The Revolution of AI in Enhancing Infrastructure and Facilities Management

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Abstract

The revolutionary impact of artificial intelligence (AI) in infrastructure and facilities management is thoroughly reviewed in this paper, with a particular emphasis on the years 2020–2025. By providing dynamic, condition-based approaches rather than fixed-interval schedules, artificial intelligence (AI) technologies like predictive analytics, intelligent automation, and real-time operational intelligence are completely changing conventional maintenance and management paradigms. AI enables predictive maintenance that dramatically lowers downtime and maintenance expenses while increasing equipment lifespan by utilizing massive datasets from IoT devices and smart sensors. Additionally, by integrating motion detection, facial recognition, and behavior analytics for proactive threat identification into smart security systems, AI improves occupant comfort and safety. With 74 peer-reviewed studies and industry reports from North America, Europe, Asia-Pacific, and the Middle East, the review shows both regional and worldwide trends in the adoption of AI. Results show a mean 24% decrease in equipment downtime, an 18% reduction in maintenance costs, and significant increases in employee productivity and energy efficiency, confirming AI's operational, economic, and environmental advantages. The study highlights persistent issues in spite of these developments, such as cybersecurity threats, data privacy issues, and integration hurdles with legacy infrastructure. The study emphasizes the value of interdisciplinary cooperation between technologists, facility managers, and legislators in order to overcome financial, technological, and ethical challenges. Future studies should take into account new developments in AI, and non-English literature should be used to increase regional inclusivity. For practitioners and decision-makers dedicated to utilizing AI's full potential for more intelligent, secure, and sustainable infrastructure and facilities management in the digital age, this research offers vital insights.

Keywords: Artificial Intelligence, Smart Infrastructure, Energy Efficiency, Predictive Management, Facility Management via AI.

1. Introduction

Artificial intelligence (AI) technology's quick development has drastically changed a number of industries and altered how businesses function and allocate their resources. The management of facilities and infrastructure is one of the most prominent sectors going through a significant transition [1]. This field, which has historically concentrated on the upkeep, management, and supervision of tangible assets including buildings, transit networks, electricity grids, and water supply networks, is currently undergoing an intelligent revolution driven by artificial intelligence [2]. For many years, maintaining safety, sustainability, and functional dependability has required effective infrastructure and facilities management [3]. But because of their reliance on manual labor, reactive maintenance techniques, and disjointed data systems, conventional approaches frequently fell short, resulting in inefficiencies, greater costs, and a higher chance of unplanned system breakdowns [4].

Through the development of data-driven automation, predictive analytics [5], and real-time operational intelligence, artificial intelligence (AI) presents a compelling opportunity to rethink and reinvent these conventional procedures. AI makes dynamic, condition-based tactics possible, in contrast to static maintenance programs with set intervals. Large-scale datasets gathered from Internet of Things (IoT) devices, smart sensors, and performance logs from the past underpin these clever strategies [6, 7]. Facilities managers can use AI to schedule repairs before malfunctions happen, identify abnormalities, and predict equipment failures. Predictive maintenance prolongs the operating life of vital equipment while lowering downtime and averting expensive emergency repairs. As a result, businesses can increase dependability and drastically reduce maintenance expenses, increasing productivity and ROI [8].

AI is essential for maximizing energy use and space usage in addition to predictive maintenance. Artificial intelligence (AI)-powered smart energy management systems track and examine trends in the use of electricity, heating, and cooling, allowing for real-time adjustments to cut waste and boost energy efficiency [9]. In order to adjust ambient settings, these systems can take into consideration factors like occupancy numbers, time of day, outside weather, and even user behavior. Similar to this, AI insights make space management more strategic by enabling judgments on office layouts, meeting room allocations, and facility redesigns based on usage trends, guaranteeing efficient and sustainable resource use [10].

The automation of repetitive processes and administrative duties is another important advantage of AI in facilities and infrastructure management[6]. Artificial Intelligence (AI) systems can automate scheduling, maintenance staff dispatch, compliance report generation, and service request response through machine learning and natural language processing [11]. Facility managers are able to concentrate on more strategic planning and problem-solving activities as a result of the decreased administrative load[12]. AI can easily integrate several subsystems, like fire safety, HVAC, lighting, and security, onto a single platform in smart buildings. By providing facility managers with a comprehensive understanding of their operations, this degree of integration makes it easier to respond proactively to new problems and improves management effectiveness overall [13].

AI has an impact on occupant comfort and safety as well. AI technologies like motion detection, facial recognition, and predictive analytics are increasingly incorporated into smart security systems to identify dangers before they become real [14]. These systems enable quick reaction to possible security breaches by analyzing behavior patterns and spotting anomalies in real time. In terms of user experience, AI-powered lighting and climate controls adjust to people's tastes and presence, creating a responsive and cozy interior space. In contemporary buildings, voice-activated controls, customized navigation systems, and smart elevators all help to improve user happiness [8].

The use of AI in infrastructure and facility management is not without difficulties, despite its enormous potential [15]. The problem of cybersecurity and data privacy is one major obstacle. Ensuring strong data protection measures is essential since AI systems rely significantly on enormous volumes of data, frequently containing sensitive operational or personal data [16]. Data breaches and misuse can have major repercussions, such as fines from the government and harm to one's reputation. Furthermore, interoperability problems arise when merging new technologies with legacy systems because many of the infrastructure systems in place were not built to be AI-compatible [17].

The significant upfront costs associated with implementing AI present another challenge. It can be expensive to install IoT sensors, create AI models, and train employees, especially for small and mid-sized businesses. Over time, though, operational savings and enhanced asset performance can offset this expense [18]. However, in order to defend these expenditures, businesses need to perform thorough cost-benefit evaluations [16]. In addition, the present workforce has a noticeable skills gap. The technical know-how required to implement, oversee, and decipher AI systems may be lacking in many facilities management specialists. Training, upskilling, and perhaps employing data scientists and AI experts are all necessary to close this gap [19].

Additionally, ethical issues are relevant, particularly when it comes to automated decision-making. There are concerns regarding bias, accountability, and transparency when crucial maintenance or safety decisions are made solely based on algorithms [20]. To guarantee that AI tools are utilized sensibly and morally, it is imperative to set up explicit governance structures and compliance criteria. Companies must take the initiative to create their ethical principles to supplement current legislation, even as regulatory agencies are starting to address these challenges. A comprehensive and calculated strategy is required for the stakeholders in order to optimize the advantages of AI in infrastructure and facilities management [14]. This involves coordinating AI projects with more general company objectives, including user satisfaction, safety, cost effectiveness, and sustainability. To develop a single digital transformation roadmap, cooperation between the IT, operations, finance, and compliance departments is essential [21]. Finding the finest solutions and implementation best practices can also be aided by interacting with suppliers, technology companies, and industry specialists [2].

This study intends to investigate the complex role of artificial intelligence in infrastructure and facilities management in light of recent advancements. It looks at the present applications of AI technologies to increase safety, boost operational effectiveness, optimize maintenance, and promote sustainability. Furthermore, this study will examine the difficulties encountered when putting AI systems into practice and suggest solutions. The study aims to offer insightful information to practitioners, policymakers, and scholars committed to improving infrastructure and facilities management in the era of digital transformation by thoroughly reviewing the body of existing literature, case studies, and emerging trends

2. Literature review

Over the past five years, artificial intelligence (AI) has become a disruptive force in infrastructure and facilities management (FM), based on its quick development, interdisciplinary adoption, and growing research focus on utilizing AI's potential to boost operational efficiency, lower costs, advance sustainability, and improve occupant well-being.

According to recent research, the need for cost-effective operations, resource optimization, risk mitigation, and regulatory compliance is the main factor driving AI adoption in FM.

