Impact of Artificial Intelligence on Smart Cities

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Abstract[1]

A smart city makes use of available technologies to improve the efficiency of its operations and enhance the quality of life of its citizens. The technologies that have had and continue to have a significant impact on smart cities include hyperconnected networks such as the Internet of Things (IoT) and artificial intelligence (AI). AI is increasingly becoming involved in all aspects of human existence. Many see the emergence of AI as a revolution that will impact every aspect of our lives. Some see it as an evolution based on the recent advances in powerful computational platforms, and access to massive amounts of data. IoT provides an elaborate platform for collecting data from various applications. AI can analyze this data and make intelligent decisions enabling the development of smart systems. This combination is leading to the rapid development of smart systems. These systems include smart healthcare, smart transportation, smart energy, smart agriculture, and many more, addressing the needs of smart cities. Using these technologies in smart cities will certainly promote cohesive, connected, healthier, and happier communities. This paper examines the current state of AI in smart cities and discusses potential AI applications for the further development of smart cities.

Keywords: *Smart Cities, Artificial Intelligence, Smart Systems*

1. Introduction

Over the past several decades, we have seen numerous multi-dimensional demographic shifts in many aspects of the world that we live in. These evolutionary changes are driven by two direct and several indirect factors. The direct factors are the growing world population and rapidly advancing

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technologies. The indirect factors are many and include education, economy, connectivity, and globalization phenomenon, etc. Most governments around the world (at the federal, state, county, and city levels) are taking initiatives to address the challenges posed by these demographic shifts. A common goal of these initiatives is to keep improving the quality of services provided at all levels of government. Interestingly, one of the main factors – emerging technologies – that is contributing to these shifts in the world, also presents as a solution to manage these shifts.

Despite declining growth rates, the world population has been steadily growing for the past several decades (United Nations, 2022). From 2.5 billion in 1950, it is projected to reach 10 billion by 2050 representing a remarkable increase of 300% within a span of 100 years. Both the growth rate and the world population (including projections) are shown in Figure 1.
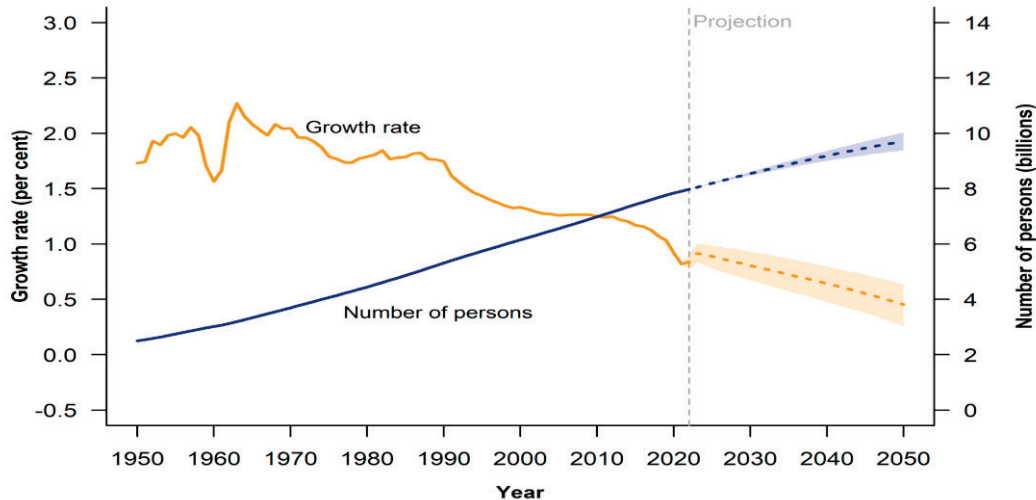

Figure 1: Word population and its growth rate – trends and projections from 1950 – 2050 [Source: United Nations, 2022].

