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ORIGINAL

Artificial intelligence-based smart city ecosystem development

Desarrollo de un ecosistema de ciudades inteligentes basado en la inteligencia artificial

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ABSTRACT

The idea of a smart city has become increasingly relevant lately. It's all about making city life better by using digital tech and new methods. As cities grow bigger and faster, they have to deal with things like traffic jams, pollution, and limited resources. To solve these issues, we can use Artificial Intelligence (AI) to run urban systems smoothly. Cities can use AI to make transport better, save energy, and make cities safer for everyone. This text will look at how AI can create interconnected, smart urban areas. It also highlights how important it is to plan carefully and involve the public. The aim is to show that if AI is used correctly, it can change cities into places that are sustainable and can handle the needs of the future. Smart cities are all about using technology and data to make life better for people in urban areas while making things more efficient. It also changes how people interact with the city by using various digital tools and connected systems. These systems improve services, transport, living conditions, and safety. Smart cities are important because they can help solve problems like climate change and crowded cities. The way smart cities combine sustainable methods shows how connected social, economic, and environmental factors are. It also shows that we need to take a broad view of how cities grow. Therefore, using Artificial Intelligence to build smart city systems is key to creating sustainable and adaptable cities for the future.

Keywords: Smart City; Artificial Intelligence; Digital Technologies; Urban Ecosystems; Transportation Systems.

RESUMEN

La idea de ciudad inteligente ha cobrado cada vez más relevancia en los últimos tiempos. Se trata de mejorar la vida urbana utilizando tecnología digital y nuevos métodos. A medida que las ciudades crecen y se aceleran, tienen que hacer frente a problemas como los atascos de tráfico, la contaminación y la escasez de recursos. Para resolver estos problemas, podemos utilizar la Inteligencia Artificial (IA) para que los sistemas urbanos funcionen sin problemas. Las ciudades pueden utilizar la IA para mejorar el transporte, ahorrar energía y hacer que las ciudades sean más seguras para todos. En este texto se analiza cómo la IA puede crear zonas urbanas interconectadas e inteligentes. También se subraya la importancia de planificar cuidadosamente y de implicar a los ciudadanos. El objetivo es demostrar que, si se utiliza correctamente, la IA puede transformar las ciudades en lugares sostenibles y capaces de satisfacer las necesidades del futuro. Las ciudades inteligentes se basan en el uso de la tecnología y los datos para mejorar la vida de los habitantes de las zonas urbanas y hacerlas más eficientes. También cambia la forma en que las personas interactúan con la ciudad mediante el uso de diversas herramientas digitales y sistemas conectados. Estos sistemas mejoran los servicios, el transporte, las condiciones de vida y la seguridad. Las ciudades inteligentes son importantes porque pueden ayudar a resolver problemas como el cambio climático y las ciudades superpobladas.

La forma en que las ciudades inteligentes combinan métodos sostenibles muestra lo conectados que están los factores sociales, económicos y medioambientales. También demuestra que debemos tener una visión amplia de cómo crecen las ciudades. Por lo tanto, el uso de la Inteligencia Artificial para construir sistemas de ciudades inteligentes es clave para crear ciudades sostenibles y adaptables para el futuro.

Palabras clave: Ciudad Inteligente; Inteligencia Artificial; Tecnologías Digitales; Ecosistemas Urbanos; Sistemas de Transporte.

INTRODUCTION

The global landscape has undergone significant transformation in recent decades, presenting considerable challenges to urban management. Accelerated technological advancement, climate change, population concentration, and a host of societal and environmental factors are reshaping the urban experience.[1] Responding to these pressures necessitates a shift towards smarter, more streamlined, and people-centric cities. The evolving definition of a smart city incorporates not just technology, but also the cornerstones of sustainability, optimized resource utilization, and a citizen-focused approach. Ultimately, the aim is to enhance daily living through data-driven insights, strategic decision-making, and the most effective allocation of available resources.[2,3]

Artificial intelligence offers practical solutions within the smart city framework, particularly in key sectors like transportation, energy infrastructure, public safety, healthcare, and ecological preservation.[4,5] For instance, in traffic management, sophisticated AI algorithms use real-time data analysis to optimize traffic flow, thereby alleviating congestion and mitigating carbon emissions. Intelligent energy systems also improve resource management by predicting electricity consumption patterns.[6,7]

An AI-driven smart city ecosystem promotes efficiency, environmental responsibility, and enhanced quality of life. This is achieved through data analytics and automation, optimizing a multitude of city services from transit and power grids to security protocols and waste disposal. AI solutions help to regulate traffic, curb energy usage, contribute to public safety, and foster quicker, more accurate medical diagnoses.[8,9,10] In essence, smart cities based on AI embody a forward-thinking model for urban habitation, cultivating efficiency, sustainability, and improved living conditions through these integrated technological applications.