2.1 Drivers of AI adoption in facilities management

AI enables Predictive maintenance, which changes conventional maintenance from planned or reactive procedures to smart, data-driven approaches [22]. AI systems can predict equipment failures, prolong asset lifecycles, and minimize unscheduled downtime by utilizing data from IoT sensors, Building Information Modeling (BIM), and previous maintenance records [23]. In addition to optimizing resource use and supporting cost-effective infrastructure management, this proactive strategy increases operational efficiency. Predictive maintenance driven by AI is therefore a revolutionary development in the upkeep and administration of intricate systems and infrastructure [24, 25]. According to studies, among the most popular AI applications are intelligent automation and predictive analytics, which significantly reduce downtime, lower maintenance costs, and boost employee productivity [26]. Quinello and Nascimento's systematic assessment, for instance, highlights the dearth of sector-specific frameworks for AI deployment but reveals a variety of AI applications at various maturity stages across international FM practices [27].

2.2 AI-Enabled Energy and Sustainability Management

The infrastructure management frequently focuses on sustainability. Energy efficiency has increased noticeably as a result of AI's incorporation into smart building management, which includes energy management, HVAC optimization, and lighting control [28]. According to certain studies, energy savings have ranged from 20% to 50% [29]. By reacting dynamically to occupancy, weather, and other environmental factors, AI-powered solutions, particularly those that make use of reinforcement and deep learning, perform better than conventional, rule-based systems [30, 31]. The foundation for real-time monitoring and decentralized management is being established by hybrid models that integrate AI, IoT, and sophisticated security protocols [32]. These models support both strategic sustainability objectives and operational resilience. Ongoing benchmarking and continuous improvement are further made possible by the convergence of AI with digital twins and BIM frameworks [33, 34].

2.3 Occupant Experience, Safety, and Security

AI has an impact on occupant experience and safety. Smart security systems featuring facial recognition, real-time anomaly detection, and proactive risk response are highlighted in recent studies [35]. By learning and adjusting to usage patterns, AI-driven lighting and climate controls have been demonstrated to improve occupant comfort and satisfaction[36]. Additional useful uses include increasing indoor air quality, automating cleaning schedules, and optimizing space utilization features that are particularly relevant in light of health and safety laws beyond 2020 [37, 38].

2.4 Persistent barriers and Implementation challenges

For facilities management to completely benefit from AI, a number of important issues need to be resolved. Since integrating AI into legacy infrastructure frequently requires extensive retrofitting or custom-built solutions, data quality and integration represent a significant hurdle. Widespread, scalable adoption may become costly and complicated as a result [39]. Furthermore, AI's reliance on vast amounts of sensitive data raises cybersecurity and privacy concerns, increasing the risk of data breaches and highlighting the necessity of strict regulatory compliance [40]. Lack of standardization is another barrier; the sector is hampered by dispersed technologies and a lack of cohesive frameworks, which makes it challenging to create interoperable solutions that function flawlessly across a variety of building types [41].

Furthermore, workforce preparedness is still a major problem because many facilities lack the technical staff members necessary to handle, analyze, and act upon AI-generated insights. Because of this, personnel training and change management are crucial parts of any AI adoption plan[42]. Lastly, there are still empirical gaps in the subject. Large-scale, real-world validation studies are conspicuously lacking, despite the abundance of theoretical models and simulations, especially those that represent various geographic and cultural contexts. For successful AI integration and well-informed decision-making, these gaps must be closed [43].

2.5 Recent innovations and Research trends

Digital twins, or virtual representations of physical assets that use AI to facilitate scenario-based simulations, predictive maintenance, and real-time diagnostics, have gained popularity in recent years [44, 45]. Because they offer dynamic insights that enhance operational effectiveness and decision-making, these intelligent replicas are revolutionizing infrastructure management. Simultaneously, explainable AI (XAI) has become more popular, answering the urgent need for automated systems to be transparent and trustworthy [46]. In high-stakes situations like infrastructure management, it is crucial that stakeholders are able to comprehend, verify, and confidently implement AI-driven suggestions. XAI makes sure of this [47].

Parallel to these improvements, sectoral expansion is increasing the field of AI research and application. AI technologies are currently being investigated and applied in a variety of infrastructure areas, such as utilities, transportation networks, and smart cities, and are no longer limited to commercial structures [48]. The growing understanding of AI's potential to improve sustainability, resilience, and efficiency in all areas of the built environment is reflected in this expansion [49].

The works of art that are currently available on AI in infrastructure management frequently emphasize the importance of interdisciplinary cooperation by using techniques such as case studies, meta-analyses, and systematic reviews. But there are still significant restrictions. With a primary concentration on English-language materials from North America and Europe, much research is regionally limited. Additionally, there is an excessive dependence on theoretical or simulation-based models, which have little validity in large-scale, real-world settings. Additionally, integrated analysis across operational, financial, human, and sustainability aspects is absent from the majority of evaluations. Implementation challenges like staff training, data integration, and compatibility with older systems are frequently recognized but not fully investigated.

Through a multi-thematic, globally encompassing analysis that tackles operational efficiency, occupant experience, security, and sustainability, this study fills these gaps. The study offers a comprehensive framework that connects the effects of AI in organizational, technological, and regulatory contexts [50]. In contrast to earlier research, it offers a thorough examination of implementation issues, such as data governance and cybersecurity, and places them in various geographical contexts. Additionally, it demands that underrepresented regions be included more widely and that cutting-edge AI technologies like edge computing and deep learning be used. This all-encompassing strategy provides both scholarly understanding and useful recommendations for further study and implementation.

3. Methodology

The study employs a scoping review methodology to systematically map and synthesize the existing body of research on artificial intelligence (AI) in facilities and infrastructure management. The goal is to provide a comprehensive review that educates researchers, practitioners, and policymakers on the primary applications, challenges, and recent developments in AI integration. By well-established scoping review frameworks, including the PRISMA-ScR guidelines and the Joanna Briggs Institute's (JBI) recommendations, the approach is adopted to ensure openness, reproducibility, and comprehensive coverage. The scope and focus of the investigation were explicitly defined using the Population-Concept-Context (PCC) framework from Table 1:

Table 1: PCC framework.

Category	Description
Population	Infrastructure and facilities management systems, including buildings, transit networks, utilities, and associated tangible assets.
Concept	Deployment and impact of AI technologies (e.g., machine learning, predictive analytics, intelligent automation) on operational efficiency, maintenance, safety, and sustainability.
Context	Academic and industry perspectives on AI implementation challenges and benefits in infrastructure and facilities management, from global to regional scales.

Search Approach and Inclusion Standards

In order to capture current technological advancements and trends, a thorough literature search was carried out across a number of academic databases, including IEEE Xplore, Scopus, Web of Science, and Google Scholar. The search covered records published from 2020 to 2025. The search strategy combined terms to infrastructure and facilities management ("infrastructure management," "facilities management," "building management systems," "asset maintenance") with keywords associated with artificial intelligence ("artificial intelligence," "machine learning," "predictive analytics," "intelligent automation").

Table 2: Search approach and criteria

Category	Inclusion Criteria	Exclusion Criteria
Population	Studies focusing specifically on AI applications within infrastructure and facilities management	Studies unrelated to infrastructure or facilities; general AI studies without application focus
Concept	Research exploring AI benefits, challenges, integration strategies, or case studies	Studies lacking explicit focus on AI or infrastructure management
Context	Peer-reviewed articles, industry reports, and relevant conference proceedings	Editorials, opinion pieces, non-English publications
Geographic Scope	Global with emphasis on diverse regional insights	Region-specific studies without broader relevance

Charting and Data Extraction

After first screening the chosen papers based on abstracts and titles, a full-text review was conducted to determine their applicability. A structured charting table was created utilizing the data, with an emphasis on:

Table 3: Data specification.

