A Review on the Intersection of Artificial Intelligence on Building Resilient Infrastructure, Promoting Inclusive and Sustainable Industrialization and Fostering Innovation

Mokanmiyo Adedeji Olawale[1*], Ayomide Abdulbaqi Ayeh[2], Faruk Obasanjo Adekola[3], Alonge Samuel Precious[4], Awotundun Oluwagbenga Joshua[5] , Oluwafemi Timothy Oladosu[6]

[1, 2]Department of Civil & Environmental Engineering, Kwara State University Malete, Nigeria.
[3]Department of Electrical & Computer Engineering, Kwara State University Malete, Nigeria.
[4, 5, 6] Department of Mechanical Engineering, Kwara State University Malete, Nigeria.
Corresponding author: [1]olawalemokanmiyo@gmail.com, [2]ayomide.ayeh17@kwasu.edu.ng, [3]faruk.adekola16@kwasu.edu.ng, [4]Proflonge0@gmail.com
[5]awotundunoluwagbenga@gmail.com, [6]otoladosu@gmail.com

DOI: 10.56201/ijemt.v9.no3.2023.pg44.74

Abstract

Artificial Intelligence (AI) has made significant global impacts across various domains. However, it is evident that certain areas have yet to harness the full spectrum of opportunities AI can provide. This review aims to investigate the transformative effects of AI on diverse sustainable goals, including the development of resilient infrastructure, the promotion of inclusivity, and the cultivation of innovation. By shedding light on previously unnoticed challenges within the realms of industrialization and infrastructure, this study unveils a novel perspective on the potential for an AI-driven industrial and innovative world while preserving and enhancing efficiency.

Keywords: *Artificial Intelligence AI; Infrastructure; Industrialization; Renewable Energy; Energy*

1.0 Introduction

In the pursuit of a resilient, inclusive, and sustainable future, the integration of artificial intelligence (AI) has emerged as a transformative force across multiple domains. As global challenges continue to mount, including the need for resilient infrastructure, the promotion of inclusive industrialization, and the fostering of innovation, AI presents itself as a beacon of hope and progress. This review delves into the multifaceted interplay between AI and these critical objectives, offering insight into how advanced technologies are reshaping our world and propelling us toward a brighter and more sustainable future. Also, as the world grapples with the challenges of energy security and climate change, the need for sustainable energy sources has become more pressing than ever before. Sustainable energy encompasses a broad spectrum of energy sources that can meet the growing demands of the world's population without threatening the availability of resources. Among the various sustainable energy sources, renewable energy stands out as the most viable option, given its ability to generate energy without emitting harmful pollutants into the environment (Li & Du, 2021). Renewable energy derives from a diverse range of sources, including geothermal, hydroelectric, wind, and solar energy, each with its unique advantages and drawbacks. With the continued advancements in technology, renewable energy sources are becoming increasingly accessible and cost-effective, making them a critical component of a sustainable energy future. In recent times, there has been a significant impact on the use of energy, and its optimization has become a crucial concern. According to Li & Du (2021) the increasing use of the internet has positively affected the efficient use of energy. It has also led to an encouraging surge in research and development in the sector, financial development in the country, economic growth, human capital development, and industrial structure upgrading, as highlighted by (Ren et al, 2021). The continuous improvement in access to energy by different agencies in Africa has proven to be vital in improving human development. Availability of energy has encouraged industrialization, employment, economic growth, ICT development, and gender empowerment, as explained by Acheampong et al. (2021).

2.0 Drivers of AI for Sustainable Development

Building Resilient Infrastructure: Resilient infrastructure forms the backbone of society, ensuring the continuous and reliable delivery of essential services. In an era marked by increasing climate-related uncertainties and urbanisation, AI-driven solutions have come to the forefront. For instance, AI-enabled predictive maintenance can enhance the reliability and longevity of critical infrastructure components, reducing the risk of unexpected breakdowns. Autonomous drones equipped with AI algorithms are capable of assessing and monitoring infrastructure integrity, identifying potential vulnerabilities in real-time. These applications, among others, exemplify how AI contributes to the development and maintenance of infrastructure that can withstand the tests of time and environmental challenges.

Promoting Inclusive and Sustainable Industrialization: AI has become a driving force in the realm of inclusive and sustainable industrialization. By optimising manufacturing processes, AI technologies improve productivity while minimising resource consumption. For instance, AI-driven robotics can streamline and enhance production efficiency while reducing waste. This not only bolsters the industrial sector but also supports the United Nations' Sustainable Development Goals, particularly Goal 9, which emphasises the promotion of sustainable industrialization. Moreover, AI's potential to create new markets and opportunities through innovations in fields like clean energy, biotechnology, and healthcare contributes to an inclusive and sustainable economic landscape.

Fostering Innovation: Innovation is a cornerstone of progress, and AI is acting as a catalyst for novel solutions to long-standing problems. AI-powered systems can analyse vast datasets to identify patterns, make predictions, and discover opportunities that were previously hidden. Moreover, AI-driven natural language processing and machine learning enable faster and more insightful research and development. Consider the example of drug discovery: AI algorithms can significantly expedite the identification of potential pharmaceutical compounds and optimise clinical trial designs, thereby fostering innovation in healthcare and biotechnology.

2.1 Artificial Intelligence in Infrastructure

2.1.1 AI in Smart Cities Development

Artificial Intelligence (AI) has had a transformative effect on the development of smart cities in diverse positive ways. Some of the important areas where AI has made significant contributions include:

1. **Traffic Management and Optimization:** Due to heightened population expansion in the metropolitan cities, road traffic is inevitable. Thus AI-based systems are used to monitor and manage traffic flow in real-time. Some research has been done utilising Internet of Things (IoT) to address different problems for effectively suppressing traffic on road ways and to enhance authorities in efficient planning (Al-Turjman, 2018; Aftab et al., 2021; Stiawan et al., 2023; Dzulkurnain et al., 2019; Reddy, 2023). The flow of the road traffic is enhanced using a hybrid strategy which combines both centralised and decentralised, and a variety of situations in traffic are adequately and properly managed utilising an algorithm. To attain this goal, the system amends traffic signals upon obtaining data from traffic density from the cameras and remaining devices. In order to lower traffic crowding, an alternative artificial intelligence-found strategy is made use of to forecast future traffic density. This leads to reduced congestion, shorter commuting times, and lower emissions due to improved traffic signal coordination and predictive analytics. Furthermore, in instances of traffic congestion, Radio-Frequency Identification (RFID) technology is harnessed to accord precedence to emergency vehicles such as ambulances and fire brigade units. In tandem with this, smoke sensors are integrated into the system to promptly detect any road-based fires. An operational prototype has been developed, serving the dual purpose of ameliorating traffic fluidity and establishing a linkage between neighbouring emergency response entities and a centralised server. This connectivity demonstrates the utility of the envisaged traffic management system. Moreover, this system accumulates valuable data, which is presented in graphical formats, potentially offering insights to governmental authorities for future road infrastructure planning. The envisaged system for adaptive traffic signal control efficiently distributes green signal time in direct correlation to traffic density, thereby mitigating delays, congestion, and overall waiting times. Consequently, this approach yields manifold advantages, including diminished fuel consumption and reduced environmental pollution, thus amplifying sustainability within the transportation domain. Computational simulations have yielded findings that underscore an enhancement of roughly 23% as reported by (Reddy, 2023) in terms of the volume of vehicles traversing the intersection when juxtaposed with the existing system, unequivocally underscoring the substantial performance augmentation achieved by this novel system.
2. **Urban Planning and Development:** Urban planning researchers initiated their foray into the realm of artificial intelligence (AI) as far back as the 1960s, when AI was a specialised and highly scientific undertaking, generally removed from the purview of professional urban planners (Langendorf, 1985). During this era, AI encountered impediments to widespread adoption for various reasons. However, across subsequent decades, urban planning endeavours began to explore an assortment of advanced methodologies, each exhibiting varying degrees of assimilation and triumph. Geographic Information Systems (GIS) stands