Central to the realization of the smart city concept is Artificial Intelligence. AI's capabilities extend across a broad spectrum, from large-scale data collection and the Internet of Things (IoT) to the operation of autonomous systems and human-computer interaction.[11,12]AI can enhance the operational efficiency of fundamental city structures, streamline urban transit, optimize energy consumption, minimize environmental impact, and, most importantly, enhance the overall quality of life for the urban population.[13,14]

Smart cities, powered by AI, foster a connected, coordinated urban environment, cultivating adaptability and long-term sustainability. This necessitates a fundamental transformation of both the built environment and the social fabric.[15] Citizens are then able to interact with a range of services from public utilities to transportation systems, and healthcare to educational facilities with improved convenience and efficiency. Furthermore, it plays an important part in realizing collective objectives, encompassing environmental protection and economic resilience.[16,17,18]

AI-enabled smart cities represent more than just a technological advancement; they also represent an opportunity for social, economic, and ecological harmony.[19] Smart urban spaces contribute to the improvement of everyday lives, setting the stage for enduringly sustainable ways of life for future generations.

DEVELOPMENT

The core of modern urban planning is being revolutionized by the incorporation of Artificial Intelligence. AI's analytical edge allows it to skillfully handle the enormous datasets produced by interconnected devices (IoT) and digital transactions. Empirical findings reliably reveal the advantageous outcomes stemming from AI-driven solutions, notably in areas like managing urban traffic, boosting energy efficiency, streamlining waste management, and fostering civic involvement. Leveraging automation and data analysis, AI systems deliver predictive insights, thereby markedly contributing to improved safety, public health, and urban transportation systems.[20,21]

Currently, cities undergoing fast-paced development are embracing smart technologies to manage burgeoning populations and address environmental concerns. Artificial Intelligence (AI) plays a vital role in facilitating data-driven decision-making within the framework of smart city environments, paving the way for more efficient, sustainable, and enhanced living spaces.[22,23]

The design philosophy underlying AI-powered smart city systems extends far beyond the adoption of advanced technology. It incorporates diverse aspects such as robust infrastructure, data management practices, human

interaction, and environmental consideration. Effective deployment of these integrated systems necessitates smooth operation and ordered collaboration among diverse scientific disciplines. In this context, the study of smart cities empowered by Artificial Intelligence establishes a collaborative arena.

This present research endeavors to undertake a comprehensive investigation into the utilization of Artificial Intelligence in urban management and public services, considering its societal repercussions and potential integration with environmental objectives. Researchers assessed the practical applications of AI within multiple urban sectors during the recent past, specifically including healthcare, education, transportation, environmental conservation, and public security. The prominence of the terms “Smart City” and “Artificial Intelligence” as gauged by keyword popularity (figure 1).