Another factor contributing to the growing world population, is the rise in life expectancy. This can also be attributed to the advances in healthcare

technologies and increasing use of these technologies in various phases of healthcare including diagnostics, medical procedures, treatment, and recovery (Ilyas, 2022). Figure 2 shows trends and projections of life expectancy at birth from 1950 to 2050 in various regions of the world (United Nations, 2022). This is a remarkable manifestation of the impactful use of emerging technologies in healthcare leading to an impressive increase in the longevity of human life. Among the aging population, number of seniors (65 years and older) was 727 million (9.3% of the world population) in 2020. According to the United Nations (2023) report, this number is expected to reach 1.5 billion (16% of the world population) by 2050. Most of the seniors from this segment of the population, require some assistance. Once again emerging technologies can be very helpful in providing assistance to this group of population (seniors) and improving their quality of life.
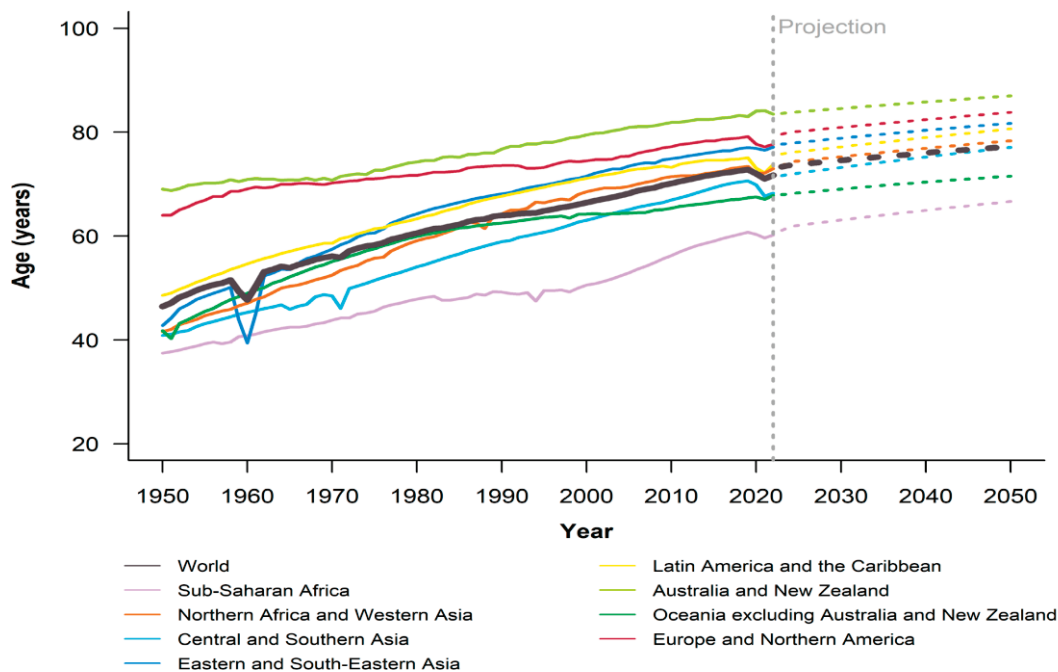

Figure 2: Trends and projections of life expectancy at birth in various regions of the world from 1950 – 2050 [Source: United Nations, 2022].