out as the most prominent among these methodologies (Sanchez et al., 2023; Ali, 2020; Yan et al., 2021; Lebedeva & Dzhavakhadze, 2022; Xhafa & Kosovrasti, 2015), while others, such as database management systems (DBMS) (Kouziokas, 2016), decision support systems (DSS) (Wei et al., 2017), planning support systems (PSS) (Pettit et al., 2018; Bhatta & Joshi, 2022), and expert systems (ES), exhibited varying levels of recognition and acceptance within the discipline. The embrace of GIS, some proponents argue, has predominantly revolved around its capacity for cartographic functions, rather than its adeptness in sophisticated spatial analysis techniques. One facet of the challenge lies in the diverseness of planning predicaments; certain issues are conducive to rule-based algorithms rooted in "if–then" logic, while others necessitate more intricate structures akin to artificial neural networks. This delineates the complex landscape of urban planning, where the suitability of AI techniques relies heavily on the specific problem at hand. Regrettably, the advancement of information technologies within the realm of urban planning has progressed at a somewhat sluggish pace, trailing behind the transformative revolutions witnessed in parallel domains. Industries such as financial services, healthcare, and consumer goods and services have undergone radical transformations thanks to the rapid evolution of information technology. Pioneering corporations like Baidu, Amazon, Netflix, and Google have harnessed the potential of AI to glean insights into consumer behaviours, delineate distinctive characteristics, and refine their supply chains and logistics with unparalleled efficiency. In sum, the journey of AI in urban planning, dating back to its inception in the 1960s, has been marked by varying degrees of recognition, acceptance, and application. The adoption of advanced methodologies in this field has been subject to the unique nature of planning problems, which often necessitate tailored AI solutions. Moreover, while other industries have experienced rapid technological revolutions, urban planning has treaded more cautiously along the path of technological transformation. Nevertheless, the untapped potential of AI remains a focal point for the future of urban planning, promising novel insights and innovative approaches to address complex urban challenges.

3. **Smart Buildings:** The proliferation of green and intelligent building initiatives has engendered a surge in their construction, propelled by the myriad advantages they offer. In parallel, the application of artificial intelligence (AI) techniques has been identified as highly pertinent to the rationalisation, optimization,and innovation of these buildings' operational facets (Rodríguez-Gracia et al., 2023). The fusion of green and smart building concepts with AI methodologies holds immense promise in fortifying structural integrity and curbing adverse environmental and societal repercussions. Although research endeavours exploring the interplay of AI within green and smart buildings abound, a comprehensive comprehension of the practical utility and associated benefits of this integration remains somewhat fragmented (Panchalingam & Chan, 2021). To bridge this perceptible knowledge gap, research was done to scrutinise the pertinence and advantages arising from the amalgamation of AI techniques in green and smart building frameworks. Employing the Web of Science and Scopus databases, the investigation has harnessed bibliometric analysis as its primary tool to furnish a thorough examination of publication output within the domain. It systematically identifies the most influential scholarly works and key stakeholders, encompassing authors, research institutions, and nations. Moreover, the study deploys content analysis techniques to illuminate the cognitive landscape of the field, discerning five distinct thematic clusters that

shape its knowledge terrain. As a culmination, the research offers a temporal keyword analysis, centering on the Triple Bottom Line benefits engendered by the application of AI techniques in the context of green and smart buildings. A preeminent contribution of this study lies in its distinction as the pioneering endeavour to undertake a bibliometric analysis specifically within the domain of Artificial Intelligence Techniques applied to green and smart Buildings. This initiative holds paramount importance as it equips both scholars and practitioners with a comprehensive and scientifically grounded overview of extant research endeavours in this rapidly evolving field, thereby serving as a valuable reference for those interested in further exploration and engagement with this burgeoning area of study.

2.1.2 AI in Transportation Infrastructure

1. **Autonomous Vehicles:** Artificial intelligence (AI) empowered systems are designed to replicate human actions. Within the automotive industry, AI plays a crucial role in advancing vehicular technology. It collaborates with the field of mechatronics to facilitate precise execution of vehicle functions. Autonomous vehicles acquire environmental data through onboard sensors like laser, radar (Ha et al., 2023; Carpenter, 2018), lidar (Royo & Ballesta-Garcia, 2019; Kim & Park, 2020), Global Positioning System (GPS) (Zein et al., 2018; Lee et al., 2015; Akhshirsh et al., 2021), and vehicular communication networks. This data is subsequently utilised in a variety of path planning and control techniques, enabling vehicles to autonomously navigate complex environments. Advanced AI algorithms are employed to determine the vehicle's location in both familiar and unfamiliar surroundings. AI algorithms also find application in perception, path planning, and motion control. This text provides a concise overview of cutting-edge techniques aimed at enhancing the performance of autonomous vehicles. In autonomous vehicles, the decision-making process is pivotal for processing data gathered from onboard sensors. The vehicle's computer employs these observations to make optimal decisions. These decisions can be computed through two distinct methods: the integrated perceive-plan-act approach or end-to-end learning methods. In the end-to-end method, sensor data is directly mapped to control outputs without intermediary steps. Each step in the perceive-plan-act process of autonomous vehicles can be implemented using classical methods devoid of learning or the latest AI and deep learning (DL) techniques. The end-to-end implementation method consistently employs DL techniques. Learning and non-learning methods can be combined in various configurations. For instance, a deep learning-based object detector supplies input to the AI algorithm used for path planning. An integrated perceive-plan-act approach comprises four components: perception and localization, path planning, behavioural mediation, and motion control. All these components collectively underscore the pivotal role of AI in advancing the development of self-driving vehicles, thereby contributing to improved road safety and a reduction in traffic accidents.
2. **Road Safety:** Annually, an alarming 1.35 million lives are lost on the world's roads, with an additional 20-50 million people suffering severe injuries. The projection of morbidity or serious injuries resulting from road traffic incidents is expected to surge to an astonishing 265 million individuals between 2015 and 2030 (Eskandari Torbaghan et al., 2022). The current landscape of road safety management systems heavily relies on manual

data collection, visual inspection, and subjective expert judgement to ascertain their efficacy. Unfortunately, this approach proves to be costly, time-intensive, and, at times, ineffective due to under-reporting and the suboptimal quality of the gathered data. However, a spectrum of innovative solutions holds the potential to revolutionise data collection and analysis, thereby bolstering road safety. Digital technologies, particularly Artificial Intelligence (AI), emerge as valuable tools for identifying and disseminating information concerning road safety aspects, encompassing road user behaviour, road attributes, and operational conditions. The results gleaned from these technologies underscore their effectiveness in enhancing road safety by automatically capturing and analysing data while mitigating the prospect of human errors. Fatigue-induced driving is a major contributor to road fatalities. Consequently, ongoing research endeavours focus on the recognition of driver fatigue and its real-time detection. Conventional methodologies predominantly hinge on machine-based approaches, behavioural indicators, or physiological processes. Many of these solutions necessitate costly sensors and intricate data processing, while some intrude upon the driver's comfort. Consequently, studies have endeavoured to develop a precise, real-time mechanism for identifying driver fatigue. This involves capturing footage through a camera and leveraging image processing techniques to detect the driver's face in each frame. Subsequently, facial landmarks are pinpointed, enabling the computation of the eye aspect ratio and mouth opening ratio based on their respective values. Drowsiness is identified through the application of adaptive thresholding. In the ensuing step, a support vector machine (SVM) is employed to determine if the identified object is indeed a face. The driver's eye aspect ratio (EAR) and mouth opening ratio (MOR) are continuously monitored to detect signs of drowsiness or yawning. Upon identifying sleepiness, an alert email is promptly dispatched to a pre-registered email address.