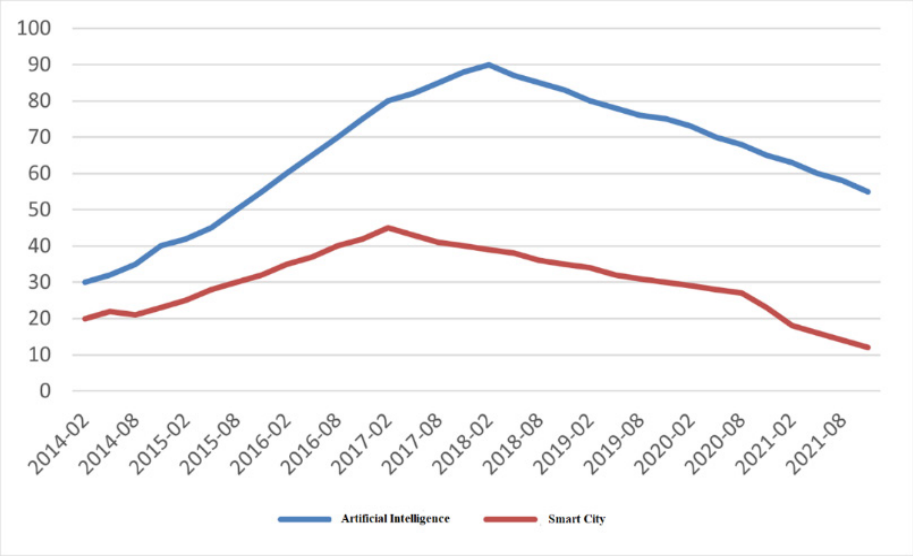

Figure 1. The popularity of the words “Artificial Intelligence” and “Smart City” since 2014 (source: Google Trend)

Future research directions can be conceptualized as the creation of more secure networks, designed to minimize the risks associated with Artificial Intelligence (AI) security. This research offers valuable guidance for urban planners and researchers by systematically evaluating the application of AI in smart cities. The importance of establishing more flexible regulatory frameworks to improve the efficiency of AI implementation in cities is emphasized. It highlights the importance of multidisciplinary research and collaborations to enhance AI’s contribution to sustainable urban development. This is a significant source for a deeper understanding of the transformative role of AI in smart cities and its impact on various sectors.[6,13]

One of the most significant application areas of AI is the transportation sector. Self-driving cars, working in conjunction with intelligent road systems, are creating a smoother and safer transportation environment. These technologies enable vehicles to communicate with each other and the components of the road infrastructure, which minimizes the risk of accidents. For example, smart road signs and traffic lights send real-time information to vehicles, optimizing operations such as speed regulation and route changes.[20,21]

AI technologies play a crucial role in optimizing energy and creating smart grids. AI models analyze and predict energy demand to maximize the use of renewable energy sources – solar, wind, and hydropower. For example, the output of solar panels and wind turbines can vary according to weather conditions, but intelligent systems anticipate these changes in advance and adjust energy consumption accordingly.

These systems also prevent energy waste. For example, alternative energy sources are activated during peak electricity demand on electrical grids, ensuring balancing. At the same time, smart buildings and facilities automatically turn devices on and off to minimize energy consumption.

The application of AI increases efficiency not only in production but also in energy distribution. These technologies monitor energy losses and optimally schedule repair work, thereby providing both economic and environmental benefits.

AI technologies are also causing revolutionary changes in the field of security. Surveillance systems integrate facial recognition technology and behavioral analytics to detect potential threats in real-time. For example, suspicious movements in crowded places are immediately identified and alerts are sent to law enforcement agencies. This makes it easier and faster to prevent crimes.[23]

Predictive policing uses big data and statistical models to predict the likelihood of crimes occurring. For example, the crimes that repeatedly occur in a certain area are analyzed and the police forces are strategically deployed. This contributes to both a reduction in crime and a more efficient management of resources.

AI is also widely used in the healthcare sector and plays an important role in improving the quality of medical services. AI is used to analyze medical images in diagnostic processes, allowing for more accurate and faster diagnoses. For example, AI algorithms can detect even small abnormalities in X-rays and MRIs, providing doctors with the opportunity for early intervention.[18,19]

Smart hospitals are equipped with sensors that remotely monitor patients' condition and analyze data in real-time. This immediately alerts medical personnel if there are any sudden changes in the patients' condition. In emergency services, AI technologies determine the closest ambulance and the optimal route in emergency situations. This leads to the effective use of resources and the reduction of time loss, especially in disaster situations.

AI technologies provide innovative solutions for solving environmental problems. Smart sensors continuously analyze air and water quality, monitoring pollution indicators. For example, devices measuring air pollution levels in large cities send alerts when they reach a level that is dangerous to human health.[20]

AI aids in crafting climate change adaptation strategies, too. Algorithms scrutinize prolonged climate predictions and fine-tune preparedness for upcoming catastrophes. These forward-looking models assist in implementing preemptive actions, diminishing the adverse effects of environmental calamities.

Furthermore, Artificial Intelligence finds application in waste management operations. Consider intelligent sensors embedded within refuse receptacles; these devices gauge fullness levels and communicate data to waste disposal providers. Consequently, it warrants more efficient resource allocation, simultaneously curbing environmental contamination.

