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Artificial Intelligence in Smart Cities

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ABSTRACT

Artificial intelligence (AI) refers to a branch of computer science and engineering dedicated to developing systems and algorithms capable of performing tasks that typically require human intelligence. It is at the heart of smart city development, driving the efficiency and safety of these urban environments. Smart cities represent the future of urban living, where technology and data-driven solutions come together to improve the quality of life for residents. From optimizing transportation systems to managing environmental resources, enhancing governance, improving quality of life, fostering economic growth, and empowering citizens, AI plays an important role in unlocking the full potential of smart cities. AI enables cities to become more efficient, sustainable, and responsive to the needs of their inhabitants. Roads, bridges, buildings, and other urban infrastructure can be monitored efficiently using AI and aerial imagery. This paper reviews the role of artificial intelligence in shaping smart cities. It provides valuable guidance for policymakers, urban planners, and technologists involved in shaping the future of smart cities.

KEYWORDS: *artificial intelligence, machine learning, AI, generative AI, smart cities, urban AI.*

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INTRODUCTION

Humanity has always been striving for progress by building more and more technologically advanced cities in which more and more intelligent people, aware of the environment, live. As urbanization continues to pose new challenges for cities around the world, the concept of smart cities is a promising solution, with artificial intelligence (AI) playing a central role in this transformation. Smart cities use advanced technologies, data analytics, and digital infrastructure to enhance the efficiency, sustainability, and quality of life for residents [1]. They could become even smarter through increased application of AI.

Artificial intelligence is the ability of a system or a program to think and learn from experience. It is machine-displayed intelligence that simulates human behavior or thinking and can be trained to solve specific problems. AI algorithms capable of performing tasks that typically require human intelligence. These tasks include, but are not limited to, learning, reasoning, problem-solving, perception, and natural language understanding and generation.

Cities are increasingly at the confluence of the world's most pressing issues: dealing with extreme weather events, managing migration, maintaining affordability, and ensuring public safety. Smart cities are cities, towns, and communities that rely on the implementation of information and communications technology (ICT) and infrastructure, including artificial intelligence/machine learning (AI/ML) and Internet of things (IoT) technologies, to enhance quality of life and safety for citizens. Any city or town that has added sensors to its infrastructure, including something as simple as streetlights, is already a smart city. AI smart cities are underpinned by pervasive digital infrastructure including connectivity and compute resources to support the collection and analysis of data. Figure 1 shows a typical smart city [2].

WHAT IS ARTIFICIAL INTELLENCE?

The term "artificial intelligence" (AI) is an umbrella term John McCarthy, a computer scientist, coined in 1955 and defined as "the science and engineering of intelligent machines." It refers to the ability of a computer system to perform human tasks (such as

thinking and learning) that usually can only be accomplished using human intelligence [3]. Typically, AI systems demonstrate at least some of the following human behaviors: planning, learning, reasoning, problem solving, knowledge representation, perception, speech recognition, decision-making, language translation, motion, manipulation, intelligence, and creativity.

The 10 U.S. Code § 2358 define artificial intelligence as [4]:

1. "Any artificial system that performs tasks under varying and unpredictable circumstances without significant human oversight, or that can learn from experience and improve performance when exposed to data sets.
2. An artificial system developed in computer software, physical hardware, or other context that solves tasks requiring human-like perception, cognition, planning, learning, communication, or physical action.
3. An artificial system designed to think or act like a human, including cognitive architectures and neural networks.
4. A set of techniques, including machine learning, that is designed to approximate a cognitive task.
5. An artificial system designed to act rationally, including an intelligent software agent or embodied robot that achieves goals using perception, planning, reasoning, learning, communicating, decision making, and acting."

AI provides tools creating intelligent machines which can behave like humans, think like humans, and make decisions like humans. The main goals of artificial intelligence are [5]:

1. Replicate human intelligence
2. Solve knowledge-intensive tasks
3. Make an intelligent connection of perception and action
4. Build a machine which can perform tasks that requires human intelligence
5. Create some system which can exhibit intelligent behavior, learn new things by itself, demonstrate, explain, and can advise to its user.

AI is not a single technology but a range of computational models and algorithms. The concept of AI is an umbrella term that encompasses many different technologies. AI is not a single technology but a collection of techniques that enables computer systems to perform tasks that would otherwise require human intelligence. The major disciplines in AI include [6]:

- Expert systems
- Fuzzy logic
- Neural networks
- Machine learning (ML)
- Deep learning
- Natural Language Processors (NLP)
- Robots

These computer-based tools or technologies have been used to achieve AI's goals. Each AI tool has its own advantages. Using a combination of these models, rather than a single model, is recommended. Figure 2 shows a typical expert system, while Figure 3 illustrates the AI tools. These tools are gaining momentum across every industry. Analytics can be considered a core AI capability.