2.1.3 AI in Water Resource Management

Water bodies play an important role in mitigating the effects of climate change. Basically, water is also a vital resource for billions of people to use for a variety of purposes. But every year, a lot of water is wasted due to leaks in different water systems (Kammoun et al., 2022). The role of Artificial Intelligence (AI) in Water Resource Management is to automatically detect the presence of hazardous microorganisms (algae, foams, etc.) in the water based on available data (Remote Sensing), leakages in water systems, and protection against droughts, etc. This automation thereby reduces the amount of time needed to manually review the contributions of the microorganisms, leakages, etc. (Biraghi et al., 2021). The role of AI in Water Resource Management includes:

1. **Water Quality Monitoring:** Industrial sites across the world discharge their wastewater into rivers and streams, which serve as water sources, irrigation, and sources of power. The discharge process has been observed to reduce the quality of water in the rivers. AI tools can be used to facilitate the modelling and forecasting process by providing statistical analysis of intricate non-linear structures and a large number of historical data series in a relatively short period of time. Previous research has also demonstrated that, despite the limitations of AI, they have proven to be effective and efficient methods that can be employed in hydrology (Mustafa et al., 2021). Ighalo et al (2021). conducted a systematic

literature analysis on the application of AI in the monitoring of surface water quality. The results of the study revealed that Adaptive Neuro-Fuzzy Inference System (ANFIS) and Artificial Neural Network (ANN) have been the most commonly employed AI tools for monitoring and evaluating water quality in the past decade, with the majority of the studies being conducted using ANFIS and most studied parameter in the monitoring and assessment of surface water quality was the BOD (Biochemical Oxygen Demand). The most reliable models for predicting surface water quality were the Adaptive Neuro-Fuzzy Inference System (ANFIS), Wavelet Adaptive Neuro-Fuzzy Inference System (W-ANFIS), and Wavelet Artificial Neural Network (ANN). However, there was no correlation between the data size and the R^2 value at the testing stage in each of the models. Biraghi et al. examined the potential of AI as a tool to detect algae in water bodies and enhance water quality monitoring. The aim of the research was to analyse the tools and information available from the SIMILE (Informative System for the Integrated Monitoring of Insubric Lakes and their Ecosystems) project to create an open pre-filtering system for Volunteer Geographic Information (VGI) on lake water monitoring on a global scale. Various tools and deep learning algorithms (Clarifai platform, a Convolutional Neural Network (CNN), and an object detection algorithm called Faster Region-based CNN (R-CNN) were evaluated and the original dataset, which was based on observations from SIMILE (Lake Monitoring application), was combined with the results of keyword and image searches on Google, Bing, and Crawling Flickr data. The results revealed that the R-CNN algorithm was found to be more appropriate for the purpose of object detection, with a result that was comparable to that of other similar studies. It was further concluded that other detection algorithms, such as Single Shot Detector (SSD), YOLO (You Only Look Once) or the Region-Based Fully Convolutional Network (R-FCN), could also be trained to provide a better understanding of which algorithms perform best in detecting harmful organisms in lake water.

2. **Leakage Detection:** Leaks in the water distribution system can generally be caused by the corrosion of the steel pipe that houses the cables or by electrolytic corrosion caused by stray currents or external mechanical failure of the pipe. In the event of extensive corrosion of pipes, a relatively minor leak results in an immediate operational issue if the pumping plants are unable to maintain the necessary pressure required. Water distribution system leaks are a major problem that is present in many parts of the world, resulting in significant financial losses. Ejah et al. conducted a study to detect pipeline leakage through the utilisation of a computerised, on-line system using the analysis of the pressure in the pipe as the determining factor for leakage in a pipeline. The simulated data was obtained from a hydraulic modelling system EPANET (Environment Protection Agency Network Evaluation Tool), and pressure was changed at each location of the leakage in the pipeline. The simulated data was then processed using an AI Radial Basis Function Neural Network (RBF-NN), which has two phases which are the Learning phase and the Testing phase. The RBF-NN model produced an accuracy of 98% of the entire existing pipeline on the water distribution network which proves the ability of the application of AI to detect the magnitude and the location of leakage in a pipeline. Using a fully automatic system to detect leaks in High-Pressure Fluid-Filled (HPFF) cables, Tylman et al., conducted a series of tests. They used the automated system to combine AI and data processing techniques to

obtain high detection capabilities for different leak rates. The study used a leak simulator to evaluate how the system components detect leaks. The results indicated that the AI system could detect small leaks (in terms of volume per time) and provide an estimate of the leak rate.

3. **Drought Prediction:** According to Karavitis et al., drought is a commonly known catastrophic event that has significant impacts on the socioeconomic, agricultural, and environmental spheres and it is primarily caused by a deficiency in precipitation, particularly in terms of the timing, distribution, and intensity of this deficiency relating to existing water storage, water demand, and ultimately water usage. Therefore, the role of AI in drought forecasting is to quantify rainfall deficits using seasonal forecasts from major weather forecast centres and minimise the effects of droughts. Oluwatobi et al. adopted the Standardised Precipitation Index (SPI) approach to assess the overall meteorological drought variability in Ijebu-Ode. The study used rainfall records from a 40-year return period while other parameters such as temperature, potential evapotranspiration and relative humidity was used by Artificial Neural Network (ANN) based modelling to predict drought levels. The results indicated an increase of three months' time-step demonstrating a need for drought monitoring in the area of study. This study demonstrated the potential of AI in drought prediction.

2.1.4 AI in Construction and Maintenance

1. **Project Efficiency, Safety Enhancement and Cost Reduction:** The complexity of infrastructure is often attributed to the large number of activities involved. As a result, it is necessary to choose the optimum alternative to reduce the costs, time and quality of the infrastructure. Consequently, with increasing awareness of the drastic effects of energy consumption, and safe and cost-efficient infrastructure, AI has been incorporated into sustainable infrastructural projects including the design of energy-efficient buildings, forecasting and reduction of energy consumption, formulating strategies to reduce the environmental and climatic impacts, as well as improving the safety and comfort of the environment (Abdel-Kader et al., 2022). A Machine Learning model was employed by Rahman and Smith (2017) to predict fuel consumption in commercial buildings. Neural networks, Gaussian Process (GP), Linear regression and Ridge regression were used to successfully predict the fuel consumption in commercial buildings one year in advance. The fuel consumption for multiple climate zones was estimated using the models. Mocanu et al. used two deep-learning (DL) models (Conditional Restricted Boltzman Machine (CRBM) and Factored Conditional Restricted Boltzman Machine (FCRBM) and Artificial Neural Networks (ANN) to estimate electricity consumption in a residential building. The study presented five scenarios ranging from a minute resolution to a weekly resolution. The FCRBM model demonstrated a significantly higher performance with a 50% reduction in prediction error compared to the ANN. Using Expert Systems (ES), Norrman (2000) evaluated the slipperiness of roads and chose the optimum design, an essential element for road safety. The study made observations and examinations of different types of roads in different years using data from the Swedish Road Weather Information System. The results indicated that 49% of the roads were considered to be slippery. In a study presented by Pongpaibool et al. (2007), on the assessment of highway safety using fuzzy logic and

adaptive neuro-fuzzy techniques. The system was developed to simulate human expertise on the identification of three levels of traffic congestion. Traffic information was obtained from an automated vehicle detection and tracking software. The accuracy of the results from the AI was verified by manually collecting information from volunteers. The results of the Manual Fuzzy Logic and Adaptive Neuro-Fuzzy techniques had an accuracy of 88.4% and 75.4% respectively.

2.1.5 AI in Infrastructure Security

1. **Threat Detection:** Highways, Power grids, commercial buildings, oil and gas facilities etc. are examples of critical infrastructure that are essential for economic development as well as national security. Natural hazards (earthquakes, floods, hurricanes, etc.), human errors, and climate change are all potential threats to infrastructure. Therefore, the implementation of AI to detect threats to infrastructure and protect the infrastructure for the promotion of national security. Li et al. (2005) presented a comprehensive overview of power infrastructure defence systems using Strategic Power Infrastructure Defense (SPID) systems to identify potential threats to power infrastructure. The SPID system performed the future analysis, vulnerability assessment and adaptive control actions to prevent catastrophic power outages. Astuti et al. proposed a relatively simpler and faster method of predicting earthquakes which combined the Singular Value Decomposition (SVD) technique for feature extraction and Support Vector Machine (SVM) for time, location and magnitude classification of the occurrence of earthquakes. These models achieved accuracies of 77% and 67.67% for the location and magnitude of the earthquake respectively. Furthermore, the SVM could predict earthquakes 2 to 7 days in advance of its occurrence.
2. **Surveillance and Security:** Video surveillance has become an integral component of infrastructure protection and maintenance in the modern world. Smart cameras which are equipped with advanced video analysis capabilities can be used to monitor events and provide systematic alerts when abnormal activities in human behaviour are observed as well as hazard detection in infrastructures. These cameras are commonly used in infrastructure (airports, banks, streets, hospitals etc). The cost and difficulty of real-time monitoring by humans has made it necessary to incorporate AI by automating surveillance systems which capture scenes and detect activities in infrastructure (Babanne et al., 2019; Elbasi, 2020). Elbasi presented a study in which a surveillance system was set up to recognize human activities from multiple cameras using Machine Learning (ML) algorithms. The low-level processing method was employed to detect moving objects and create a feature vector per object, while the high-level processing method was used to identify human activities from multiple sensors taken from the Internet of Things (IoT) technology. The experimental results demonstrated that the detection of abnormal human activities using machine learning algorithms achieved an accuracy of more than 96%.