Another relevant impact of the growing world population and increased use of emerging technologies is the rising level of urbanization. Figure 3 shows the trends and projections of the urban population from 1950 to 2050 in the world, in more developed countries, and in developing countries (United Nations, 2019). The figure shows that the urban population was 750 million (30% of the world population) in 1950 and is expected to reach 6.9 billion (68% of the world population) by 2050. Such a rise in urbanization is certainly leading to very densely populated cities and requires innovative approaches to address the needs of such cities.
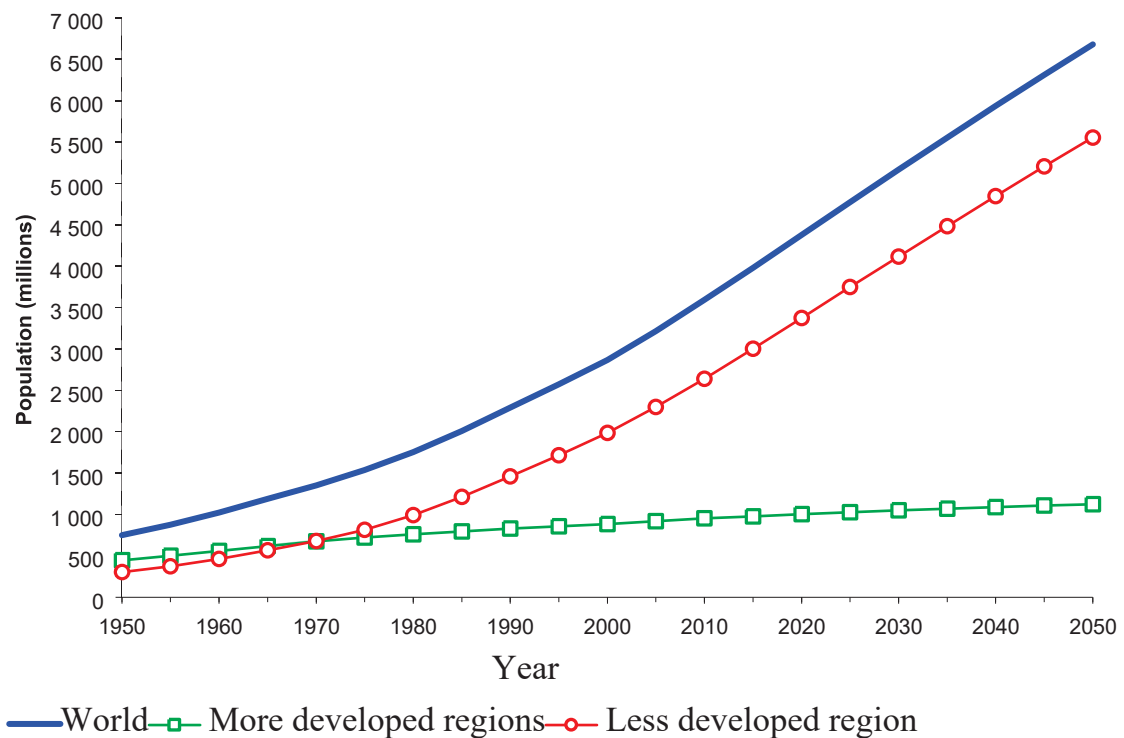

Figure 3: Trends and projections of urban population of the world in different regions of the world from 1950 – 2050 [Source: United Nations, 2019].

The success of a city's development depends on its ability to recognize and address the unique needs of population. Particularly, densely populated cities face their own set of challenges in addition to the usual urban demands.

Despite this, they share many similarities with other cities. It is crucial to recognize and address these similarities, while also considering the unique challenges of densely populated cities that include:

- Adequate housing
- Educational opportunities
- Food supply
- A clean environment
- Security
- Services such as healthcare, transportation, utilities, waste management etc.

The concept of smart cities is being viewed as a possible solution for efficiently and effectively addressing the needs of large and densely populated cities.

2. Smart Cities

The idea of smart cities was conceived in 1960s based on the analysis of limited data collected from a variety of sources. This idea led to the first generation of smart cities with the use of technologies available at that time. This initiative also tested the impact of technologies in our daily life activities. This effort has now evolved into a more methodical approach and is based on four steps – the continuous collection of data, the ongoing analysis of collected data, the communication of data analysis results, and appropriate actions (TWI, 2023). The efficiency of these four steps has enormously improved because of impressive technological advances including highly efficient sensors used to collect data, huge data storage abilities, massive processing power, and fast, reliable, and pervasive connectivity for communication.

A smart city makes extensive use of information and communication technologies in combination of all other available technologies to improve the quality of service for its citizens. The use of these technologies also enhances operational efficiencies and the delivery of services. Smart cities are focused on ensuring the happiness of their citizens and communities. They plan to do so by utilizing cutting-edge technologies and innovative solutions to develop and environment that is not only livable but also enjoyable for all. This creates an environment to provide the citizens with opportunities to improve their chances of reaching the highest level in Maslow's hierarchy of human needs – starting from physiological needs, safety and security, love and belonging, self-esteem to self-actualization. The detailed pyramid shown in Figure 4 depicts all the five levels of Maslow's hierarchy (Mcleod, 2023).