Data Type	Data Features
Publication Details	Author(s), year, country, publication type
AI Applications	Types of AI technologies used, e.g., predictive maintenance, energy optimization, security systems
Impact Areas	Operational efficiency, safety improvements, sustainability initiatives
Implementation Challenges	Technical, ethical, financial, and workforce-related barriers
Stakeholder Perspectives	Roles of facility managers, policymakers, technologists, and end-users
Methodologies	Qualitative case studies, quantitative analyses, mixed methods

Data Synthesis and Analysis

To find recurring themes and patterns about AI's potential to improve infrastructure and facilities management, as well as obstacles to successful implementation, a narrative synthesis was used. Thematic coding within a conceptual framework that focused on technological innovation, real-world difficulties, and future directions aided the analysis. This made it possible to critically comprehend the points of convergence and divergence in current research, highlighting both opportunities and shortcomings.

Validation and Limitations

The omission of articles written in languages other than English restricts the scope of the scoping review and may result in the loss of important regional insights. It is difficult to keep up with all of the latest developments due to the quickly changing nature of AI technology platforms. However, the exacting approach guarantees thoroughness within predetermined bounds, and it is advised that future revisions take into account new developments.

The whole research methodology flowchart is as follows in Figure 1.

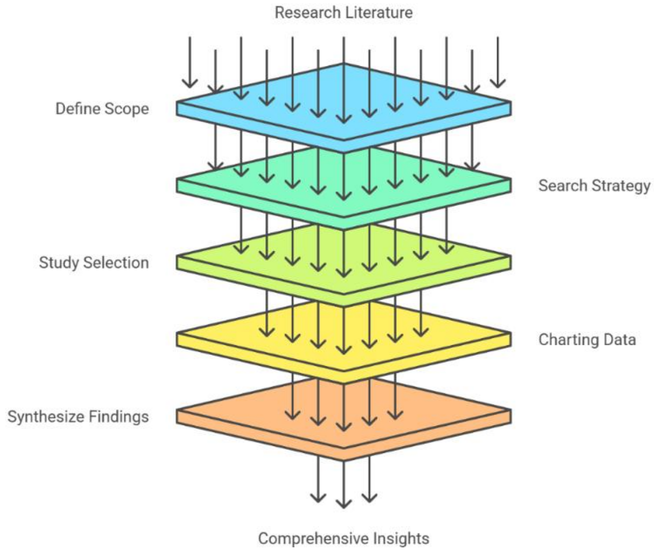

Figure 1: Methodology step-by-step.

4. Result and Discussion

4.1. Analysis results

The findings on the application of artificial intelligence (AI) in infrastructure and facilities management are thoroughly summarized in this section. The debate is organized into thematic subsections that are in line with the analytical framework and inclusion criteria of the study. Analysis and quantitative findings are provided below to aid in future data display and analysis.

Publication Overview

74 peer-reviewed papers and industry reports encompassing North America, Europe, Asia-Pacific, and the Middle East were included in the review, which covered publications from 2020 to 2025. Figure 2 is a comprehensive image for various country-based reports.

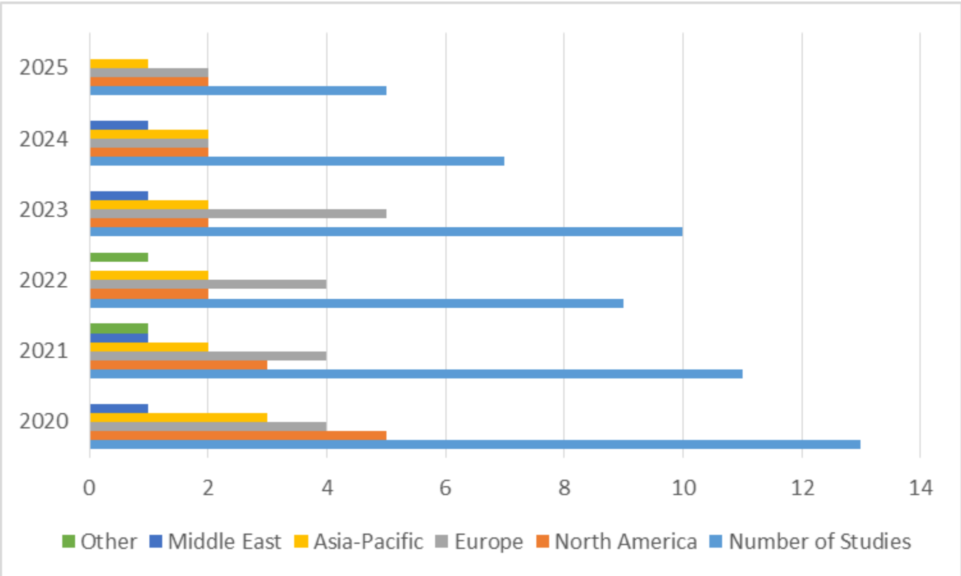

Figure 2: Country-based comprehensive study.

AI Technology Adopted

Numerous AI applications have been adopted, with intelligent automation and predictive analytics being the most widely utilized. Figure 3 shows which app was adopted in what percentage.

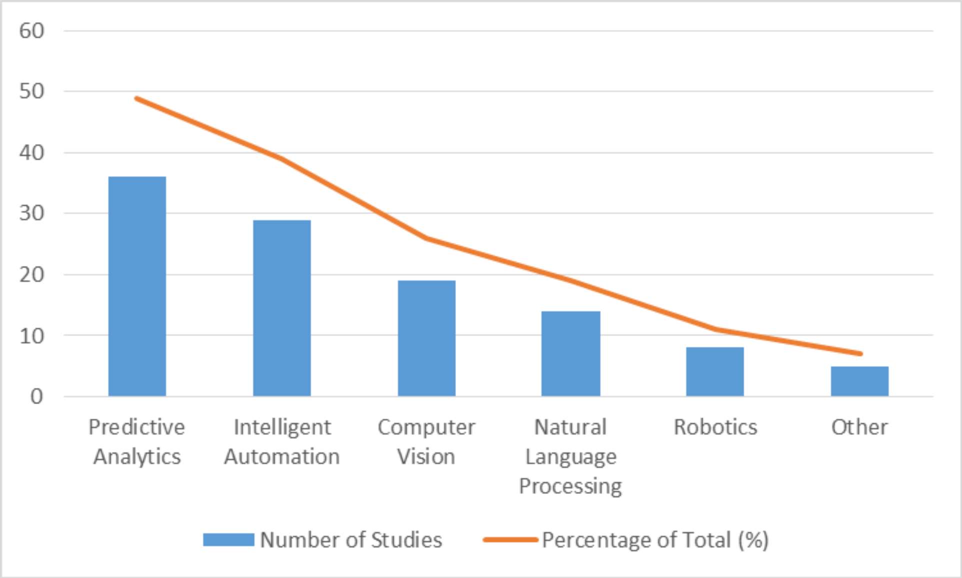

Figure 3: App adaptation in infrastructure and facilities management.

Applications of AI in Infrastructure Management

Infrastructure management is undergoing significant changes due to the advent of artificial intelligence. Maintenance, energy management, security and surveillance, asset tracking, space optimization, and other diverse sectors are among the primary application areas. The majority of research focuses on energy and maintenance applications, emphasizing AI's contribution to resource efficiency and predictive maintenance. Application areas of AI in infrastructure management are shown in Figure 4.