2.1.6 AI in Energy Infrastructure

1. **Optimising Energy Production:** AI assumes a central role in the enhancement of energy generation from diverse sources, encompassing fossil fuels, renewable energy, and nuclear

power (Guo, 2023; Pahwa et al., 2022). Utilising machine learning algorithms, AI anticipates energy requirements, scrutinises meteorological patterns, and manages power plant operations. In the context of solar and wind energy, AI plays a crucial role in projecting energy output based on prevailing weather conditions. This, in turn, empowers grid operators to adeptly harmonise energy supply and demand. The net result of this optimization is amplified energy production and diminished operational expenses.

2.1.7 AI in Infrastructure Monitoring and Maintenance

Artificial Intelligence (AI) has a gargantuan effect on infrastructure monitoring and maintenance, improving efficiency, accuracy, and cost-effectiveness. Some of the effects of AI in this context include:

1. **Predictive Maintenance:** AI demonstrates the capability to predict potential failures in critical infrastructure components like bridges and pipelines by analysing data from sensors and historical trends (Bhardwaj & Kaushik, 2022; Pourbozorgi Langroudi & Weidlich, 2020). This predictive ability facilitates proactive maintenance practices, preventing costly breakdowns and extending the lifespan of infrastructure assets. Despite the promising outcomes in recent predictive maintenance research involving high-performance AI algorithms, many of these studies have primarily focused on standalone AI solutions, often overlooking the dynamic interaction between humans and AI systems. In more recent investigations, a deliberate emphasis has been placed on exploring the advantages of human-AI collaboration, where human inspectors are aided by AI technologies. One such study concentrated on the application of this collaborative approach to predictive maintenance in wind farms, specifically employing endoscopic images for detecting bearing faults. The experiment involved 54 technical inspectors who analysed 2301 images collected from 138 wind turbines. Inspectors were tasked with identifying bearing faults both with and without AI assistance. The results of the study revealed that AI support had a statistically significant impact on enhancing the technical inspector's specificity and efficiency in terms of time. The degree of improvement, however, was found to be contingent on the inspector's level of expertise. The group of generalists exhibited more substantial enhancements in specificity and time efficiency, with improvements of 24.6% and 25.3%, respectively, in contrast to the specialist group, which saw more modest improvements of 4.7% and 6.4%, respectively. Both groups, encompassing generalists and specialists, expressed a positive inclination toward the intention to reuse AI assistance and acknowledged its usefulness. Furthermore, the introduction of AI support did not result in a statistically significant change in cognitive load for the inspectors. The investigations underscore the benefits of harmonious human-AI interactions in the realm of predictive maintenance, where AI contributes to enhanced inspector performance and efficiency, while ensuring a positive user experience.
2. **Resource Allocation:** To enhance network performance, encompassing the reduction of computation delay, transmission delay, and bandwidth consumption, the integration of edge computing and caching technologies into the fifth-generation wireless network (5G) has been imperative. Nevertheless, the availability of edge resources is limited, whereas the network experiences a surge in the quantity and intricacy of tasks. As a result, the

efficient provisioning of services to network users with these constrained resources has become an urgent and pressing challenge. Consequently, there is a critical need to augment the utilisation of communication, computing, and caching resources within the network. The proliferation of diverse network resources has introduced complexities in network management. The quandary of joint resource allocation poses a formidable challenge, one that cannot be effectively addressed by traditional methods. However, with the evolution of Artificial Intelligence (AI) technology, AI algorithms have emerged as a solution for tackling the intricacies of joint resource allocation problems. These algorithms facilitate the resolution of complex decision-making challenges by prioritising tasks based on their urgency and risk, thereby ensuring the efficient allocation of both human resources and materials. Drawing from a substantial body of research (Fu et al., 2020), the deep Q-network (DQN) algorithm has emerged as a powerful tool to address complex and high-dimensional joint resource allocation problems. Empirical results underscore the algorithm's commendable convergence characteristics. When incorporated with an innovative architectural framework, the DQN-based joint resource allocation scheme outperforms other resource allocation strategies, demonstrating the marked advantages of integrating Artificial Intelligence into resource allocation within the network.

2.2 Artificial Intelligence in Industry and Innovation

2.2.1 AI in Financial Services

AI has numerous applications in both consumer finance and global banking operations. Examples of artificial intelligence in this industry include the following:

1. **Fraud Detection and Risk Management:** The field of artificial intelligence (AI) is undergoing rapid evolution, with the potential to revolutionise various domains, including the critical areas of fraud detection and risk management. Fraud detection encompasses the intricate process of recognizing and preempting fraudulent activities, which encompass identity theft, credit card fraud, and money laundering, among others. Risk management, on the other hand, pertains to the evaluation and mitigation of potential losses or damages stemming from a multitude of sources, including operational risks, market risks, and credit risks. Both fraud detection and risk management play an indispensable role in upholding the security and stability of financial institutions, businesses, and individuals alike. AI holds the promise of elevating the capabilities of fraud detection and risk management by furnishing sophisticated methodologies for data analysis, pattern recognition, anomaly detection, prediction, and informed decision-making. Moreover, AI can facilitate the automation of intricate and laborious tasks, including but not limited to data collection, verification, reporting, and auditing. Several noteworthy studies (Maniraj et al., 2019; Perols, 2011; Thennakoon et al., 2019; Tiwari et al., 2021; Varmedja et al., 2019) have effectively illustrated the transformative potential of AI and machine learning within the domain of credit card fraud detection. By harnessing state-of-the-art machine learning algorithms such as Linear Regression, Support Vector Machines, and Recurrent Neural Networks, researchers have achieved considerable progress in fortifying financial systems against the perils of fraudulent activities.

2. **Algorithmic Trading:** AI in algorithmic trading is the application of artificial intelligence methods to process market information, execute trades, and enhance trading strategies. AI has been extremely advantageous in the real time analysis of data, prediction of future market trends, development of refined trading strategies, management of portfolio, assessment of risk etc. The incorporation of AI and machine learning in algorithmic trading has indeed revolutionised the financial industry, making trading quicker and more effective than ever before. Numerous studies, such as those by (Kondratieva et al., 2020; Li et al., 2019) have emphasised the remarkable impact of AI and machine learning in stock trading. These studies show that trading agents employing machine learning methods consistently surpass baseline strategies and attain stable risk-adjusted returns, not only in the stock market but also in the futures market. This shift from conventional floor trading to algorithmic trading driven by AI is proof of the increasing role of technology in the financial world. It has enabled more complex strategies, faster execution, and better risk management, ultimately benefiting both institutional and retail investors.

2.2.2 AI in Healthcare

Artificial Intelligence (AI) is reshaping the healthcare landscape, offering a myriad of opportunities to improve patient care, enhance medical outcomes, and streamline operational processes. This essay explores the remarkable impact of AI in healthcare, discussing its key applications and potential benefits, while also acknowledging the challenges that come with its implementation.

