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Implementation of AI for smart cities & challenges: Review

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***Abstract*—The 21st century has ushered in a transformative era for human civilization, driven by the convergence of advanced networking technologies and industrial modernization. This period of rapid change has redefined our understanding of urban living and given rise to ground breaking concepts such as the "smart city." At its core, a smart city leverages artificial intelligence (AI) to redefine urban environments, enabling more efficient service delivery and enhancing the quality of life for residents. The integration of AI into urban infrastructure represents a significant milestone in societal advancement, highlighting the importance of fostering and expanding AI capabilities.**

***Index Terms*—AI, Smart city, Transportation safety, IOT.**

I. INTRODUCTION

Modern day cities are rapidly turning towards adaptation of specialized technologies to address problems related to civilizations, ecosystems, morphology and similar other aspects. Smart city, which is a newly emerging concept and not too old in Indian context. This emerging trend encourages the prospects of assimilating and promoting adaptation of technologies such as artificial intelligence, robotics, sensitive sensors and big data through internet of things. Up to some extent even there exist adaptations of augmented and virtual reality for designing of smart urbanization.

II. LITERATURE REVIEW

As urbanization accelerates globally, cities face increasingly complex challenges, making the concept of smart cities a compelling solution. At the heart of this transformation is artificial intelligence (AI), which serves as a critical enabler of innovative urban development. This study provides a comprehensive literature review of AI applications in smart cities, emphasizing six core domains: smart mobility, smart environment, smart governance, smart living, smart economy, and smart people.

Wolniak, R. et al.[1], explored the deployment of AI in each domain, highlighting key advancements, implementation barriers, and prospective future directions. The primary objectives of this analysis are threefold: to identify AI-driven solutions and applications across smart city initiatives; to uncover the challenges and obstacles hindering the adoption of AI technologies in urban settings, and to investigate emerging trends and future opportunities for integrating AI into smart city ecosystems.

Senthil Kumar Jagatheesaperumal et al.[2], given the road safety have become a critical priority due to the growing urban population and the interconnected nature of modern urban environments. Innovative technological solutions are essential to address potential risks and promote safer urban communities. This paper proposes a comprehensive vehicle safety framework specifically designed for smart cities, utilizing the Artificial Intelligence of Things (AIoT). The framework integrates multiple advanced sensors, such as eye-blink sensors, ultrasonic sensors, and alcohol detection sensors, to enhance road safety.

The eye-blink sensor plays a vital role in detecting potential driver fatigue or distractions, issuing real-time audible alerts to prevent accidents and improve road safety. Ultrasonic sensors contribute by providing continuous real-time data on vehicle speed and proximity, ensuring smoother traffic management. To mitigate risks associated with alcohol consumption, the framework includes an alcohol detection sensor that monitors the driver’s alcohol levels. When excessive alcohol levels are detected, the system employs GPS and GSM technologies to reduce vehicle speed and notify relevant authorities, ensuring immediate intervention.

Furthermore, the framework enhances inter-vehicle communication using Light Fidelity (Li-Fi) technology, which leverages Visible Light Communication (VLC) for faster, more reliable data exchange between connected vehicles. This advanced communication mechanism fosters a more cohesive and intelligent urban transportation network.

By integrating AIoT technologies, the proposed system establishes a robust platform for safer and smarter urban mobility. This framework not only offers significant improvements in road safety but also sets the stage for further advancements in intelligent transportation systems, paving the way for a more sustainable and efficient future in smart city transportation.

Amin Ullah et al.[3], introduced concept of smart cities, emphasizing the transformative roles of the Internet of Things (IoT) and machine learning (ML) in fostering a data-driven urban ecosystem. Smart cities harness technology and data insights to enhance citizens' quality of life and streamline urban service delivery. IoT and ML have emerged as cornerstone technologies, enabling smart city solutions that rely on large-scale data acquisition, analysis, and informed decision-making processes.

A comprehensive overview of smart city applications, highlighting the diverse ways IoT and ML contribute to urban innovation. It also examines the challenges of deploying these technologies in city environments, including infrastructure demands and systemic integration issues. Additionally, this study analyzes and compares case studies of successful smart city implementations that have utilized IoT and ML, illustrating practical benefits and insights.

The findings reveal the transformative potential of IoT and ML in shaping urban environments, paving the way for cities to become more livable, sustainable, and efficient. However, significant hurdles remain, particularly regarding data privacy, security, and ethical concerns. Addressing these challenges is crucial to unlocking the full potential of smart city technologies and ensuring their sustainable and responsible adoption.