ARTIFICIAL INTELLIGENCE IN SMART CITIES

More and more people are moving to urban areas in search of better opportunities. The parallel phenomena of urbanization and digitalization have enabled the rapid expansion of urban AI into everyday spaces, places, and lives. This phenomenon, which we can refer to as urban AI, is being built on the foundation of previous technological developments in cities. Urban AI is the study of the relationship between artificial intelligence systems and urban contexts, including the built environment, infrastructure, places, people, and their practices. It is the application of artificial intelligence in smart cities to analyze data, optimize operations, and improve quality of life through technologies like AI-powered traffic management, energy optimization, and waste management. AI in urban settings may not only be the subject of scrutiny, but also a tool for the evidence-based study of cities [7].

In order to make lifestyles in cities more comfortable and cost-effective, the city must be smart and intelligent. A city is identified as a densely populated area. A "smart city" is an urban center that makes use of information and communication technology to support governmental systems, promote economic development, and improve quality of life. Figure 4 shows the three elements of a smart city [8]. Smart cities promise to revolutionize urban areas as these cities invest in human and social capital, infrastructure, and disruptive technologies to fuel sustainable economic growth efficiently and manage assets, resources, and services. Cities are becoming smarter as a result of their rapid progress and AI-powered analysis of the massive datasets generated by managing and maintaining these urban centers. These cities aim to create more efficient, sustainable, and safer spaces by leveraging innovations like AI and open data. Smart city AI technologies can be

categorized into machine learning (ML), natural language processing (NLP), speech, vision, expert systems, and robotics. Figure 5 shows a representation of AI in smart cities [9], while Figure 6 shows six major AI technologies used in smart cities [10].

APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN SMART CITIES

Artificial intelligence (AI) is applied in smart cities for optimizing transportation and energy use, improving healthcare, enhancing security, and streamlining governance. Figure 7 shows different applications of AI in smart cities [10]. Common areas of application include the following [1,2,10]:

- *Smart Mobility*: Smart mobility addresses the seamless integration of innovative technologies to enhance transportation systems. This involves the use of intelligent traffic management, efficient public transportation, and the implementation of sustainable modes of travel, such as electric vehicles and bike-sharing programs. The goal is to optimize urban mobility, reduce congestion, and minimize the environmental impact of transportation. The convergence of AI and smart mobility technologies is an important factor in efficient, sustainable, and interconnected transportation systems. Smart mobility platforms powered by AI enable seamless integration of various transportation modes, including public transit, ride-sharing, and bike-sharing. Smart mobility initiatives focus on using emerging technologies, such as autonomous vehicles and drones, to advance mobility solutions and improve the efficiency and accessibility of urban transportation systems. For example, AI can be used to optimize traffic flow and reduce congestion by analyzing vast datasets in real time. The very interesting case of using AI in smart mobility is connected with the safe mobility of senior citizens. Smart mobility initiatives may encounter ethical considerations related to safety and privacy in AI-driven transportation systems.
- *Smart Environment:* The concept of a smart environment revolves around leveraging technology to monitor and manage the urban surroundings efficiently. This includes the implementation of smart waste management systems, air and water quality monitoring, and the integration of green spaces. A smart environment also means rational and responsible resource management. One of the important aspects related to a smart environment is energy saving and the effective use of energy in cities. Another important aspect of a smart environment is the air quality in cities. Environmental artificial intelligence in smart cities can also be used to predict the quality of drinking water. AI algorithms can revolutionize energy management by optimizing consumption, integrating renewable sources, and enhancing grid stability.
- *Smart Governance:* Smart governance is the application of technology and innovation to improve decision-making and planning in governing organizations. It includes e-governance, decision-making policies, disaster prevention, and urban planning. The integration of artificial intelligence in smart governance is transforming the landscape of public administration, offering innovative solutions to enhance efficiency, transparency, and citizen engagement. Urban administrators, particularly in major cities worldwide, are exploring the deployment of advanced information technologies, including AI, to deliver e-governance services. Privacy concerns emerge prominently as AI systems in smart governance often rely on vast datasets that may contain sensitive personal information.
- *Smart Living:* Smart cities are constantly developing, and the area of smart living is important for the inhabitants. One of its elements may be smart buildings/homes that are supposed to make people's lives more comfortable; save energy, resources, and money; improve safety; and enable greater control of a given apartment or other building by residents. Smart homes often use heating and cooling devices called Heating, Ventilation, and Air Conditioning (HVAC) systems. They are have smart thermostats and smart lighting. Intelligent lights are also present on the streets. Smart cities also offer smart healthcare, which aims to improve healthcare delivery and outcomes. Smart living is more and more connected with wearable technologies, such as virtual reality (VR), augmented reality (AR), and mixed reality (MR). These technologies give a lot of opportunities for smart living experiences.
- *Smart Economy:* A smart economy is an economy centered on technical innovation, sustainability, a high level of social wellbeing, and resource efficiency as factors for success. It includes smart business, e-commerce, retail, smart shopping, peer-to-peer marketplace, peer-to-peer labor services, smart supply chains, and smart sharing services. AI is creating a fertile ground for entrepreneurship and innovation in the smart city. AI-powered platforms can connect startups with potential investors and partners, facilitating