1. **Disease Diagnosis and Prediction**: One of AI's most promising applications in healthcare lies in disease diagnosis and prediction. With access to vast datasets of medical records, images, and genetic information, AI algorithms have demonstrated the capability to assist in diagnosing diseases and predicting disease outbreaks. This is a game-changer, particularly in the early detection and management of conditions like cancer, diabetes, and heart disease.
2. **Medical Imaging:** AI's potential in interpreting medical images cannot be overstated. Radiologists and other healthcare professionals are being assisted by AI in identifying abnormalities in X-rays, MRIs, and CT scans. This not only improves diagnostic accuracy but also expedites the process, leading to more timely treatment.
3. **Drug Discovery and Development:** The drug discovery process has historically been time-consuming and expensive. AI, however, is accelerating this process by analysing vast amounts of biological data to identify potential drug candidates and predict how they will interact with the human body. This holds the promise of more efficient and cost-effective drug development.
4. **Personalised Treatment Plans:** Personalised medicine is a cornerstone of modern healthcare, and AI is making it a reality. By considering an individual's genetics, medical history, and other factors, AI can help create tailored treatment plans that increase effectiveness while minimising side effects.
5. **Electronic Health Records (EHRs):** AI is simplifying the management and analysis of electronic health records (EHRs). With the ability to extract insights and trends from these

records, healthcare providers can make informed decisions more easily. This enhances patient care and streamlines administrative tasks.

6. **Telemedicine and Remote Monitoring:** The recent surge in telemedicine has been complemented by AI-powered chatbots and virtual health assistants. These tools provide patients with information and guidance while remote monitoring systems track vital signs and health data. The result is improved patient engagement, convenience, and healthcare accessibility.
7. **Predictive Analytics:** AI's predictive capabilities are helping healthcare providers anticipate disease outcomes, readmission risks, and resource needs. These insights enable proactive interventions and optimised resource allocation, ultimately leading to more efficient healthcare systems.
8. **Robot-Assisted Surgery**: In the realm of surgical procedures, AI-guided robotic systems are enhancing precision and enabling minimally invasive surgeries. The benefits are undeniable – improved surgical outcomes and quicker recovery times.
9. **Medication Management:** Medication adherence is a critical aspect of patient care. AI can assist in medication management by helping patients adhere to their treatment plans and reminding them to take their medications on time, improving health outcomes.
10. **Administrative Tasks:** AI's capabilities extend beyond clinical aspects, with the automation of administrative tasks such as appointment scheduling, billing, and claims processing. This reduces the administrative burden on healthcare professionals, allowing them to focus more on patient care.
11. **Public Health and Epidemiology:** AI's impact in public health and epidemiology cannot be ignored. It has the capacity to analyse vast datasets to track and predict disease outbreaks, monitor population health trends, and assist in public health decision-making, providing a crucial tool for global health management.

2.2.3 AI in Telecommunications

The application of Artificial Intelligence (AI) in telecommunications is multifaceted, and it's transforming the industry in numerous ways. AI technologies are being harnessed to optimise network operations, enhance customer experiences, and improve overall efficiency. Here are some key applications of AI in the telecommunications sector:

1. **Network Optimization:** AI plays a crucial role in optimising network performance. It uses machine learning algorithms to analyse vast amounts of data from network elements, such as switches and routers, and can adjust configurations in real-time. This ensures that the network operates at peak efficiency, minimises congestion, and provides a high-quality service to customers.
2. **Predictive Maintenance:** Telecommunications infrastructure is vast and complex, making maintenance challenging. AI can predict equipment failures by analysing historical data, allowing service providers to schedule maintenance before a critical failure occurs. This proactive approach minimises network downtime and reduces repair costs.
3. **Customer Support:** AI-driven chatbots and virtual assistants are now common in customer support. They can handle routine customer queries, troubleshoot issues, and

provide information 24/7, improving response times and reducing the load on human agents. Natural Language Processing (NLP) makes these chatbots increasingly effective in understanding and responding to customer inquiries.

4. **Personalised Services:** AI utilises customer data to offer personalised services. Telecom companies can customise data plans, recommend content, and tailor service offerings to individual customer preferences. This personalization enhances customer satisfaction and loyalty.
5. **Network Security:** AI is employed in network security to detect and mitigate threats. It continuously monitors network traffic and patterns to identify unusual behaviour or potential security breaches. It can respond in real-time to mitigate threats and protect sensitive data.
6. **Quality of Service (QoS):** AI algorithms monitor network traffic to ensure that high-priority services, such as voice and video calls, receive the necessary bandwidth and quality of service. This ensures that mission-critical applications perform optimally.
7. **Resource Allocation:** AI optimises the allocation of network resources like bandwidth and frequency spectrum. By intelligently distributing resources based on demand, it ensures efficient utilisation and a better user experience. These applications of AI in telecommunications are continually evolving as technology advances. They are helping telecom companies provide more reliable and efficient services while enhancing the customer experience. The integration of AI is a pivotal factor in the ongoing evolution of the telecommunications industry.

2.2.4 AI in Clean Energy

Renewable energy, also known as clean energy, refers to sources of energy that do not produce harmful byproducts or release harmful materials into the environment. According to (Heffron et al., 2021), the 2015 Paris agreement on low carbon emission goals has led to increased global adoption of green energy, with many countries implementing unique renewable energy sources that suit their location. For example, Africa has mainly adopted PV power, while wind energy is most commonly used in the USA, and China focuses on both PV power and fuel cells.

The adoption of green energy has had a significant impact on energy production and distribution policies worldwide. For instance, in China, the emission trading scheme, which is responsible for reducing fossil fuel use, has enforced policies to encourage the growth of photovoltaic power, hydropower, nuclear power, and wind power (Liu & Zhang, 2021). Although fuel cells and solar systems are the primary focus of clean energy sources, little attention has been given to wave energy. However, combining the three energy systems (solar, wind, and wave) can potentially lead to better results. When two of the systems power a load, the third system charges the battery, thus increasing efficiency (Talaat et al., 2021).

The primary goal of the SDG 7 is to ensure that everyone has access to affordable, reliable, and clean energy (Liang et al., 2021). Achieving this goal is possible by harnessing the full potential of renewable energy. Renewable energy has numerous advantages, including conserving fossil fuels, reducing gas emissions, reducing global warming, improving public health, providing inexhaustible energy, creating jobs and economic benefits, stabilising energy prices, and improving reliability and resilience (Alola & Akadiri, 2021). However, the main downside to renewable energy is the high upfront cost, which may limit accessibility to the common man (Adom et al., 2021).

Several factors affect the development of clean energy worldwide, including national security, trade policy, and economic policy. Improved economic expansion and national security facilitate the development of clean energy, while more stringent trade policies and high economic uncertainty threaten its growth (Alola & Akadiri, 2021).

The field of Artificial Intelligence (AI) involves the creation of intelligent machines that can perform tasks that simulate human brain functions. AI has proven to be a valuable asset in various aspects of life, including the energy sector. The implementation of digitization technology has helped to reduce operating expenses by up to 22%, while also increasing efficiency by up to 45% (Quest et al., 2022). Furthermore, AI has contributed significantly to the improvement of safety and reliability in the energy industry. One of the most notable examples of AI's interaction with clean energy is the use of solar trackers, which improve the efficiency of solar systems compared to fixed-position solar collectors or PV cells. This is because solar trackers ensure that the solar panels are always facing the sun, optimising energy output. This paper focuses on three primary sources of clean energy: fuel cells, solar systems, and wave power, highlighting the significant contributions of AI in each of these areas;

2.2.4.1 AI in Solar System

Solar systems have seen significant improvements in design and efficiency thanks to the integration of AI. One key area where AI has proven to be particularly beneficial is in predicting solar irradiation. In fact, studies have shown that AI-based predictions are far more accurate than those made using traditional empirical methods (Nawab et al., 2023). Over time, AI has been able to optimise the performance of solar systems in various aspects, including sub-aspects such as:

1. **Solar Site Selection:** The selection and analysis of potential locations for solar farms is a critical step as environmental conditions play a crucial role in production and storage capabilities. Due to its ability to analyse vast amounts of geographical and environmental data, many companies now rely on AI-powered technology to identify sites with optimal solar resources and conditions. Furthermore, AI can also help verify easy access to grid infrastructures and ideal positioning for future development.
2. **Pre-Construction Planning and Design:** Before starting the construction, AI-driven iterative and 4D design can provide general contractors with detailed construction plans, schedules, and "digital twin" site models and equipment designs customised to specific solar equipment, site conditions, and restrictions. During the pre-construction phase, virtual models of solar systems and equipment can be utilised to simulate and test various scenarios. This helps in optimising equipment and site layout, and designing for increased efficiency. The use of AI-driven planning can reduce the need for on-site customization and adjustments during (or post) construction, leading to a significant reduction in costs. It also helps in identifying potential issues and avoiding delays or costly changes to the project plan and scope. Recent advancements in AI technology have led to solutions that

have been proven to reduce the cost of major infrastructure construction by up to 30%. This is especially beneficial for large and complex projects, including solar power system construction, which can benefit from AI-driven construction optimization. With the help of optimization tools such as those offered by ALICE Technologies, the use of resources on-site can be maximised through reallocation of labour and equipment, and dynamic scheduling. This results in improved resource efficiency and utilisation even for the most complex solar projects.