The collective use of all the available technologies in a smart city, can be very effective in:

- Supporting better living
- Supporting better services
- Supporting connected, cohesive, and happy communities
- Continuously improving overall quality of life for citizens
- Reducing operational costs
- Making operations efficient
- Supporting economic growth
- Supporting the efficient use of resources
- Promoting sustainable infrastructure
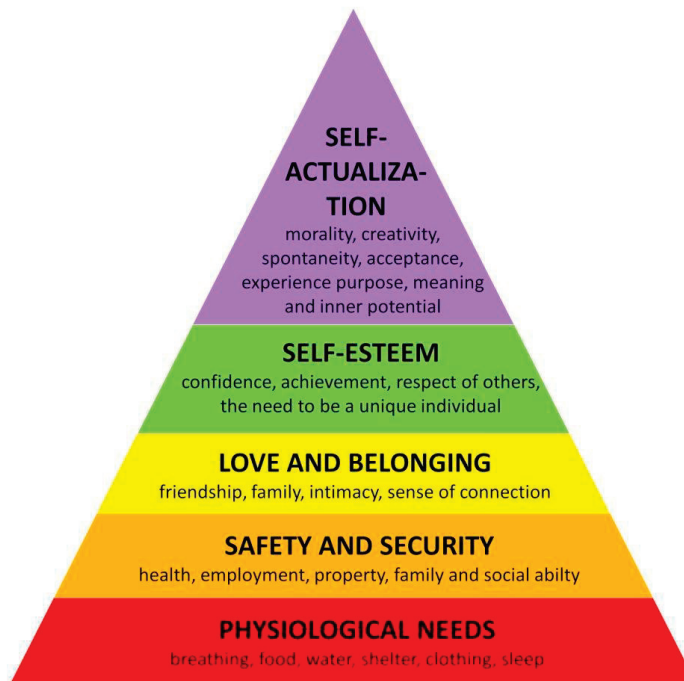- Making many more aspects of smart cities better

Figure 4: Maslow's hierarchy of human needs [Source: Mcleod, 2023].

For achieving these goals, the following aspects are necessary to be included in the planning and development of smart cities:

- Smart healthcare
- Smart transportation/mobility
- Smart energy infrastructure
- Smart security
- Smart buildings
- Smart infrastructure
- Smart agriculture
- Smart governance
- Many other smart aspects …

All these aspects require extensive use of a wide range of technologies. Along with the availability of massive storage and high-speed computing, two other

technologies are expected to play an important role in smart cities. These two technologies are the Internet of Things (IoT) and artificial intelligence (AI). The IoT provides pervasive connectivity where everything (including commonly used appliances) is connected to the Internet with a uniquely identifiable Internet address. These connected things present an ideal platform for collecting data as needed for various smart applications. Artificial intelligence presents a simulated environment where machines learn (via training) using collected data, try to act like humans, and mimic human behavior (Ilyas, 2022a).

3. Artificial Intelligence (AI)

Until about a century ago, intelligence had been associated with humans. This is because humans have an innate ability to think, analyze situations, make plans, learn, acquire skills, develop solutions, and solve surrounding problems. This is referred to as human intelligence (Colom et. al., 2010).

On the other hand, artificial intelligence (AI) refers to non-human or machines (such as computers). It is a branch of science that attempts to make computers behave as humans and mimic the process of human cognition, decision-making, and actions. Researchers have had interest in artificial intelligence for a long time. The research activity in this field has seen several ups and downs. The recent enhanced level of research interest among scholars is expected to continue due to advances in the associated technologies such as big data, massive storage, and fast processing. Another significant factor for research growth in this field is that AI is being viewed as a field that will automate many common applications and will have a profound impact on almost every aspect of our life (IBM, 2023).