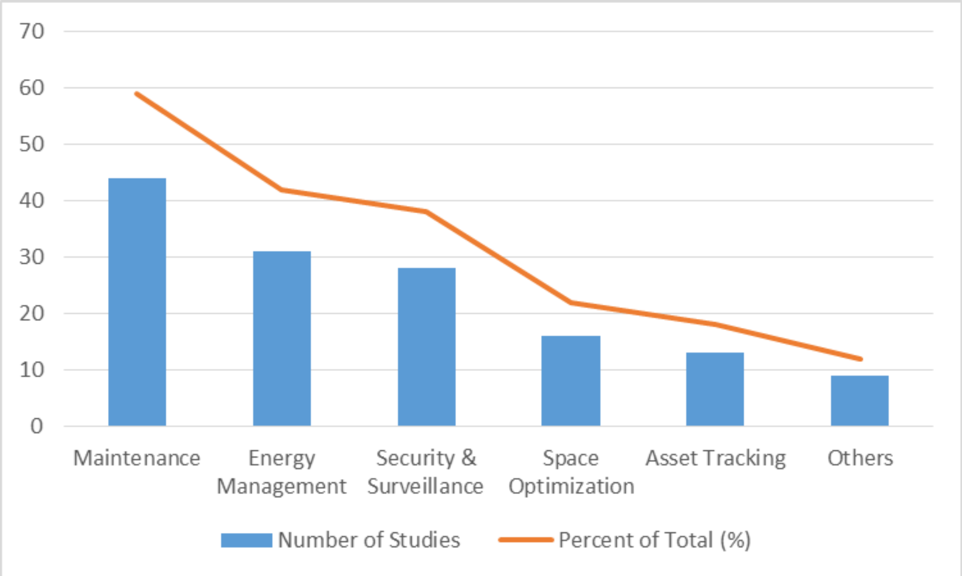

Figure 4: Application areas of AI in infrastructure management.

AI-Assigned Improvements in Operational Efficiency

Infrastructure operations have seen notable increases in efficiency as a result of AI-driven solutions. Reduced maintenance expenses and downtime, increased uptime, and increased employee productivity are important quantifiable results. An improvement in efficiency is shown in Table 4.

Table 4: Improvement of efficiency in AI-assigned solutions.

Indicator	Mean Improvement (%)	Min (%)	Max (%)	Number of Studies
Downtime Reduction	24	10	55	21
Maintenance Cost Reduction	18	7	34	16
Increased Uptime	12	4	28	14
Staff Productivity (tasks/day)	21	8	39	12

Sustainability and Results of Energy Use

The updated table that highlights each sustainability metric's three comparative variables, median improvement, minimum, and maximum, is shown below in Figure 5. In comparing graphs, this simplified format works well for visual depiction.

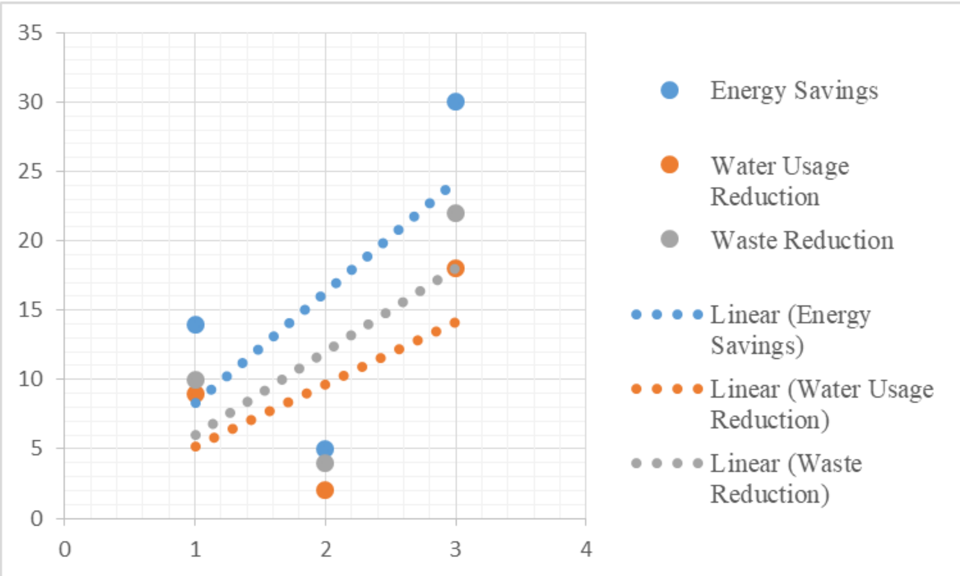

Figure 5: Sustainability matrices for AI in infrastructure management.

Improvements in Safety and Security

The mean improvement, minimum, and maximum for important safety and security indicators are compiled in the following Figure 6.

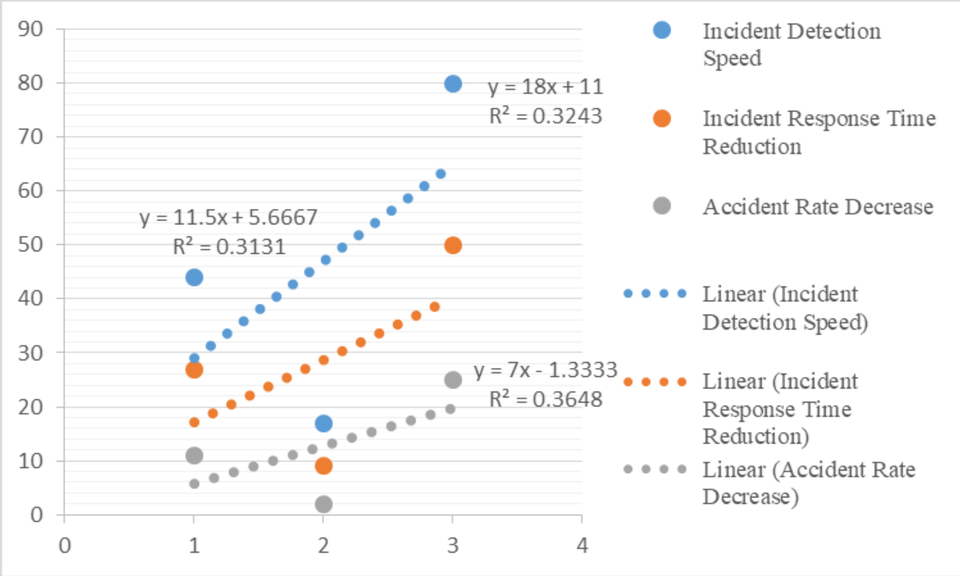

Figure 6: Safety and security improvement analysis.

Implementation Difficulties

There are a number of challenges associated with integrating AI into infrastructure management, such as organizational resistance, financial expenses, skills gaps, privacy concerns, and technical integration. Figure 7 is an implementation graph for difficulties faced.

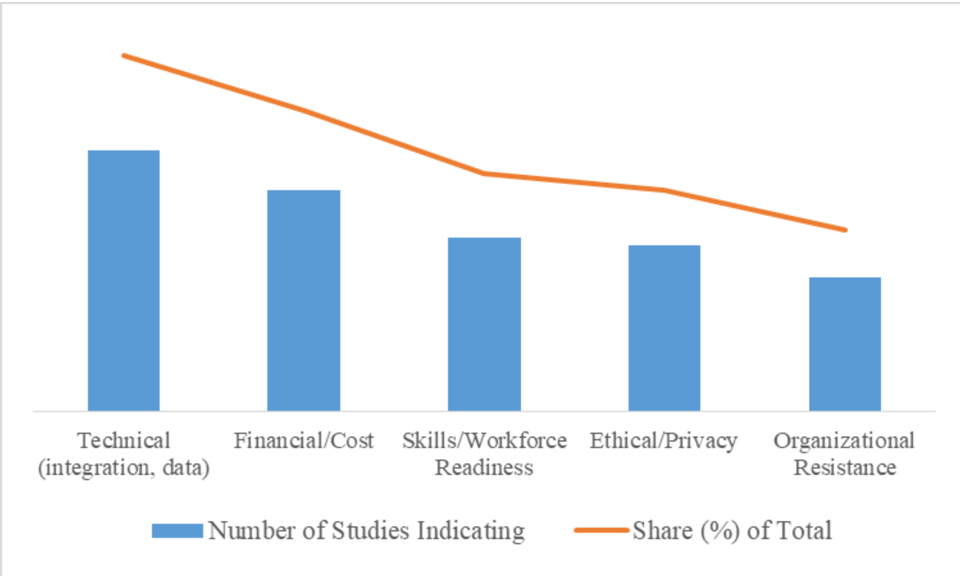

Figure 7: Implementation difficulties due to the use of AI in infrastructure management.