collaboration and knowledge sharing. AI can also be used to analyze market trends and identify new business opportunities, providing invaluable insights for entrepreneurs.

- *Smart People*: The area of "smart people" in smart cities encompasses initiatives and technologies that empower residents with the skills, knowledge, and resources to actively engage and benefit from urban advancements, including education, digital literacy, community participation, and lifelong learning opportunities. AI not only introduces enormous technological changes but also has a huge impact on people's behavior and lifestyle. Artificial intelligence can be implemented into almost every area of human life. Another feature of a smart city in the context of a smart people area is inclusivity. AI-powered smart home systems, telehealth services, and digital initiatives contribute to improving the quality of life for residents by promoting safety, health, and convenience in various aspects of daily life. Key barriers to the implementation of AI solutions in smart cities in the area of smart people include lack of trust, resistance to change, ethical considerations, and the digital divide. People's lifestyles are changing under the influence of solutions based on artificial intelligence.
- *Smart Transportation:* Transportation, traffic, and logistical issues affect most large cities across the world. This is due to the fast-growing human population and the growing number of automobiles on the road. Multi-modal transportation networks, electric and autonomous vehicles, and the rise of intelligent infrastructure are all factors categorizing the ongoing shift toward smarter transportation networks, some of which can be supported by AI/ML. The intelligent transportation system (ITS) is a convergence of control systems, sensors, actuators, and information and communication technologies (ICTs) that generates massive amounts of data and significantly influences the next generation of transportation in the modern smart city. AI will play a role in ITS and smart transportation networks through the continued support of horizontal technologies such as data fusion and computer vision as well as through applications like fleet management, optimized public transportation routing, and intelligent intersections.
- *Smart Healthcare:* This is a healthcare delivery method that uses wearable tech, the IoTs, and mobile Internet to constantly access data and connect people, resources, and institutions. This includes smart hospital, telemedicine, telenursing, smart healthcare tracking, e-health record, patient monitoring, and pandemic predictions. Many traditional cities are attempting to imitate the notion of smart city healthcare by implementing traditional technologies and devices by merging medical resources with AI-integrated solutions. AI in healthcare must give real-time, actionable, and tailored information to patients and clinicians to aid treatment decisions. Figure 8 shows the integration of AI in smart healthcare [10].
- *Smart Education:* This is a learning paradigm tailored to the needs of emerging digital natives. It includes smart classroom, smart library, virtual reality-based learning platforms, student tracking management, and learning tools for special needs students. Modern educational system has shifted to e-learning platforms which now everyone can learn through the Internet.
- *Digital Government*: Digitizing government services can reduce barriers to civic participation, promote transparency of data, and improve access. AI will support government's ability to deliver enhanced, personalized digital government services to residents. These services can include digital IDs, online services such as permitting and filing taxes, and support for electronic healthcare services. Governments will turn to AI, namely service chatbots, to free up employee resources and better serve constituents, with an emphasis on adopting trustworthy, explainable AI applications.
- *Public Safety*: Every city has the difficult task of combating crime and enhancing public safety. When it comes to fighting crime, AI is a powerful new friend. With AI and smart cities, public safety is also improved as violation of laws can be prevented and lives can be saved by using the sensor and camera networks. AI enhances public safety by enabling real-time security and alerts. The interconnected nature of smart city infrastructure, comprising networks, sensors and communication systems, creates opportunities for malicious actors to exploit vulnerabilities and launch cyberattacks. While surveillance-based or "safe city" initiatives can raise privacy concerns, cities can address these by working with vendors that follow "privacy by design" principles, as well as by establishing data retention policies and engaging the community early and often regarding camera-based deployments. Computer vision enables many smart city outcomes related

to public safety and efficiency. Figure 9 shows how AI enhances public safety [9].