Therefore, employing Artificial Intelligence significantly contributes to smart city development, thereby boosting the well-being of citizens. Tackling environmental challenges, streamlining transportation networks, and enhancing security along with healthcare provisions exemplify the substantial capabilities of AI systems (figure 2).

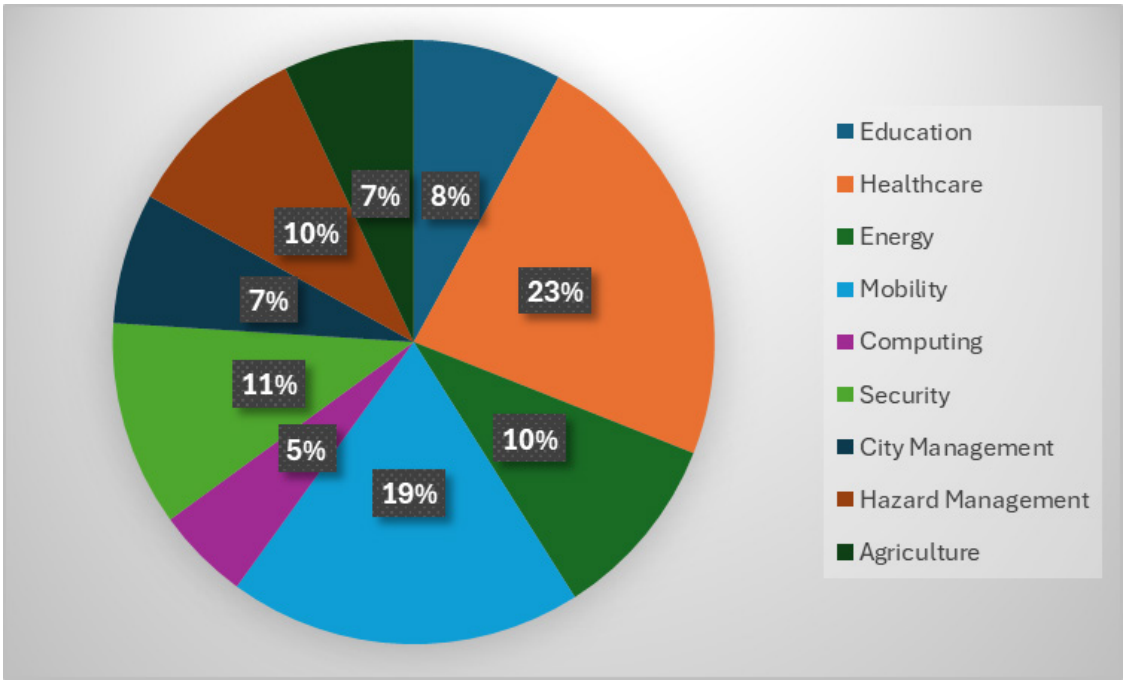

Figure 2. Analysis of AI-based applications in key smart city areas

CONCLUSION

AI is currently reshaping the urban landscape, driving operational gains, fostering ecological consciousness, and placing citizen welfare at the forefront. Its implementation within smart city programs enhances transportation systems, reinforces security protocols, streamlines healthcare delivery, and refines environmental management. This ultimately contributes to a more livable urban experience. Nonetheless, robust regulatory structures, coupled with transparent and easily interpretable AI models, are crucial to navigating ethical quandaries and safeguarding individual privacy rights. Smart city systems powered by AI are ushering in the cities of tomorrow, uniting various advancements. At this juncture, the seamless integration of technology with societal values, along with the prioritization of environmental equilibrium and stringent data protection, is paramount for successful smart city projects. Smart cities signify not merely technological breakthroughs, but also embody societal evolution, environmental responsibility, and economic strength. Continued research in this

domain offers promising prospects for developing more efficient and sustainable urban spaces. In conclusion, AI is central to making urban living both more comfortable and environmentally sustainable, becoming a vital component of smart city infrastructures. Such technologies are enhancing overall quality of life through the application of intelligent, environmentally sound, and people-focused solutions in urban environments.

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Validation: Rasul Dashdamirli, Vuqar Abdullayev.
Drafting - original draft: Rasul Dashdamirli, Vuqar Abdullayev.
Writing - proofreading and editing: Rasul Dashdamirli, Vuqar Abdullayev.