Historically, humans have always been interested in automation and faster processes. Until the 1600s, these aspects were limited to fictions and

fantasies. The word "engine" was mentioned for the first time in the early 1700s. There was no tangible progress or focused effort in this subject until the early 1900s. A fictional concept of developing artificial people (robots) was mentioned in 1921 and triggered renewed interest in this field. The term "artificial intelligence" surfaced for the first time in 1956 at a workshop proposed by John McCarthy followed by several promising developments during the next several decades (Reynoso, 2023). The prominent ones among these developments include the participation of IBM's Watson in Jeopardy, sophisticated robots (such as humanoids), autonomous vehicles, Amazon's Alexa, and natural language processing. The rapid pace of these developments and their transformational impact are expected to continue. This is because AI thrives on the availability of massive amounts of data (thanks to extensive connectivity platforms such as Internet of Things) and massive data storage capabilities, in providing data-driven decisions. In addition, fast computing platforms support the rapid execution of AI algorithms to support applications such as autonomous vehicles, faster development of medicines including vaccines, and agricultural processes.

4. The Role of AI in Smart Cities

As mentioned earlier, smart cities make extensive use of all available technologies to improve the quality of life and services for its citizens, and to enhance operational efficiencies and delivery of services. Artificial intelligence (AI) has emerged as one of the most relevant technologies for smart cities (Cugurullo, 2020). In many applications, AI can provide to us (humans) several viable options based on the past historical data and trends. Such options can be evaluated by humans for making a final decision to implement. Such a combination of artificial intelligence and human intelligence is referred to as augmented intelligence (AuI) and can be very effective in many sectors of smart cities (Ilyas, 2022).

Many aspects of smart cities that can benefit from artificial intelligence. In this paper, we focus on four important sectors (as shown in Figure 5) of smart cities and discuss how artificial/augmented intelligence can be effectively used to enhance the operations of these sectors.
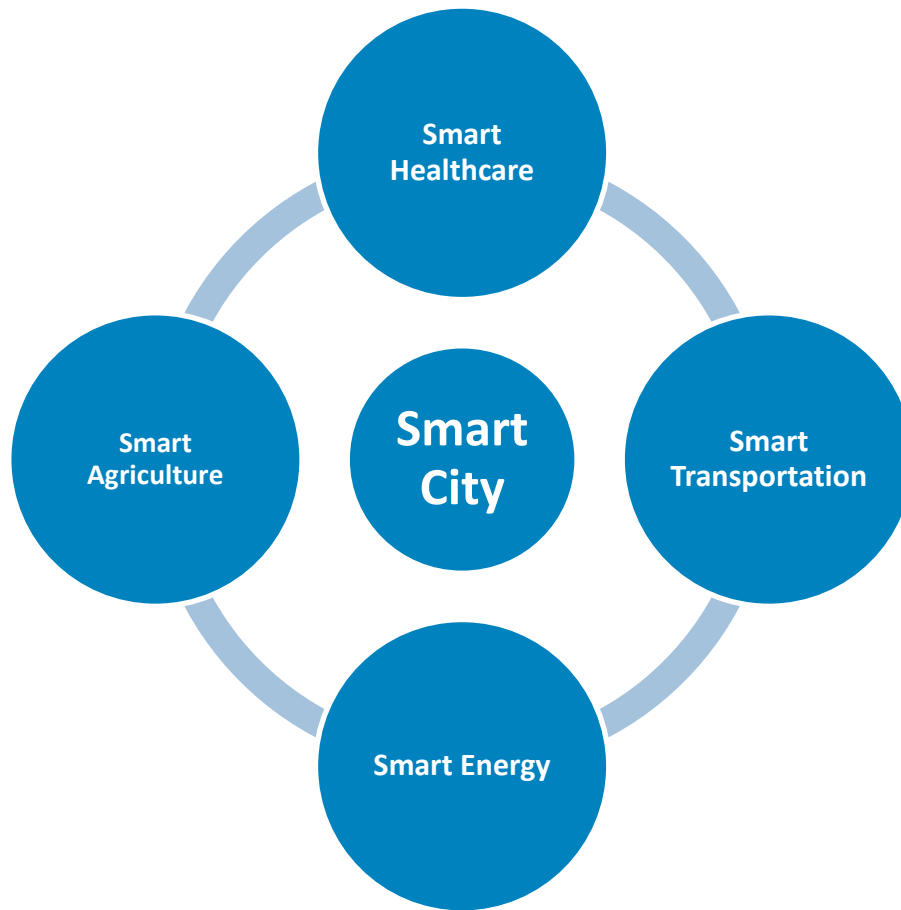

Figure 5: Four important sectors of smart cities discussed in this paper.