BENEFITS

AI provides significant benefits to smart cities by improving traffic management, enhancing public safety through real-time monitoring, increasing energy efficiency with smart grids and building management, optimizing resource management like water and waste, and streamlining citizen services through chatbots and data analysis. Other benefits include the following [10,11]:

- *Automation:* Implementing AI can result in the automation of organizational processes. This saves time and effort, while also avoiding costly errors. AI is poised to transform business operations through automation across various domains, such as supply chain management, inventory control, and customer service functions. This automation holds the promise of enhancing productivity and streamlining operations for businesses operating within smart urban landscapes.
- *Traffic Management:* Traffic congestion and accidents are major challenges for any growing city. AI-powered systems can analyze real-time traffic data, predict congestion, and optimize traffic flow. For example, intelligent traffic lights can adjust their timings based on traffic volumes, reducing wait times and minimizing emissions. AI can also assist in route planning for public transportation, making it more efficient and reliable. Traffic management reduces congestion and pollution by limiting cars sitting idle and facilitates safer and shorter commute times. Figure 10 shows a typical city traffic [11].
- *Parking Management:* Finding parking in busy urban areas is a common challenge. Smart parking management systems leverage the power of AI to monitor the availability of parking spaces in real-time, providing drivers with accurate and updated information on where to find available spots. Smart parking systems can also facilitate dynamic pricing models based on demand, ensuring more efficient use of parking resources.
- *Waste Management:* The rising amount of waste generated worldwide is inducing issues of pollution, waste management, and recycling, calling for new strategies to improve the waste ecosystem, such as the use of artificial intelligence. The ability of smart cities to solve environmental problems in general and waste management in particular is an important subject that needs to be addressed. Effective waste management is vital for maintaining cleanliness and sustainability in smart cities. AI-powered systems can improve the efficiency of waste collection, processing, and recycling. By using AI-enabled cameras to track waste accumulation, cities can streamline collection routes, reduce fuel consumption, and prevent overflowing bins. Figure 11 shows AI in waste management [12].
- *Energy Efficiency:* AI optimizes energy consumption in buildings through smart HVAC and lighting, manages smart grids to balance demand and supply, and improves the integration of renewable energy sources.
- *Anomaly Detection:* AI can detect irregularities or unexpected events, such as spotting accidents on roads, identifying damaged infrastructure, or flagging suspicious activities in public spaces.
- *Improving City Efficiency*: AI-powered image processing plays a crucial role in improving the overall efficiency of smart cities. From waste management to infrastructure maintenance and smart mobility, AI-driven solutions enable cities to optimize operations, reduce costs and create sustainable environments. Figure 12 shows how AI improves city efficiency [9].
- *Predictive Analytics:* One of the most exciting future trends in smart cities is the use of predictive analytics through AI-powered image processing. For example, AI systems can predict traffic accidents based on historical data and real-time video feeds or detect infrastructure failures before they become critical.
- *Smart Energy:* Modern societies rely on energy to function. Due to population growth and increasing comfort requirements, the world's energy consumption and accompanying CO2 emissions have expanded substantially. AI-based energy forecasting approaches are crucial since most smart city utilizations require higher energy.
- *Smart Agriculture:* This is revolutionizing the agricultural industry in terms of social, economic, and environmental sustainability. Some researchers have explored ways to combine digital technology with agriculture and AI to development of smart, long-term agricultural systems. The Internet of things (IoT) has proven itself as a viable technique for agriculture automation and decision-making.
- *AI Chatbots:* Over a period of time, chatbot is getting an extra edge over other methods as it is the quickest and easiest way to connect. Chatbots let citizens navigate government entitlements and create easy access for citizens to understand and engage with local services. Chatbot automates

citizen queries, analysis of citizen pain areas, payment of taxes, and citizen engagement using AI. Citizens can get regular reminders of payment before the due date in their local language through AI Chatbot. AI-powered chatbot will increase transparency between government and citizen services. Figure 13 shows how AI chatbot works for smart cities [13].

- *Citizen Services:* AI-powered chatbots can handle routine inquiries, and data analysis can help tailor city services to resident needs. AI also facilitates better communication and more responsive governance by helping to categorize and route citizen reports on issues like potholes.