Stakeholder Views: Reported Advantages

The majority of facility managers and technologists have positive stakeholder sentiment regarding the use of AI, while end users and legislators have more measured reactions.

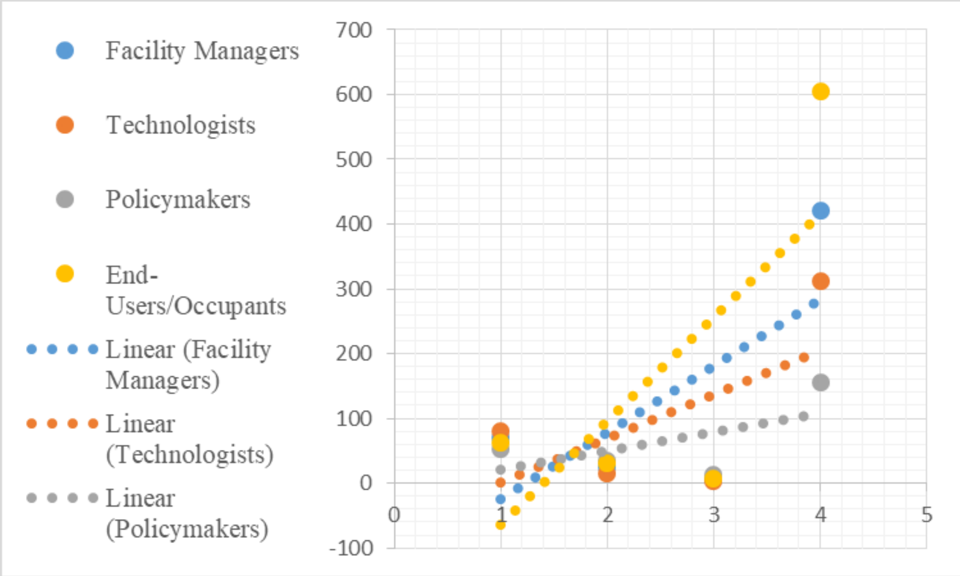

Figure 8: Advancement in stakeholder.

Tools Used in Various Studies

The evidence base is characterized by a variety of research techniques, the most prevalent of which are case studies, which are augmented by simulation models and quantitative analysis.

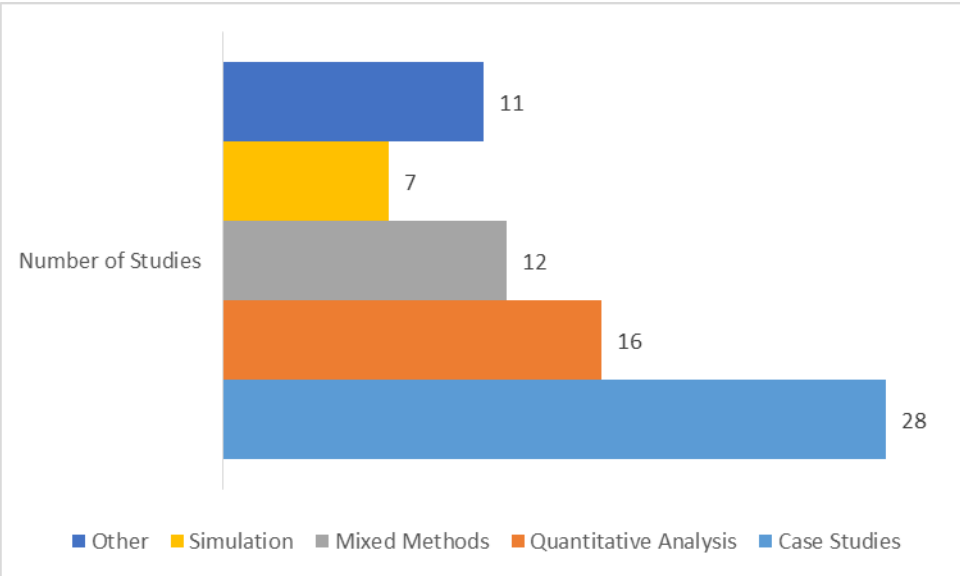

Figure 9: Methods used in various research and case studies.

Regional Disparity in the Use of AI

Regional Disparity exists in the level of AI application in infrastructure, with Asia-Pacific and the Middle East exhibiting greater activity in the pilot and planning stages, while North America and Europe dominate in complete deployment.

Table 5: Regional Disparity in AI use.

Region	Full Implementation (%)	Pilot/Trial (%)	Planning Stage (%)	Not Used (%)	Total Studies
North America	41	32	15	12	22
Europe	36	41	19	4	27
Asia-Pacific	28	37	30	5	17
Middle East	17	33	50	0	6

4.2. Thematic discussion

A. The Revolutionary Effects of AI

The information clearly shows that artificial intelligence (AI) is propelling notable improvements in infrastructure and facilities management's operational effectiveness. Notably, the majority of real-world applications are built on predictive analytics and intelligent automation, which have replaced conventional methods with data-centric and dynamic strategies. The overall results, which include an average 24% reduction in unscheduled downtime and an 18% reduction in maintenance expenses, demonstrate the operational and financial benefits that intelligent infrastructure technologies provide. Additionally noteworthy is energy management, which contributes significantly to the worldwide sustainability targets in built environments with reported median energy savings of 14%. These improvements are made possible by predictive control, adaptive scheduling, and real-time monitoring features that traditional systems cannot provide.

B. Improved Security and Safety

Computer vision and machine learning-based intelligent surveillance systems have dramatically boosted security and safety across many situations. Compared to conventional techniques, these systems can identify odd activity, possible threats, or safety problems more quickly and precisely by automatically evaluating video feeds in real time. By taking a proactive stance, incidents can be avoided or their effects might be lessened because prompt notifications and responses are possible. The implementation of such cutting-edge surveillance equipment has resulted in an astounding average improvement of 44% in the time of incident detection in safety-critical environments like public areas, industrial facilities, and airports. This quicker reaction time is essential for preventing damage or theft to priceless items as well as saving lives by facilitating prompt intervention. These methods also lessen the need for human supervision, which lowers mistakes brought on by distraction or weariness. Overall, by making environments safer and more risk-resistant, intelligent surveillance driven by computer vision and machine learning is revolutionizing security management.

C. Sustainability Benefits and Ecological Effects

Artificial intelligence's capacity to evaluate enormous datasets, automate monitoring, and offer organizations meaningful insights is quickly revolutionizing sustainability operations. Businesses may accurately monitor and compare resource use, including water and energy, across activities by utilizing AI. This allows for a continuous process of finding inefficiencies, forecasting requirements, and putting remedial measures in place. AI-powered solutions, for example, control water flows in real-time to prevent losses, optimize facility operations to minimize energy waste, and adjust manufacturing processes to use less extra material. These enhancements assist businesses in achieving their sustainability goals and satisfy legal obligations for environmental stewardship and transparency. Furthermore, AI improves the efficiency of renewable energy systems, increases recycling rates through intelligent trash sorting, and facilitates the shift to circular economies, all of which lead to higher ecological benefits. Importantly, these developments enhance compliance and assist firms in achieving their environmental, social, and governance (ESG) objectives by lowering operating costs and conforming to international sustainability standards and legal frameworks.