Zhenjun Yan et al [4], explored the diverse applications of AI in smart cities, emphasizing its central role in revolutionizing modern urban life. From intelligent transportation systems and energy optimization to public safety and healthcare innovations, AI's integration into urban systems provides solutions to persistent challenges while driving unparalleled efficiencies. The study delves into the symbiotic relationship between AI and smart cities, illustrating how AI enables optimized resource allocation, informed decision-making, and overall improvements in urban living standards. Moreover, the necessity of advancing AI technologies within the framework of smart cities, emphasizing the interconnected nature of technological innovation and urban development are highlighted. It indicates how fostering AI advancements can propel cities toward a future characterized by sustainability, resilience, and continuous innovation. By addressing the challenges and opportunities associated with AI deployment in urban environments, the analysis incorporates ethical, regulatory, and societal considerations into the discussion.

It aims to contribute to the growing discourse on smart cities and the transformative potential of AI. By examining the broad spectrum of AI applications in urban settings and emphasizing its pivotal role in shaping the trajectory of the modern era, it reinforces the urgent need to prioritize AI development as a cornerstone of sustainable urban progress and global advancement.

Artificial intelligence (AI) is increasingly integrated into various applications and infrastructures of smart cities, often operating unnoticed by citizens. Despite its potential to enhance urban living, AI's influence on daily life can evoke uncertainty, concerns, or even fears among citizens. To create sustainable and citizen-acceptable smart cities with AI-enabled functionalities, a Human-Centered AI (HCAI) approach provides a valuable framework for understanding public perceptions. However, limited research has been conducted to systematically examine citizens' views on AI within the context of smart cities.

Anu Lehtiö et al [5], addressd the gap by conducting a two-phase study. In the preliminary phase, a survey (N = 91) was used to explore citizens' perceptions and experiences with AI. The second phase involved in-depth, scenario-based interviews (N = 7) to gain deeper insights into how citizens perceive AI in smart city settings. The findings revealed five key themes: (1) a resistance to being excessively monitored, (2) a preference for maximizing benefits with minimal effort, (3) discomfort with AI mimicking human behavior, (4) a tendency to avoid AI if perceived risks are high, and (5) a lack of concern about AI in certain contexts.

These themes highlight critical human-centered requirements that should inform the design and implementation of AI systems in future smart cities. By prioritizing these considerations, AI solutions can align more closely with citizens' values and expectations, fostering trust and acceptance in smart city advancements.

Abdul Rehman Javed et al.[6], studied a comprehensive survey of Explainable Artificial Intelligence (XAI) technologies within the context of smart cities. XAI, by offering insights into the decision-making processes of black-box AI models, empowers informed human action, enhances user understanding, and fosters trust in AI-driven systems.

It is also investigated the societal, industrial, and technological trends driving the demand for XAI in smart cities. It explores the key enablers of XAI technologies within this domain, including advancements in machine learning, data science, and high-performance computing. Furthermore, the study delves into various XAI technology use cases in smart cities, such as predictive maintenance, traffic optimization, and personalized urban services.4 It examines the challenges associated with implementing XAI in real-world urban environments, including data privacy, ethical considerations, and the need for robust evaluation methodologies. The study also outlines current and future research directions, including the development of standardized frameworks for XAI in smart cities and the exploration of innovative XAI techniques, such as model-agnostic explanations and human-centered AI design. This research provides a valuable resource for researchers, policymakers, and practitioners seeking to understand and implement XAI-driven systems for building more intelligent, equitable, and sustainable smart cities.

Danuta Szpilko et al.[7],investigated the integration of artificial intelligence (AI) in smart cities has significantly enhanced efficiency, accessibility, and overall quality of life. However, this advancement also presents challenges, particularly in the realms of data security and privacy, stemming from the pervasive use of Internet of Things (IoT) technologies. This seeks to classify scientific research on AI-related issues in smart cities and identify emerging areas for future exploration.

A systematic literature review, supported by bibliometric analysis, was conducted using the Scopus and Web of Science databases. The research query included TITLE-ABS-KEY (“smart city” AND “artificial intelligence”) for Scopus and TS = (“smart city” AND “artificial intelligence”) for Web of Science, yielding 3101 qualified publications for analysis. The bibliometric assessment identified seven key research domains: safety, living, energy, mobility, health, pollution, and industry.

Urban mobility, driven by AI innovations such as autonomous vehicles (AVs), electric vehicles (EVs), and unmanned aerial vehicles (UAVs), has witnessed substantial advancements. However, persistent security and privacy concerns underscore the need for continued research in this area. Similarly, AI’s influence on energy management and sustainability highlights the necessity for standardized regulations to promote the adoption of renewable energy and the development of integrated local energy systems.

Moreover, the application of AI in healthcare, environmental management, and industrial processes calls for further exploration, particularly regarding data governance, privacy, and security. Addressing these challenges is essential to ensure ethical, responsible, and sustainable digitization in smart cities, fostering long-term societal benefits.