CHALLENGES

The adoption of AI in smart cities faces several challenges like data privacy and security concerns, ethical considerations like discrimination, a lack of robust infrastructure, the digital divide, and regulatory issues. Other challenges include [1,2]:

- *Ethical Concerns:* Ethical considerations and societal acceptance constitute significant barriers as well. The use of AI in smart cities, particularly in areas like facial recognition and public surveillance, raises ethical concerns. Issues related to algorithmic bias, fairness, and accountability demand careful scrutiny. Ensuring that AI systems operate transparently, equitably, and align with societal values is crucial to overcoming ethical challenges and garnering public trust.
- *Data Privacy:* Another hurdle is the issue of data privacy and security. The extensive deployment of sensors and video-based surveillance systems in AI smart cities leads to the collection of vast amounts of personal data. This data encompasses individuals' movements, behaviors, preferences, and interactions with urban infrastructure. Establishing robust data protection measures, complying with regulations, and building trust among the public are challenges that must be addressed to facilitate successful AI implementation in smart governance.
- *Financial Constraints:* Financial constraints hinder the widespread adoption of AI in the smart economy. These pose a substantial barrier, particularly for governments with limited budgets. The initial investment required for AI infrastructure, software development, and ongoing maintenance can be substantial. Overcoming financial barriers involves strategic planning, budget allocation, and identifying cost-effective solutions to make AI implementation feasible for smart governance initiatives.
- *Lack of Regulations:* A notable challenges lies in the lack of standardized regulations and ethical frameworks governing AI implementation. The absence of clear guidelines poses challenges in ensuring responsible and fair use of AI technologies. Developing comprehensive regulations that address ethical considerations, bias mitigation, and accountability is essential for fostering trust in AI systems within the smart economy.
- *Digital Divide:* Another challenge is the digital divide, which results from the fact that some generations, especially younger ones, will be able to adopt solutions based on artificial intelligence more quickly, while other generations (such as older people) will have problems understanding solutions based on AI. The benefits of AI may not reach all citizens equally due to disparities in access to technology and digital literacy.
- *Sustainability*: Sustainability is dear to city leaders as they manage resource utilization, migration, and climate events. With a vulnerability map, the city can better prepare and mitigate flood impacts when weather events occur.
- *Resident Experience:* Improving citizens' interactions with government can enhance satisfaction and optimize employee resources. By offering digital government service portals, such as an online permitting platform, governments can reduce barriers for their citizens.
- *Security:* Security concerns may become more prevalent as the population of the smart city grows. AI is now entering the security sector to safeguard citizens due to the improvement of many IoT-based systems. With the advent of IoT-based platforms, intelligence systems for cyber security are evolving rapidly.

FUTURE OF ARTIFICIAL INTELLIGENCE IN SMART CITIES

Smart cities around the world work with different missions and objectives with a prime focus to make their citizens lives easier. Smart city initiatives in many countries are now focusing on AI-based smart applications. The rapid advancement of artificial intelligence presents huge opportunities for smart cities to address urban challenges and improve the quality of life of residents. As urban areas continue to grow and evolve, smart cities are emerging as the future of urban living. The responsible AI initiative of the future society aims to provide the knowledge, skills, and practical tools. As technology continues to evolve, it is clear that AI-powered analysis will play a

crucial role in the growth and development of smart cities.

CONCLUSION

A smart city leverages cutting-edge technology to optimize operations, improve public services, and create a better quality of life for residents. AI and the IoT are two important technologies that have the potential to turn cities into sustainable smart cities. By integrating Internet of things (IoT) devices and artificial intelligence (AI), these cities use real-time data to enhance everything from public safety to transportation. AI technology is being used to develop smart cities to alleviate the strain on local resources and enhance governance and services. More information on artificial intelligence in smart cities is available from the books in [14-21] and the following related journals:

- The AI Journal
- AI Magazine
- Journal of Intelligence
- Applied Artificial Intelligence
- Smart Cities

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Figure 1 A typical smart city [2].