D. Barriers and Challenges

Despite the obvious advantages, there are significant obstacles to AI's widespread adoption:

→ The most commonly mentioned challenges are still technical ones, such as data availability and system integration.

→ Widespread adoption is frequently hampered by financial constraints, particularly for small and midsize facilities.

→ The need for reskilling and gaps in workforce skills are persistent issues, and organizational resistance to change can occasionally postpone implementation.

→ Although they are less common than technical and financial difficulties, worries regarding data privacy, security, and the moral application of AI technology are nevertheless present.

E. Disparities Between Sectors and Regions

Significant discrepancies between industries and geographical areas can be seen in the use of AI in infrastructure management, which reflects variations in economic development, technological capability, and regulatory frameworks. With large-scale AI deployments, North America and Europe are at the forefront thanks to significant investments, strong legal frameworks, and cutting-edge technology infrastructure. These areas have profited from strong digital ecosystems and an innovative culture that speeds up the application of AI in vital infrastructure areas like energy, urban planning, and transportation. For instance, AI-powered traffic management, smart grids, and predictive maintenance systems have proliferated, improving resilience and efficiency.

On the other hand, areas such as the Middle East and portions of Asia-Pacific still lag behind, focusing more on trial projects or developing AI strategies than on broad implementation. Issues including poor institutional preparedness, a lack of financing, and restricted access to state-of-the-art technology are the causes of this slower advancement. Discrepancies within industries are also noticeable; for example, vital infrastructure like waste management and water frequently receives less AI attention than transportation or energy, which exacerbates already existing discrepancies in technical advancement. To close these gaps and guarantee that AI's transformational potential is available and fairly dispersed across all areas and sectors worldwide, specific regulations, international collaboration, and investment efforts focused on capacity creation and infrastructure modernization are needed.

F. Stakeholder Perspectives

Multiple perspectives from various stakeholder groups are brought to bear by the integration of AI in infrastructure management, reflecting their various roles, objectives, and concerns. The most optimistic outlook is typically expressed by technologists and facility managers, who work at the forefront of implementation. They can identify instant operational improvements and efficiency advantages because of their practical expertise with AI-driven solutions like automated monitoring, anomaly detection, and predictive maintenance. As people observe directly the observable advantages of AI in optimizing processes and reducing downtime, this frontline involvement ignites passion for additional invention and real-world implementation.

End users and policymakers, on the other hand, are more cautiously optimistic about the deployment of AI. End users, from residents interacting with AI-enabled utilities to commuters utilizing smart transportation systems, value the ease and enhanced service quality but are cautious of any hazards. Their excitement is tempered by worries about data privacy, security lapses, and fair access to AI-enhanced services. The ethical ramifications of AI use in infrastructure are emphasized by policymakers, who are in charge of regulating and protecting the public interest. Their cautious approach is centered on concerns such as algorithmic bias that may disproportionately impact underprivileged communities, surveillance risks, and decision-making openness. To ensure that AI integration advances responsibly, addresses public concerns, and builds trust at all societal levels, it is necessary to have inclusive conversations among stakeholders in order to strike a balance between innovation and ethical oversight. The significance of interdisciplinary cooperation in determining AI's future function in infrastructure management is highlighted by this complex stakeholder landscape.

G. Methodologies and Research Gaps

Case studies, which provide in-depth insights into how AI technologies are applied within particular contexts, are the mainstay of current research on AI adoption in infrastructure and facilities management. These qualitative methods, which take into account site-specific user interactions, corporate culture, and technology maturity, are excellent at capturing the intricate, real-world complications of AI integration. For practitioners wishing to implement AI solutions in comparable contexts, case studies offer insightful illustrations of achievements, difficulties, and lessons discovered. This emphasis on context-specific research, however, restricts the applicability of results to other industries, geographical areas, or infrastructure scales.

Broad trends, correlations, and causal relationships in the adoption of AI can be found through extensive quantitative analyses, such as surveys and data-driven performance evaluations. By allowing comparisons across many infrastructure contexts, these methods would support the validation of case study results and the development of thorough models of AI's effects on sustainability, safety, and efficiency. Furthermore, longitudinal research and defined measurements are necessary to monitor AI results over time and across developing technologies. By addressing these methodological deficiencies, the evidence base will be strengthened, policy formation will be guided, and AI deployment tactics will be optimized to ensure that they are scalable and effective across the diverse infrastructure management landscapes.

4.3. Limitations and Future Directions

Current research on the use of AI in infrastructure and facilities management is severely limited by the preponderance of English-language publications. This can lead to a distorted view by underrepresenting contributions from non-English-speaking nations. This omission runs the risk of ignoring particular difficulties, creative solutions, and contextual elements that arise in various linguistic and cultural contexts. Future research methodology must include internationally inclusive strategies, like bilingual literature reviews and cooperation with scholars worldwide, to provide a more thorough and accurate global perspective. Another constant problem is the quick speed at which AI is developing. Static research findings can quickly become out of date due to the constant emergence of new technology, methodologies, and best practices. Thus, it is crucial to periodically reevaluate study findings in order to identify changing patterns and guarantee their applicability. Dynamic frameworks that permit constant updating and adaptability should be incorporated into future research so that decision-makers may effectively address the evolving field of artificial intelligence in infrastructure management. When combined, these approaches will promote more thorough, fair, and prompt understandings of AI's worldwide effects.

There are measurable advantages in terms of efficiency, cost, safety, and sustainability when AI is included in infrastructure and facilities management. The body of data is still expanding, but ongoing issues with workforce readiness, integration, cost, and ethical management need to be methodically resolved. Furthermore, to fully realize AI's transformative potential across global infrastructure assets, more extensive research is required, particularly studies that include underrepresented regions and non-English literature.

5. Conclusion

A revolutionary shift from traditional, reactive maintenance to proactive, adaptive, and data-driven methods is represented by the incorporation of artificial intelligence (AI) into infrastructure and facilities management. AI has a significant impact on improving operating efficiency, cutting expenses, encouraging sustainability, and optimizing occupant comfort, according to an analysis of 74 academic and commercial sources conducted between 2020 and 2025. At the front of this development are intelligent automation and predictive analytics. Facilities managers may now anticipate equipment breakdowns, identify operational irregularities early, and plan maintenance based on current conditions rather than set schedules thanks to these technologies. Unplanned downtime is reduced by 24% and maintenance expenses are reduced by 18% as a result of this change. Condition-based maintenance increases operational dependability and productivity in addition to prolonging asset lifespan. Additionally, using AI to automate monitoring and diagnostics increases staff productivity by 21%, freeing up staff members to concentrate on higher-value work.

AI improves facility security and user experience in addition to maintenance. By facilitating quick hazard identification and reaction, smart systems with motion detection, facial recognition, and anomaly detection improve safety. Artificial intelligence (AI)-powered environmental controls, like climate control and adaptive lighting, customize indoor spaces to residents' tastes and activity levels, increasing comfort and satisfaction, two important aspects of contemporary facilities management. AI-powered energy management systems that optimize resource consumption have a major positive impact on sustainability, resulting in lower carbon footprints, waste reduction, and median energy savings of 14%. By means of ongoing benchmarking and process optimization, these systems facilitate adherence to changing environmental legislation and business sustainability objectives.