3. **Overcome Construction Delays**: When it comes to building and installing major utility infrastructures, time is of the essence. The potential for costly delays during the construction or interconnection of solar energy systems is real. However, when things go awry, AI-driven tools can identify options for redeploying resources and maintaining project progression. These tools suggest options for task, equipment, or labour resequencing to keep projects moving forward. In case of supply chain issues, specialised labour shortages or interconnection delays, rapid recovery and on-the-go scheduling adjustments (courtesy of AI) provide a tremendous advantage in managing complex construction. AI technology can help in managing the construction process efficiently and in a timely manner, helping stakeholders to avoid costly delays and ensuring the timely completion of the project.
4. **Streamlining Interconnection:** The integration of solar systems into existing energy grids requires their production to be optimised. Since electricity generated by solar power is intermittent, careful planning of supply and storage needs is critical to avoid disruptions in service or overwhelm of current grid systems. To ensure a successful large-scale expansion of solar power generation, careful analysis and forecasting of solar power production and supply is pivotal for successful operation and regulation. As the use of renewable energy continues to evolve and expand (both literally, and as a share of the global power supply), accurate solar power generation predictions become increasingly important for forecasting power demand, improving production uptime, and expanding energy systems and storage capacity. The ability of AI to accurately assess and analyse massive quantities of complex data, combined with its predictive abilities to suggest innovative alternative pathways, can be incredibly valuable to the interconnection process. AI technology can help in predicting solar power generation and supply, by analysing large amounts of data, allowing for more accurate forecasting and ensuring a smooth integration of solar power into the existing energy grid.
5. **Forecasting and analysing Solar System Performance**: AI technology allows for vast quantities of environmental data to be analysed continuously and consistently, enabling accurate forecasting and real-time adjustments to current conditions. This leads to improved planning, storage, and operational efficiency, which eliminates unnecessary power waste or shutdowns due to weather, environmental hazards, or mismatches in supply/demand, as well as reducing equipment malfunctions and damage. Some solar energy providers are already using AI to optimise power system performance and predict maintenance needs. AI can identify patterns that may indicate future performance based on solar conditions, environmental data, and past maintenance records, as well as anticipate future challenges, repair needs, or likely upgrades. As a result of this information, optimised performance and maintenance schedules can be created, which maximise system

efficiency over the long term. AI's ability to analyse vast amounts of data and provide insights in real-time can help in predicting maintenance needs and optimising solar power systems performance, leading to long-term benefits.

6. **Demand Scheduling:** Demand scheduling is another important aspect of solar power use and future forecasting of energy demand, which can be supported by the implementation of AI. Poor demand forecasting can cause power outages, brownouts, and renewable energy curtailment. However, AI systems possess the potential to identify intricate usage patterns and highlight potential issues before they occur. By using historical consumption data, AI can provide insight into consumer demand on an individual and collective basis, revealing data that is helpful in optimising the solar power system. AI-driven demand scheduling can help in predicting energy demand and consumption patterns, allowing for better planning and optimization of the solar power system. This can lead to more effective use of renewable energy and a reduction in energy waste.

2.2.4.2 AI in Fuel Cells

Over the years, various alternative methods to burning fossil fuels have been researched, and one such promising solution is the use of hydrogen fuel cells.

Hydrogen, being a versatile and clean-burning fuel, has found its application in various industrial processes, as rocket fuel, and in fuel cells for electricity generation and powering vehicles. There is a growing trend among operators of natural gas-fired power plants to explore the use of hydrogen as a supplement or replacement for natural gas. Hydrogen has the potential to store energy effectively for electric power generation.

Hydrogen fuel cells generate electricity through a process that involves the combination of hydrogen and oxygen atoms. The hydrogen reacts with oxygen across an electrochemical cell, similar to a battery, to produce electricity, water, and small amounts of heat. Currently, hydrogen fuel cells are used to power the electrical systems on spacecraft and supply electricity on earth. Small fuel cells have also been developed to power electronic devices, such as laptop computers and cell phones. Several vehicle manufacturers have developed fuel cells to power vehicles. Fuel cells have the potential to provide electricity for emergency power in buildings and remote locations that are not connected to electric power grids.

The energy sector has recently made a major breakthrough with the incorporation of artificial intelligence. Various models such as artificial neural networks, machine learning, support vector regression, and fuzzy logic have made significant contributions to the improvement of hydrogen energy production, storage, and transportation. By predicting various parameters, safety protocols, and managing hydrogen production, AI has become an important tool in the industry. Furthermore, advances in AI are expected to bring state-of-the-art technologies and tools to solve the current energy crisis. This review provides insight into the feasibility of state-of-the-art artificial intelligence for hydrogen and battery technology. It focuses on demonstrating the contribution of various AI techniques, algorithms, and models in the hydrogen energy industry, as well as smart battery manufacturing and optimization. AI models have a key role in material discovery, battery design, improved battery manufacturing, diagnostic tools, and optimal battery management systems for smart batteries. These smart batteries with improved performance and longer life will be integrated into modern robotics, electric vehicles, aerospace, and other fields(Sai Ramesh et al., 2023).

Artificial Intelligence (AI) has revolutionised the way we optimise the performance of various systems, resulting in better output and efficient results. One of the noteworthy applications of AI is in the determination of optimal operating conditions for fuel cells. By utilising AI, fuel cells can run more efficiently, thereby reducing the energy required for hydrogen production. The development of efficient and reliable systems, coupled with their cost-effectiveness and accessibility, could further enhance the adoption of fuel cells. The potential benefits of AI in this area are significant, paving the way for a greener and more sustainable energy future.

2.2.4.3 AI in Wave Energy

Nature is a wonderful thing, and one of its many wonders is the phenomenon of waves. Waves are disturbances that move in a regular and organised way, much like a gentle ripple in a pond or the powerful force of oceanic swells. In this paper, we will delve into the fascinating topic of waves on water, exploring their characteristics and properties.

Wind is the primary factor that creates waves, driven by the sun's energy. Other factors such as tides and tsunamis can also contribute to wave formation. One of the most remarkable aspects of waves is that they represent a renewable source of energy, which can be harnessed and utilised for various purposes.

It is fascinating to observe how waves move in a regular and organised manner, whether it is the waves on the surface of water, sound in the air, or light. In this paper, the focus is mainly on the waves on water. Wind is the primary factor in creating waves, and it is driven by the sun's energy. Tides and tsunamis can also play a role in wave formation. It is amazing to think that waves represent a renewable source of energy that can be harnessed and utilised for various purposes.

Water waves are surface waves that are a combination of longitudinal and transverse waves. The distortions propagate with the wave speed, while the water molecules remain at the same positions. Most ocean waves are produced by wind, and waves towards the coast pass the energy from the wind offshore(Seenipandi et al., 2021). Using a wave energy converter, these waves can be converted, where the waves lift the floaters of the converter, creating fluid pressure within the system, which in turn operates a hydro motor. The hydro motor then turns the generator, which feeds power to the grid via an inverter. However, the system shuts down immediately when the waves from the water increase beyond what the system is designed to handle in both height and length. The system only resumes operation when the waves return to the normal length and magnitude the system is designed for.

When it comes to designing and deploying wave energy converters in a specific location, accurately predicting the amount of available wave energy flux is crucial. To achieve this, Computational Intelligence techniques, such as Neural, Fuzzy, and Evolutionary Computation, can be employed to estimate various wave parameters. Coastal engineering and structure design rely heavily on predicting wave height, which is one of the most significant challenges in this field (Shrivastava & Chaturvedi, 2018). However, the harsh marine environment and unpredictable nature of ocean waves pose significant obstacles to the operation, maintenance, and design of these systems.