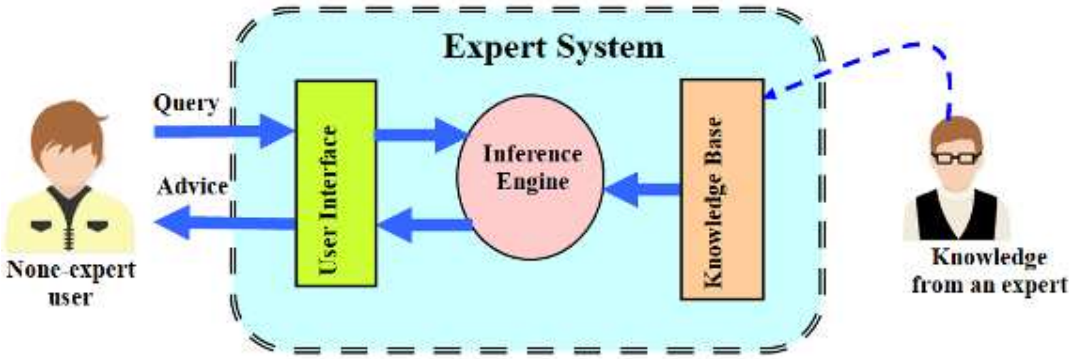

Figure 2 A typical expert system.

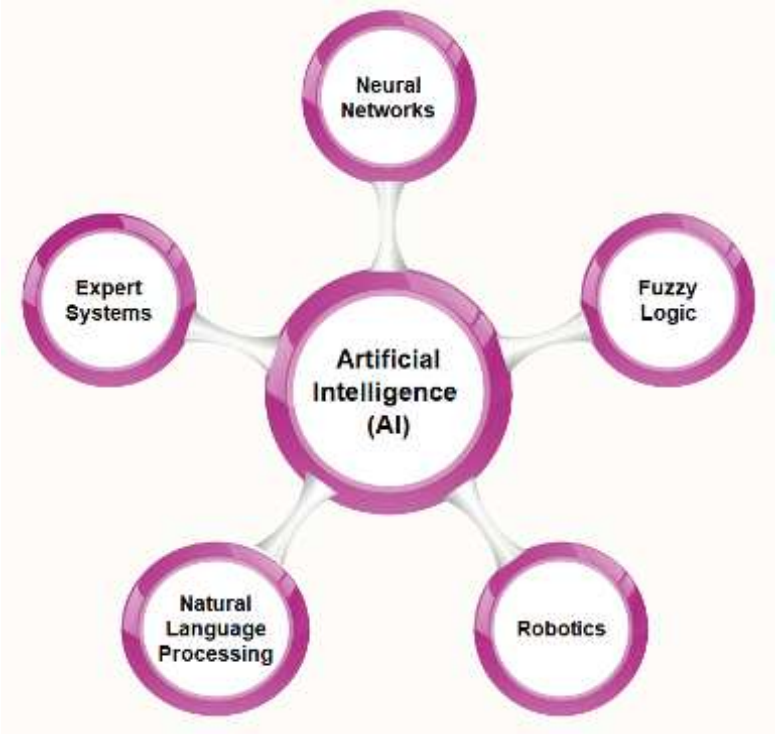

Figure 3 AI tools.

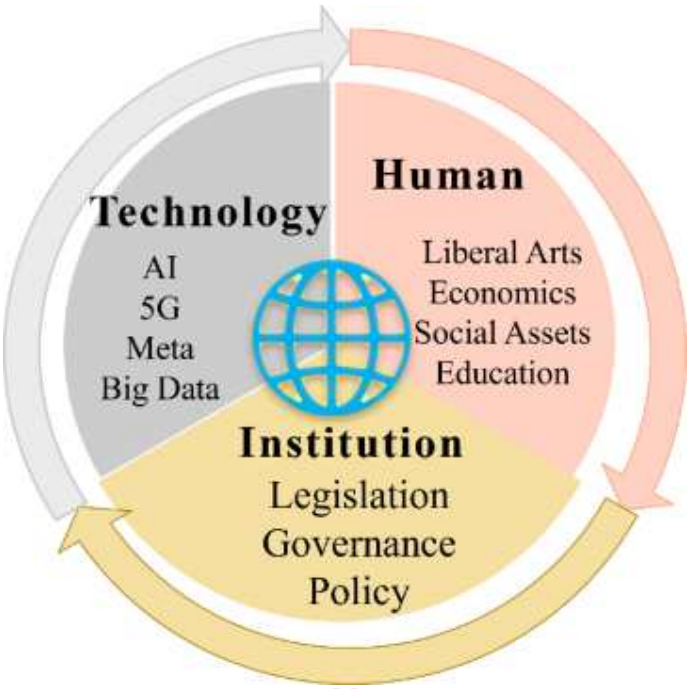

Figure 4 The three elements of a smart city [8].