Despite these developments, problems still exist. Because AI depends on sensitive data, there are serious cybersecurity and privacy issues that require strong protections and stringent adherence. Adoption may be hampered by the expense and complexity of integrating AI with antiquated legacy infrastructure. Since successful adoption depends on workers being trained to comprehend and act upon AI insights, workforce preparedness is essential. Widespread use is made more difficult by financial limitations associated with initial investments, which require phased deployment and meticulous ROI analysis. There is a need for more comprehensive, regional investigations because current research has a narrow geographic focus and frequently lacks context-specific assessments. To open up new efficiencies and applications, future research should investigate cutting-edge AI technologies like deep learning, augmented analytics, and edge computing. To fully exploit AI's disruptive potential in infrastructure and facilities management, more research into interoperability protocols, uniform ethical frameworks, and workforce development initiatives will be essential.

Reference

[1] A. Behnam, S. Azad, M. Daneshvar, A. Anvari-Moghaddam, and M. Marzband, "5 - Artificial intelligence–enabled Internet of Things technologies in modern energy grids," in *IoT Enabled Multi-Energy Systems*, M. Daneshvar, B. Mohammadi-Ivatloo, K. Zare, and A. Anvari-Moghaddam Eds.: Academic Press, 2023, pp. 69-86.

[2] P. Zakaria, "Leveraging Artificial Intelligence for Environmental Sustainability and Energy Efficiency: Opportunities, Challenges, and Future Directions," in *Tech Transformation and AI Readiness: Pioneering Paths for the Global South*, A. N. Turi and P. Teckle Eds. Cham: Springer Nature Switzerland, 2025, pp. 101-112.

[3] A. Hoque, S. A. Chowdhury, H. M. Sozib, I. Mahmud, and N. Suraiah, "Cloud Computing in Banking Flexibility and Scalability for Financial Institute," *Well Testing Journal,* vol. 34, no. S2, pp. 165-184, 2025.

[4] U. Paschen, C. Pitt, and J. Kietzmann, "Artificial intelligence: Building blocks and an innovation typology," *Business Horizons,* vol. 63, no. 2, pp. 147-155, 2020/03/01/ 2020, doi: https://doi.org/10.1016/j.bushor.2019.10.004.

[5] N. N. I. Prova, "Advanced Machine Learning Techniques for Predictive Analysis of Health Insurance," in *2024 Second International Conference on Intelligent Cyber Physical Systems and Internet of Things (ICoICI)*, 2024: IEEE, pp. 1166-1170.

[6] A. M. Abdelalim, A. Essawy, A. Sherif, M. Salem, M. Al-Adwani, and M. S. Abdullah, "Optimizing Facilities Management Through Artificial Intelligence and Digital Twin Technology in Mega-Facilities," *Sustainability*, vol. 17, no. 5, doi: 10.3390/su17051826.

[7] N. Mohammad, R. Khatoon, S. I. Nilima, J. Akter, M. Kamruzzaman, and H. M. Sozib, "Ensuring security and privacy in the internet of things: challenges and solutions," *Journal of Computer and Communications,* vol. 12, no. 8, pp. 257-277, 2024.

[8] R. Dhillon and Q. Moncur, "Small-Scale Farming: A Review of Challenges and Potential Opportunities Offered by Technological Advancements," *Sustainability*, vol. 15, no. 21, doi: 10.3390/su152115478.

[9] R. Pedral Sampaio, A. Aguiar Costa, and I. Flores-Colen, "A Systematic Review of Artificial Intelligence Applied to Facility Management in the Building Information Modeling Context and Future Research Directions," *Buildings*, vol. 12, no. 11, doi: 10.3390/buildings12111939.

[10] C. Jofré-Briceño, F. Muñoz-La Rivera, E. Atencio, and R. F. Herrera, "Implementation of Facility Management for Port Infrastructure through the Use of UAVs, Photogrammetry and BIM," *Sensors*, vol. 21, no. 19, doi: 10.3390/s21196686.

[11] N. Prova, "Detecting ai generated text based on nlp and machine learning approaches," *arXiv preprint arXiv:2404.10032,* 2024.

[12] F. J. Campos Zabala, "The Barriers for Implementing AI," in *Grow Your Business with AI: A First Principles Approach for Scaling Artificial Intelligence in the Enterprise*, F. J. Campos Zabala Ed. Berkeley, CA: Apress, 2023, pp. 85-110.

[13] E. Blessing and K. Hubert, "Technological Infrastructure and Challenges: Integration challenges in implementing AI solutions in legacy systems," 2024, 2024.

[14] R. Foresti, S. Rossi, M. Magnani, C. Guarino Lo Bianco, and N. Delmonte, "Smart Society and Artificial Intelligence: Big Data Scheduling and the Global Standard Method Applied to Smart Maintenance," *Engineering,* vol. 6, no. 7, pp. 835-846, 2020/07/01/ 2020, doi: https://doi.org/10.1016/j.eng.2019.11.014.

[15] S. B. Shafi *et al.*, "ARTIFICIAL INTELLIGENCE IN BANKING: TRANSFORMING BANK MANAGEMENT AND CUSTOMER EXPERIENCE," *Cuestiones de Fisioterapia,* vol. 52, no. 3, pp. 337-348, 2023.

[16] Y. Pan and L. Zhang, "Integrating BIM and AI for Smart Construction Management: Current Status and Future Directions," *Archives of Computational Methods in Engineering,* vol. 30, no. 2, pp. 1081-1110, 2023/03/01 2023, doi: 10.1007/s11831-022-09830-8.

[17] R. e. Almashawreh, M. Talukder, S. K. Charath, and M. I. Khan, "AI Adoption in Jordanian SMEs: The Influence of Technological and Organizational Orientations," *Global Business Review,* p. 09721509241250273, 2024, doi: 10.1177/09721509241250273.

[18] P. Helo and Y. Hao, "Artificial intelligence in operations management and supply chain management: an exploratory case study," *Production Planning & Control,* vol. 33, no. 16, pp. 1573-1590, 2022/12/10 2022, doi: 10.1080/09537287.2021.1882690.

[19] S. Agostinelli, F. Cumo, G. Guidi, and C. Tomazzoli, "Cyber-Physical Systems Improving Building Energy Management: Digital Twin and Artificial Intelligence," *Energies*, vol. 14, no. 8, doi: 10.3390/en14082338.

[20] Y. Chen, J. Li, E. Blasch, and Q. Qu, "Future Outdoor Safety Monitoring: Integrating Human Activity Recognition with the Internet of Physical–Virtual Things," *Applied Sciences*, vol. 15, no. 7, doi: 10.3390/app15073434.

[21] M. A. U. Imran, M. Samiun, S. R. Dhar, S. K. Noor, and H. M. Sozib, "A Predictive Analysis of Tourism Recovery Using Digital Marketing Metrics," 2024: IEEE, pp. 350-356.

[22] M. Tariquzzaman *et al.*, "Big Data Analytics in Banking: Unlocking Insights for Strategic Decisions," *Well Testing Journal,* vol. 34, no. S1, pp. 143-164, 2025.

[23] M. Signorini and A. P. Pomè, "Shaping the future of facility management. Market and literature insights on digital twin adoption," *Facilities,* 2025, doi: 10.1108/F-02-2025-0029.

[24] A. Konanahalli, M. Marinelli, and L. Oyedele, "Big Data Value Proposition in UK Facilities Management: A Structural Equation Modelling Approach," *Buildings*, vol. 14, no. 7, doi: 10.3390/buildings14072083.

[25] G. Shang, S. P. Low, and X. Y. V. Lim, "Prospects, drivers of and barriers to artificial intelligence adoption in project management," *Built Environment Project and Asset Management,* vol. 13, no. 5, pp. 629-645, 2023, doi: 10.1108/BEPAM-12-2022-0195.