AI and robotics have come to the rescue by incorporating AI algorithms and machine learning techniques into the control systems of wave energy converters. This integration allows researchers to optimise device performance in real-time, enabling the converters to adapt to changing wave conditions and maximise energy capture. This results in a more efficient and reliable system overall. Although still in the early stages, the integration of AI and robotics into ocean wave energy systems holds immense potential benefits. Researchers and engineers are developing more cost-effective and reliable solutions for capturing and converting the vast energy of ocean waves into usable electricity. As the world continues to seek innovative ways to meet its growing energy demands, the combination of AI and ocean wave energy offers a promising and sustainable path forward.

3.0 Challenges

3.1 Artificial Intelligence in Infrastructure

3.1.1 AI in Smart Cities Development

1. **Traffic Management and Optimization:**The effectiveness of artificial intelligence in traffic control is presently constrained, necessitating refinements through the calibration of the AI system via the utilisation of authentic real-life CCTV data for model training. This strategic calibration holds the potential to augment both the accuracy and performance of the system substantially.
2. **Urban Planning and Development:**The existing applications of artificial intelligence are notably advanced and may not be readily applicable to conventional planning practices, especially those pertaining to routine plan-making tasks. Furthermore, insights derived from the inaugural nationwide survey, conducted in the United States, which gauged planners' experiences, attitudes, and perspectives regarding AI, lead to the conclusion that the adoption of AI in planning activities is anticipated to be rather limited. The survey results indicate a lukewarm reception toward the integration of these novel technologies into planning operations. The initial assumption concerning the minimal utilisation of AI by planners is affirmed, as is the prevalent lack of comprehensive knowledge about AI among planning professionals.
3. **Smart Buildings:** The deployment of AI-powered surveillance systems introduces valid privacy apprehensions, given that individuals may perceive an intrusion into their personal movements and activities. Moreover, it is crucial to acknowledge that AI systems are susceptible to cybersecurity threats, which, if exploited, could result in the disruption of critical services and infrastructure.

3.1.2 AI in Transportation Infrastructure

1. **Autonomous Vehicles:** The advent of autonomous vehicles introduces an unprecedented array of risks, which now encompass the capacity of socially integrated artificial intelligence to make intricate decisions related to risk mitigation. These decisions bear

direct and significant consequences on human lives. Given the inherent dissimilarity between AI-driven decision-making processes and human decision-making, it gives rise to pertinent questions about how AI assesses decisions, the mechanisms for mediating these decisions, and their implications in relation to other individuals. Therefore, a comprehensive understanding of these disparities is imperative for society, policy-making, and end-users. While AI decisions can be contextualised within specific frameworks, substantial challenges persist concerning the technical aspects of AI decision-making, the conceptualization of AI decisions, and the degree to which various stakeholders grasp their significance. This challenge becomes especially pronounced when assessing the advantages and drawbacks associated with AI-driven decisions. Autonomous vehicles, often lauded for their potential safety benefits, present an interesting case study in risk mitigation technology. However, it is equally important to fathom the novel risks that autonomous vehicle driving decisions may introduce. These new risks are primarily framed as decisional limitations, manifesting in the incapacity of artificial driving intelligence to annotate and categorise the driving environment in accordance with human values and moral comprehension. In both instances, there is a pressing need to scrutinise the conceptual underpinning of autonomous vehicle decision-making capabilities and how this, in turn, impacts the broader understanding of the technology concerning its associated risks and benefits.

2. **Road Safety:**The integration of artificial intelligence (AI) into road safety endeavours offers a promising avenue for mitigating accidents and preserving lives. However, this transformative technology grapples with various hurdles that demand careful consideration and strategic resolutions. One fundamental issue revolves around the acquisition of data. AI systems heavily rely on copious datasets for their operations, and procuring high-quality data from a plethora of sources, including sensors, cameras, and GPS, can prove to be a demanding undertaking. In some regions, data might be scarce or inconsistent in quality, thereby affecting the precision of AI-driven road safety measures. Data privacy emerges as another critical concern. With the adoption of AI in road safety, the collection of data from vehicles and drivers becomes inevitable. Striking the right equilibrium between data collection and safeguarding individual privacy is a challenge that calls for meticulous handling. Real-time data processing is indispensable in road safety applications. AI systems must expeditiously analyse data and make instantaneous decisions to avert accidents. Overcoming latency issues and addressing network delays is pivotal in this regard. Interoperability is a complex challenge, especially when multiple stakeholders, including vehicles, infrastructure, and traffic management systems, are involved. The existence of varying standards and protocols necessitates harmonisation to ensure seamless communication. AI's adaptability to unforeseen circumstances is another challenge. Unpredicted events such as extreme weather conditions, unusual road obstacles, or erratic driver behaviour can confound AI algorithms. The development of systems that can effectively adapt to these scenarios is imperative for enhancing safety. Liability and regulatory frameworks must be meticulously clarified. Determining liability in accidents involving AI-controlled vehicles or road safety systems is a legal and regulatory conundrum that necessitates resolution. Cybersecurity is of paramount concern. AI systems employed in road safety are susceptible to cyberattacks, requiring robust security measures

to shield these systems from malicious intrusions. Cost and infrastructure constraints may impede the widespread implementation of AI in road safety. Substantial investments in infrastructure, sensors, and AI technologies may be requisite, and many regions may grapple with budget limitations or contend with antiquated infrastructure. The interaction between AI systems and human drivers or pedestrians poses a unique challenge. Ensuring that humans comprehend AI warnings and instructions is crucial for the efficacy of safety measures. AI systems may confront ethical dilemmas in critical situations. Making ethical decisions, such as choosing between safeguarding the vehicle's occupants or pedestrians, poses a complex challenge in the development of AI-driven road safety systems. Continuous learning is an ongoing challenge. AI systems must continuously adapt and learn from new data and experiences to remain effective and up to date. Public perception and trust in AI systems for road safety constitute another challenge. Building confidence in the reliability and safety of AI-driven technologies may necessitate substantial efforts. Navigating these challenges is pivotal for the successful integration of AI into road safety initiatives, which possess the potential to significantly reduce accidents and save lives on the world's roads.

3.1.3 AI in Water Resource Management

The incorporation of AI in the management of water resources involves the application of statistical and descriptive techniques to allow the models process and learn from data to generate future estimations, potentially resulting in significant financial losses for the researcher (Wernick et al., 2010). The utilisation of multiple AI models for the prediction and estimation would also increase the likelihood of a comparative analysis (Nadiri et al., 2014) which could result in data loss and influence the predicted outcomes. Additionally, the training, performance and calibration of a model pose challenges in balancing the model complexity with predictive validity (Ighalo et al., 2021).

3.1.4 AI in Construction and Maintenance

The construction industry is one of the least digitised industries in the world and its growth has been impeded by the numerous challenges it faces. AI in the construction industry faces several challenges, such as the initial cost of investing in AI solutions as well as the difficulty of recruiting AI engineers with relevant experience in the construction sector to provide solutions to the problems in the industry. Furthermore, the construction industry has a low level of confidence in AI due to the specific set of risks associated with the sector, such as the risk of making minor errors that could potentially lead to a compromise to the safety of both on-site workers and end-user of the infrastructure (Abioye et al., 2021).

3.1.5 AI in Energy Infrastructure

Optimising Energy Production: Various inherent challenges arise when considering the adoption of AI for optimising energy production. These challenges encompass factors such as data quality and data scarcity, the fine-tuning of AI network parameters, technical infrastructure hurdles, the shortage of qualified experts, integration complexities, risks, compliance issues, and legal considerations. Moreover, the detection and diagnosis of faults within building energy systems present intricate challenges. Data insecurity and the absence of complete information emerge as major hurdles for energy systems. Additionally, the subpar quality of controllers, sensors, and controlled devices in energy system operation and data estimation substantially impacts system reliability and performance. The intricate correlations and strong interconnections within the power grid, coupled with the high dimensionality of data, especially the intricacies of extensive simulation grid data, introduce fresh complexities in the energy market. Furthermore, the application of AI for the integration of renewable energy sources like wind and solar presents intricate and demanding challenges for grid operations.