The rapid increase in population density within urban areas has become a prominent trend in recent years. According to data from the United Nations Population Fund, cities housed approximately 3.3 billion people, accounting for 54% of the global population in 2014. By 2050, this figure is projected to rise to 5 billion, or 68% of the world's population. To enhance the quality of life and optimize costs in these urban environments, the concept of smart cities has emerged, characterized by the use of computational intelligence technologies for efficient decision-making.

H.M.K.K.M.B. Herath et. al.[8],investigated the role of artificial intelligence (AI) in shaping smart city frameworks. A review of 133 academic research articles published between 2014 and 2021, predominantly from Scopus (97%) and Web of

Science (73%), highlights AI's application in diverse domains, including healthcare, education, environmental management, waste disposal, agriculture, smart transportation, risk mitigation, and security. The findings reveal that healthcare (23%), mobility and transportation (19%), privacy and security (11%), and energy management (10%) are among the sectors most significantly impacted by AI integration in urban systems.

The onset of the COVID-19 pandemic in 2019 has particularly accelerated the adoption of AI technologies in the healthcare sector, with advancements increasing by 60% during this period. Analysis indicates that AI methodologies such as Artificial Neural Networks (ANN), Recurrent Neural Networks (RNN) including Long Short-Term Memory (LSTM), Convolutional Neural Networks (CNN) and Region-based CNN (R-CNN), Deep Neural Networks (DNN), and Support Vector Machines (SVM) including Least Squares SVM (LS-SVM), have demonstrated considerable influence across various smart city applications.

The concept of "smart cities" aims to address the challenges of growing urbanization by promoting sustainable energy consumption, environmental preservation, economic growth, enhanced quality of life, and increased access to advanced Information and Communication Technologies (ICT). ICT serves as a backbone for policymaking, decision-making, implementation, and the delivery of essential urban services in smart cities. This analysis focuses on exploring the roles of artificial intelligence (AI) and machine learning (ML) in advancing smart city initiatives.

Venkata Dwaraka Srihith,.et al.[9] provided innovative approach with Advanced educational technologies like Deep Reinforcement Learning (DRL) and Machine Learning (ML) to formulating optimal policies within the complex ecosystems of smart cities. The study delves into their applications across various domains, including smart transportation, cybersecurity, energy-efficient management of smart grids (SG), and the strategic deployment of Unmanned Aerial Vehicles (UAVs) to enhance 5G and beyond 5G (B5G) communication networks. Additionally, It examines the integration of AI and ML in smart healthcare systems for real-time monitoring and improved service delivery. It outcomes extends to identifying unresolved research challenges and potential future directions. These insights aim to advance the realization of the smart city concept, addressing existing gaps and paving the way for more intelligent, efficient, and sustainable urban living solutions.

Pushpendu Rakshit et. al.[10], designed a model on such technological paradigm shift to really withstand with the terminology of smart cities. There already exists an India’s smart village, Punsari in the state of Gujrat, thus depicting a model. Focus is on urban potentials with artificial intelligence and proposed a framework / prototype of the city of Navi Mumbai, Mumbai, Maharashtra. This is an empirical, explorative research based on both qualitative and quantitative data. A framework for Navi Mumbai is proposed in this research, utilizing empirical research to bridge gaps in urban development through technology. By integrating human and artificial intelligence, the framework aims to enhance social, economic, and ecological sustainability, thereby improving living standards and promoting cohesive societies.

III. ADVANTAGES OF AI IN URBAN SYSTEMS

1. Automation of Urban Functions: AI enhances operational efficiency by automating tasks like traffic control and waste management.
2. Improved Decision-Making: Real-time data analysis enables better urban planning and resource management.
3. Environmental Management: AI optimizes energy use and reduces waste, contributing to more sustainable urban environments.
4. Economic Growth: AI fosters innovation and creates new business opportunities across sectors like healthcare and transportation.

IV. CHALLENGES IN AI DEPLOYMENT FOR SMART CITIES

1. Regulatory and Discrimination Issues: AI may introduce biases, necessitating fair and equitable regulations.
2. Privacy Concerns: Extensive data collection for AI applications raises privacy risks.
3. Data Quality and Access: Limited access to high-quality data hinders the effectiveness of AI systems.
4. Workforce and Economic Impact: AI implementation may result in job displacement and require a skilled workforce to manage systems.

V. CONCLUSION

The findings reveal that incorporating AI into urban systems offers significant benefits, such as automating processes, minimizing human error, enabling data-driven decision-making, enhancing environmental management, unlocking new business opportunities, and facilitating efficient urban governance. However, the implementation of AI in smart cities is not without challenges. Key concerns include regulatory issues like potential discrimination in service delivery, privacy breaches, legal and ethical dilemmas, data scarcity, a shortage of skilled professionals, high implementation costs, long project durations, and the risk of increasing unemployment.

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