Figure 5 A representation of AI in smart cities [9].

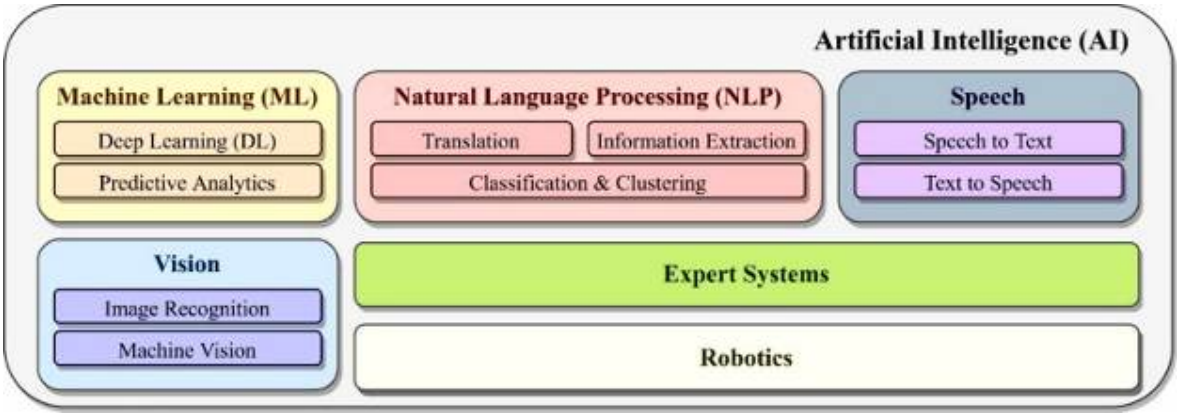

Figure 6 Six major AI technologies used in smart cities [10].

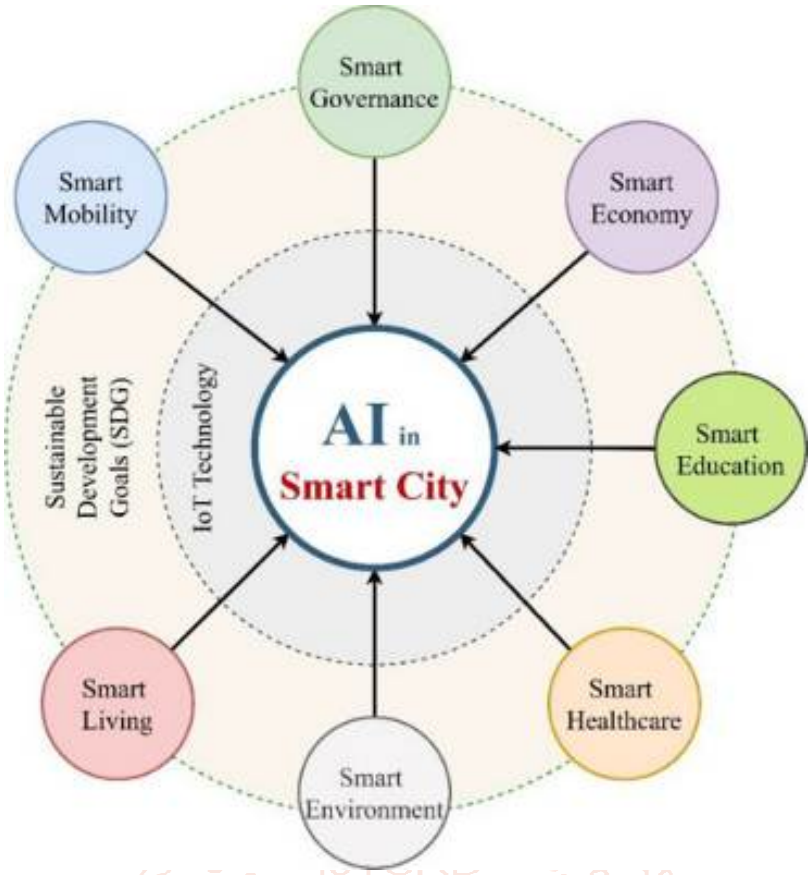

Figure 7 Different applications of AI in smart cities [10].