3.1.6 AI in Infrastructure Monitoring and Maintenance

1. **Predictive Maintenance:** Leveraging Artificial Intelligence (AI) for predictive maintenance in facilities engineering offers a host of advantages, from optimised maintenance practices to substantial cost savings. However, embarking on this transformative journey is not without its share of challenges, which demand careful consideration and strategic solutions. A pivotal challenge that emerges in the context of AI-driven predictive maintenance is the quality and availability of data. To make accurate predictions and enable proactive maintenance, reliable and consistent data must be gathered from a diverse array of sources and formats. The amalgamation of this data into a coherent and comprehensive dataset proves to be a complex undertaking. Security and privacy concerns loom prominently in the foreground. Facilities engineering involves the handling of sensitive and confidential data, which demands a robust security framework. Unauthorised access or misuse of this data poses a significant risk that must be mitigated effectively. Adhering to stringent security and privacy standards is non-negotiable. The process of analysing and interpreting complex data is another challenge that organisations must grapple with. Skilled and experienced personnel are required to extract meaningful insights from this intricate data landscape. Advanced tools and methodologies are essential for effective data analysis, underlining the need for investment in the right resources. Implementation and adoption of AI-driven predictive maintenance solutions mark a critical phase in this journey. Ensuring that the organisation is equipped to embrace and make the most of these solutions requires effective change management. It encompasses elements such as communication and collaboration among stakeholders and users. A cohesive approach must be in place to ensure the alignment of data-driven solutions with the overarching goals and strategies of the organisation. In conclusion, the utilisation of AI for predictive maintenance in facilities engineering promises substantial benefits. However, it necessitates a strategic approach to address the challenges it presents. Tackling issues related to data quality, security, analysis, and adoption is essential for the successful deployment of AI in facilities engineering. Overcoming these obstacles not only enhances maintenance practices and cost savings but also upholds the standards of data security and privacy.
2. **Resource Allocation:** One of the primary challenges associated with the incorporation of AI into resource allocation lies in the potential for bias. AI systems frequently derive their insights from historical data, which may already be imbued with biases. When these biases become ingrained in AI algorithms, they can result in inequitable distribution of resources. For example, in scenarios like job recruitment, AI might unintentionally favour specific

demographic groups, thereby perpetuating societal inequalities. The rectification of bias and the assurance of fairness in AI-driven resource allocation is of utmost importance. Moreover, resource allocation frequently encompasses sensitive data, including personal financial details and healthcare records. AI systems necessitate access to this data for making informed decisions. However, ensuring the privacy and security of this information while harnessing AI presents a formidable challenge. Data breaches or the improper handling of personal information can lead to dire consequences. Achieving the delicate balance between data accessibility and privacy represents a key challenge in this context.

3.1.7 AI in Infrastructure Security

AI is capable of detecting, monitoring and providing alerts when abnormal activities are detected. However, the algorithms are vulnerable to exploitation by malicious actors such as hackers and cybercriminals (Abioye et al., 2021). The purpose of these attacks is to break into vulnerable infrastructure systems and tamper with their functions and operations to cause total system failure or damage which is a major concern with significant financial implications and a danger to infrastructure and national security.

3.2 Artificial Intelligence in Industry and Innovation

3.2.1 AI in Clean Energy

1. Dealing with uncertain variables is one of the main challenges in energy modelling with AI. This is because energy modelling involves complex systems and numerous variables that can be difficult to accurately predict or measure.
2. Multiple changes due to project stakeholders can be a challenge when working with AI. These changes can affect the project's timeline, cost, and overall success. To address this, it's important to have clear communication and collaboration between all stakeholders from the outset. Additionally, regular check-ins and updates throughout the project can help ensure that any changes are identified and addressed in a timely manner.
3. Time-consuming model reruns can be a major challenge when working with AI. This is because AI models often require significant computational power and time to train and test. To address this, it's important to optimise the model's architecture and parameters to reduce the computational requirements. Additionally, techniques such as transfer learning and model compression can be employed to help speed up the model reruns.
4. Complexity for users during AI model utilisation can be a concern. To address these issues, it's important to provide users with the right information and proper sensitization about the AI model. Additionally, having an efficient support team on hand to promptly resolve any issues that may arise can also be beneficial in simplifying the process for users.
5. The inability to forecast or evaluate energy without sufficient detailed conditions can be a challenge in energy modelling with AI. This is because energy systems are complex and require a detailed understanding of all relevant factors to make accurate predictions. To address this, it's important to gather as much data as possible about the energy system and the conditions being evaluated. Additionally, it may be necessary to incorporate external data sources and domain expertise to build a more accurate and comprehensive model.
6. There are concerns about privacy, transparency, and accountability when it comes to this technology. However, to ensure data privacy in the context of AI, techniques such as homomorphic encryption can be used to keep the data secure. Additionally, to address

transparency issues and measure model performance in AI, simpler algorithms can be used, and specific metrics can be employed to achieve this.

7. The high development cost is also a major concern with AI. While it cannot be completely eliminated, there are certain measures that can be taken to reduce expenses. One approach is to hire individuals with a good understanding of AI to reduce the cost of training staff. Another is to have a clear roadmap for AI initiatives and select the right set of tools and platforms for building complex AI applications, which can also help in reducing costs.
8. Data security is also a major concern with regards to AI. However, this can be addressed by leveraging enterprise cloud solutions or private/permissioned blockchains. These technologies can be utilised to provide secure storage and transfer of data, thereby addressing the data security concerns surrounding AI.

4.0 Conclusion

In conclusion, this comprehensive review has successfully illuminated the multifaceted impacts of Artificial Intelligence (AI) within the realms of building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation. The discerning analysis presented herein not only sheds light on the positive aspects but also conscientiously delineates the challenges intertwined with the utilisation of AI. By meticulously documenting these aspects, this review aims to serve as a foundational resource for researchers, providing them with valuable insights to inform their decisions and steer their studies towards informed and impactful outcomes. The exploration into the effects of AI on building resilient infrastructure has unravelled a spectrum of opportunities and advancements. The infusion of AI technologies into infrastructure development has proven instrumental in enhancing resilience, efficiency, and adaptability. The nuanced examination of case studies and theoretical frameworks has allowed for a thorough understanding of how AI contributes to the creation of infrastructure capable of withstanding diverse challenges, whether they be natural disasters or evolving societal needs. Furthermore, the scrutiny extended to the role of AI in promoting inclusive and sustainable industrialization has elucidated its potential in addressing socio-economic disparities. The assimilation of AI tools in industrial processes has demonstrated the capacity to optimise resource utilisation, minimise environmental impacts, and foster economic inclusivity. This, in turn, paves the way for a more equitable and sustainable industrial landscape. In tandem with the above, the exploration of AI's impact on fostering innovation has revealed a paradigm shift in the way industries conceptualise and implement innovative solutions. AI algorithms, with their capacity for pattern recognition and predictive analysis, have become instrumental in catalysing innovation across various sectors. This review encapsulates the dynamic landscape of AI-driven innovation, underscoring its pivotal role in propelling industries towards cutting-edge solutions and novel approaches. However, amidst the promising landscape painted by the positive impacts of AI, it is incumbent upon researchers and practitioners to confront the challenges inherent in its utilisation. The delineation of these challenges within this review serves as a clarion call for a nuanced approach to AI integration. Issues such as ethical considerations, bias in algorithms, and the potential displacement of human labour demand meticulous attention. By acknowledging and addressing these challenges, the research community can collectively work towards harnessing the full potential of AI while mitigating its adverse effects. In essence, this review not only encapsulates the current state of the intersection between AI and resilient infrastructure, inclusive industrialization, and innovation but also charts a course for future research endeavours. The meticulous documentation of insights and challenges serves as a foundational stepping stone for researchers, prompting them to delve deeper into the intricacies of AI applications. As the academic community continues to explore these domains, it is imperative to maintain a critical lens, considering diverse perspectives, and collectively charting a path towards a future where AI contributes meaningfully to sustainable development and innovation.

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