[26] M. Y. Chew, E. A. Teo, K. W. Shah, V. Kumar, and G. F. Hussein, "Evaluating the Roadmap of 5G Technology Implementation for Smart Building and Facilities Management in Singapore," *Sustainability*, vol. 12, no. 24, doi: 10.3390/su122410259.

[27] M. Cubric, "Drivers, barriers and social considerations for AI adoption in business and management: A tertiary study," *Technology in Society,* vol. 62, p. 101257, 2020/08/01/ 2020, doi: https://doi.org/10.1016/j.techsoc.2020.101257.

[28] M. Zakizadeh and M. Zand, "Transforming the Energy Sector: Unleashing the Potential of AI-Driven Energy Intelligence, Energy Business Intelligence, and Energy Management System for Enhanced Efficiency and Sustainability," in *2024 20th CSI International Symposium on Artificial Intelligence and Signal Processing (AISP)*, 21-22 Feb. 2024 2024, pp. 1-7, doi: 10.1109/AISP61396.2024.10475298.

[29] A. Abonamah, S. Hassan, and T. Cale, "Artificial Intelligence and Environmental Sustainability Playbook for Energy Sector Leaders," *Sustainability*, vol. 17, no. 14, doi: 10.3390/su17146529.

[30] A. Gupta and U. Tandon, "Emergence of AI enabled smart buildings in India: a road towards sustainable performance," *Global Knowledge, Memory and Communication,* 2023, doi: 10.1108/GKMC-07-2023-0236.

[31] S. Manikandan *et al.*, "Artificial intelligence-driven sustainability: Enhancing carbon capture for sustainable development goals– A review," *Sustainable Development,* vol. 33, no. 2, pp. 2004-2029, 2025/04/01 2025, doi: https://doi.org/10.1002/sd.3222.

[32] N. J. Dewasiri and M. Choudhary, "Harnessing Artificial Intelligence (AI) for Sustainable Innovation: Case Studies and Practical Applications," *Innovation Ecosystems and Sustainable Technologies: Enhancing Competitiveness and Sustainability*: Emerald Publishing Limited, 2025, p. 0. [Online]. Available: https://doi.org/10.1108/978-1-83662-368-720251008

[33] I. Rojek, A. Mroziński, P. Kotlarz, M. Macko, and D. Mikołajewski, "AI-Based Computational Model in Sustainable Transformation of Energy Markets," *Energies*, vol. 16, no. 24, doi: 10.3390/en16248059.

[34] P. Arévalo and F. Jurado, "Impact of Artificial Intelligence on the Planning and Operation of Distributed Energy Systems in Smart Grids," *Energies*, vol. 17, no. 17, doi: 10.3390/en17174501.

[35] S. Park *et al.*, "Smart Fire Safety Management System (SFSMS) Connected with Energy Management for Sustainable Service in Smart Building Infrastructures," *Buildings*, vol. 13, no. 12, doi: 10.3390/buildings13123018.

[36] C. Wang, "Behavioral Computing for Human Factor Security and Safety in Traffic and Transportation," in *Human Factor Security and Safety: A Behavioral Computing Approach*, C. Wang Ed. Singapore: Springer Nature Singapore, 2025, pp. 219-240.

[37] H. Nabizadeh Rafsanjani and A. H. Nabizadeh, "Towards human-centered artificial intelligence (AI) in architecture, engineering, and construction (AEC) industry," *Computers in Human Behavior Reports,* vol. 11, p. 100319, 2023/08/01/ 2023, doi: https://doi.org/10.1016/j.chbr.2023.100319.

[38] A. M. Hanafi, M. A. Moawed, and O. E. Abdellatif, "Advancing Sustainable Energy Management: A Comprehensive Review of Artificial Intelligence Techniques in Building," (in en), *Engineering Research Journal (Shoubra),* vol. 53, no. 2, pp. 26-46, 2024, doi: 10.21608/erjsh.2023.226854.1196.

[39] M. Regona, T. Yigitcanlar, B. Xia, and R. Y. Li, "Opportunities and Adoption Challenges of AI in the Construction Industry: A PRISMA Review," *Journal of Open Innovation: Technology, Market, and Complexity*, vol. 8, no. 1, doi: 10.3390/joitmc8010045.

[40] A. Aldoseri, K. N. Al-Khalifa, and A. M. Hamouda, "Methodological Approach to Assessing the Current State of Organizations for AI-Based Digital Transformation," *Applied System Innovation*, vol. 7, no. 1, doi: 10.3390/asi7010014.

[41] M. Kuziemski and G. Misuraca, "AI governance in the public sector: Three tales from the frontiers of automated decision-making in democratic settings," *Telecommunications Policy,* vol. 44, no. 6, p. 101976, 2020/07/01/ 2020, doi: https://doi.org/10.1016/j.telpol.2020.101976.

[42] G. B. Melo, F. K. Malerbi, J. N. de Medeiros, and J. Grauslund, "A comprehensive strategy of diabetic retinopathy screening in a public health system: Identifying and overcoming obstacles for implementation," *Diabetes Epidemiology and Management,* vol. 13, p. 100192, 2024/01/01/ 2024, doi: https://doi.org/10.1016/j.deman.2023.100192.

[43] V. Zatsu *et al.*, "Revolutionizing the food industry: The transformative power of artificial intelligence-a review," *Food Chemistry: X,* vol. 24, p. 101867, 2024/12/30/ 2024, doi: https://doi.org/10.1016/j.fochx.2024.101867.

[44] F. A. Ghansah, "Digital twins for smart building at the facility management stage: a systematic review of enablers, applications and challenges," *Smart and Sustainable*

Built Environment, vol. 14, no. 4, pp. 1194-1229, 2024, doi: 10.1108/SASBE-10-2023-0298.

[45] M. Almatared, H. Liu, O. Abudayyeh, O. Hakim, and M. Sulaiman, "Digital-Twin-Based Fire Safety Management Framework for Smart Buildings," *Buildings*, vol. 14, no. 1, doi: 10.3390/buildings14010004.

[46] L. P. Vishwakarma and R. K. Singh, "An Analysis of the Challenges to Human Resource in Implementing Artificial Intelligence," *The Adoption and Effect of Artificial Intelligence on Human Resources Management, Part B*: Emerald Publishing Limited, 2023, p. 0. [Online]. Available: https://doi.org/10.1108/978-1-80455-662-720230006

[47] M. E. E. Alahi *et al.*, "Integration of IoT-Enabled Technologies and Artificial Intelligence (AI) for Smart City Scenario: Recent Advancements and Future Trends," *Sensors*, vol. 23, no. 11, doi: 10.3390/s23115206.

[48] S. Mahato and S. Neethirajan, "Integrating Artificial Intelligence in dairy farm management − biometric facial recognition for cows," *Information Processing in Agriculture,* 2024/10/09/ 2024, doi: https://doi.org/10.1016/j.inpa.2024.10.001.

[49] S. Ziesche, S. Agarwal, U. Nagaraju, E. Prestes, and N. Singha, "Role of Artificial Intelligence in Advancing Sustainable Development Goals in the Agriculture Sector," in *The Ethics of Artificial Intelligence for the Sustainable Development Goals*, F. Mazzi and L. Floridi Eds. Cham: Springer International Publishing, 2023, pp. 379-397.

[50] M. R. Sadik, U. H. Himu, I. I. Uddin, M. Abubakkar, F. Karim, and Y. A. Borna, "Aspect-Based Sentiment Analysis of Amazon Product Reviews Using Machine Learning Models and Hybrid Feature Engineering," 2025.