. 1-8).

Quah, T.K.N., Tay, Y.W.D., Lim, J.H., Tan, M.J., Wong, T.N. and Li, K.H.H., 2023. Concrete 3D Printing: Process Parameters for Process Control, Monitoring and Diagnosis in Automation and Construction. Mathematics, 11 (6), Pp. 1499.

Rane, N., 2023. Integrating Building Information Modelling (BIM) and Artificial Intelligence (AI) for Smart Construction Schedule, Cost, Quality, and Safety Management: Challenges and Opportunities. Cost, Quality, and Safety Management: Challenges and Opportunities (September 16, 2023).

Rashed, R., and Mahmoud, R., 2018. Urban Social Sustainability in the Era of Digital Technology: the case of NEOM, the World's Future Global Hub across Three Countries. In The International conference of Sustainable Design of the Built Environment SDBE18.

Root, M.C.E., 2023. Smartness and the City: A Comparative Study of Smart-City Ambitions and the Infrastructures of Smartness in Canadian Cities.

Rudberg, M., and Sezer, A.A., 2022. Digital tools to increase construction site safety. In ARCOM Association of Researchers in Construction Management.

Rustad, M.L. and Koenig, T.H., 2019. Towards a global data privacy standard. Fla. L. Rev., 71, Pp. 365.

Sahana, S.K., Khowas, M., and Sinha, K., 2018. Budget optimization and allocation: An evolutionary computing based model. Bentham Science Publishers.

Saleh, R.M., and Al-Swidi, A., 2019. The adoption of green building practices in construction projects in Qatar: a preliminary study. Management of Environmental Quality: An International Journal, 30 (6), Pp. 1238-1255.

Santos, R., Costa, A.A., and Grilo, A., 2017. Bibliometric analysis and review of Building Information Modelling literature published between 2005 and 2015. Automation in Construction, 80, pp. 118-136.

Sayfayn, N., 2018. Sustainable development in Saudi Arabia, past, present and future (Doctoral dissertation, Massachusetts Institute of Technology).

Seyedan, M., and Mafakheri, F., 2020. Predictive big data analytics for supply chain demand forecasting: methods, applications, and research opportunities. Journal of Big Data, 7 (1), pp. 1-22.

Sharma, R., 2022. Digitalisation of Conflict and Cooperation in the Middle East. Politics of Change in Middle East and North Africa since Arab Spring: A Lost Decade?, Pp. 182.

Sundar, S., and Sumathy, S., 2018. Security stipulations on IoT networks. Cognitive Computing for Big Data Systems Over IoT: Frameworks, Tools and Applications, pp.289-306.

Szeliski, R., 2011. Computer vision: applications and algorithms.

Wang, X., Love, P.E., Kim, M.J., Park, C.S., Sing, C.P. and Hou, L., 2013. A conceptual framework for integrating building information modeling with augmented reality. Automation in construction, 34, pp. 37-44.

Wooldridge, M., 2020. The road to conscious machines: The story of AI. Penguin UK.

Xu, J., Cheung, C., Manu, P., Ejohwomu, O. and Too, J., 2023. Implementing safety leading indicators in construction: Toward a proactive approach to safety management. Safety science, 157, p. 105929.

Yaseen, Z.M., Ali, Z.H., Salih, S.Q., and Al-Ansari, N., 2020. Prediction of risk delay in construction projects using a hybrid artificial intelligence model. Sustainability, 12 (4), Pp. 1514.

Yusuf, N., and Abdulmohsen, D., 2022. Saudi Arabia's NEOM Project as a Testing Ground for Economically Feasible Planned Cities: Case Study. Sustainability, 15 (1), Pp. 608.

Zhan, C., Sankaran, S., LeMoine, V., Graybill, J. and Mey, D.O.S., 2019. October. Application of machine learning for production forecasting for unconventional resources. In Unconventional Resources Technology Conference, Denver, Colorado, 22-24 July 2019 (pp. 1945-1954). Unconventional Resources Technology Conference (URTeC); Society of Exploration Geophysicists.

Zhang, W., Yang, D. and Wang, H., 2019. Data-driven methods for predictive maintenance of industrial equipment: A survey. IEEE systems journal, 13 (3), pp. 2213-2227. https://doi.org/10.1109/JSYST.2019.2905565