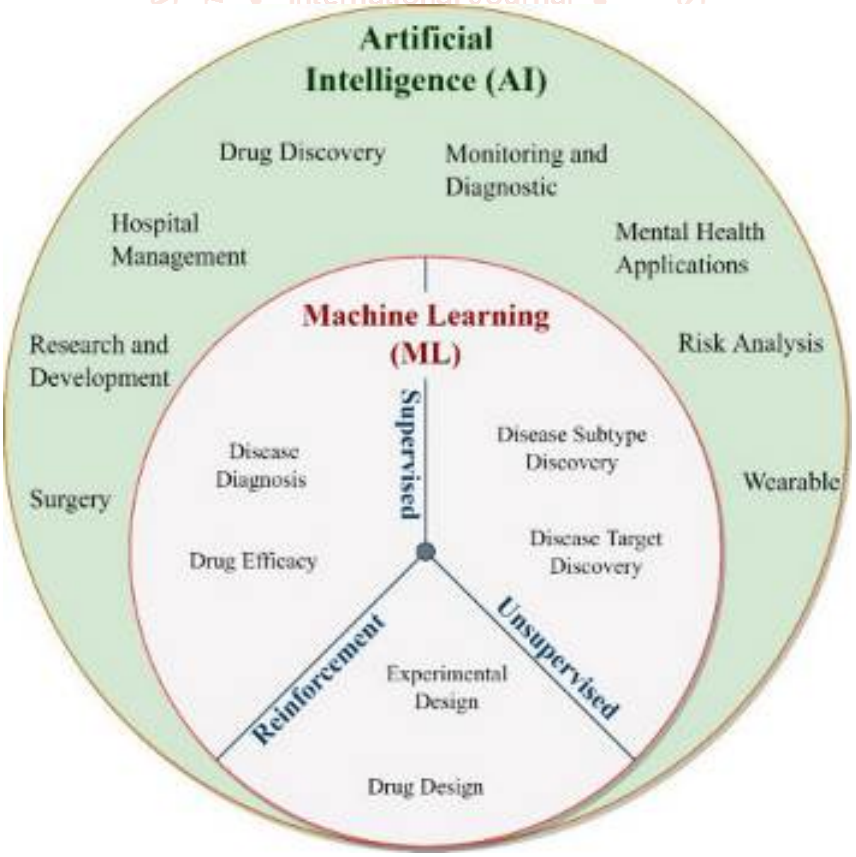

Figure 8 The integration of AI in smart healthcare [10].

Figure 9 How AI enhances public safety [9].

Figure 10 A typical city traffic [11].

Figure 11 AI in waste management [12].

Figure 12 How AI improves city efficiency [9].

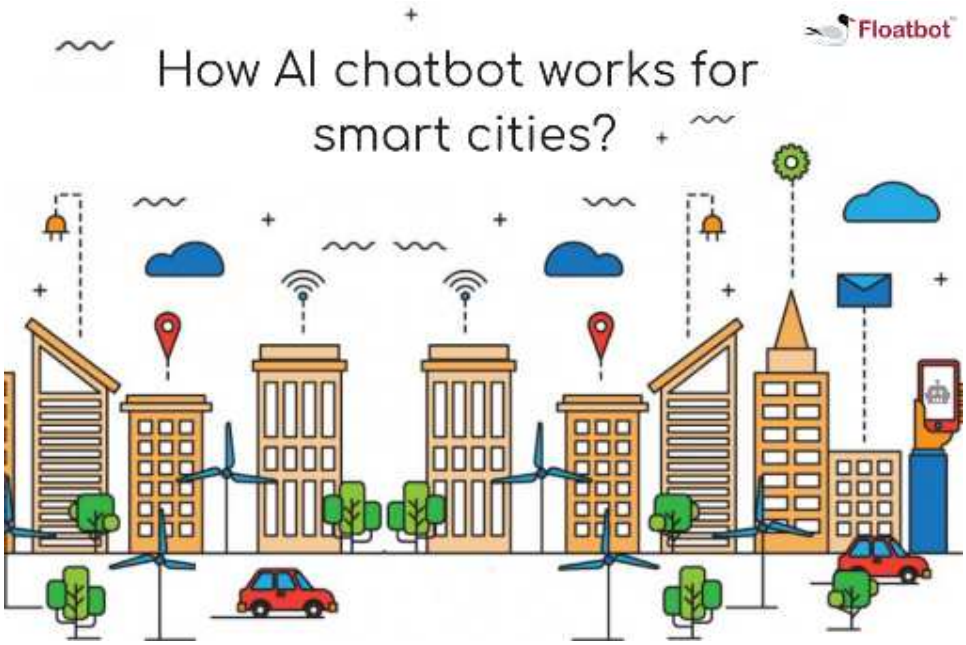

Figure 13 How AI chatbot works for smart cities [13].