4.1. The Role of AI in Smart Healthcare

Health and healthcare are important and personal to us. It involves patients, healthcare professionals, pharmaceuticals, and hospitals/clinics. It has always been desirable to use the latest technologies to deliver the best possible

healthcare. To achieve that goal, healthcare professionals and technology experts must work together, exchange needs and ideas, find workable solutions, and improve healthcare. Artificial and augmented intelligence are playing a very important role in using the past experiences and data for faster diagnostics, effective treatments, enhanced quality, improved access, and speedy recovery (Ghazal et. al., 2021).

There is another transformational shift taking place in the healthcare sector because of emerging technologies. Emerging information and communication technologies, such as the rapid growth of Internet of Things (IoT) combined with artificial intelligence, are creating much needed healthcare awareness among citizens of the world. The awareness about healthcare issues is urging people to focus on being proactive to stay healthy rather than being reactive and treating sickness. This is also creating shift in healthcare delivery models (Gordon, 2023). Artificial intelligence (AI) is at the center of addressing the needs created by this transformational shift in healthcare (Davenport et. al., 2019).

Internet of Things (IoT) presents itself as an ideal platform to collect healthcare information about patients, health conditions, diagnosis, treatment, and recovery. Using artificial intelligence (AI) can be very effective in analyzing this data, extracting patterns, and presenting viable options. In general, patients feel somewhat uneasy about AI making final healthcare decisions. To address that, it is important for healthcare professionals to evaluate options presented by AI and use their best judgement to make final healthcare decisions. This process of combining artificial and human intelligence is referred to as augmented intelligence and can be very impactful in delivering the best possible healthcare.

Although the use of AI will improve many aspects of the healthcare system, it is not expected to replace the involvement of healthcare professionals. However, it is expected to have a profound impact on the healthcare system

in improving the decision-making process of healthcare professionals leading to higher quality decisions, lower cost, and higher overall system efficiency. The use of artificial intelligence in healthcare is expected to have tremendous benefits, including the following (Dilmegani, 2023):

- Diagnostic process for medical conditions will become faster, and treatment options will become better. The decisions will be based on massively large datasets containing information about prior incidents of similar medical conditions, and the effectiveness of various treatments options.
- The availability of personalized treatment options will become common and will be based on the genetic dispositions of patients.
- A common practice is expected to emerge to coordinate, consult, and broadly share information about various medical conditions and the effectiveness of different treatment options segmented by factors such as age, gender, ethnicity, and race.
- Broader information sharing among citizens is expected to support a healthcare model focused on keeping people healthy (preventive) rather than treating sickness (reactive).

The use of emerging technologies such as artificial intelligence in healthcare is a win-win scenario for the entire healthcare ecosystem. It is expected to be tremendously beneficial for patients as well as healthcare providers in terms of improving confidence in the healthcare system, boosting the efficiency, and lowering the cost of healthcare services.

4.2. The Role of AI in Smart Transportation

Since the inception of the automotive engine to the current use of information and communication technologies (ICTs) and artificial intelligence, emerging technologies have always played an important and impactful role in the transportation industry. With the recent demographical shifts, growing

urbanization trends, the extensive use of ICTs in vehicles, and pervasive connectivity, transformational changes are taking place in the transportation sector. Car ownership is expected to keep declining and transportation is increasingly being viewed as a service. Self-driving and connected vehicles are fueling these trends. Artificial intelligence (AI) developments are playing a major role in the process. Faster computational platforms and advances in AI algorithms have made it possible for vehicles to process information, collected from their surroundings in near real-time thus enabling them to drive at highway speeds. All future vehicles will need to be connected to receive and share information with other vehicles and with transportation infrastructure (Ma et. al., 2020).

Artificial intelligence, in all its applications including transportation, requires relevant data to be effective and accurate. Being connected to emerging communication networks such as Internet of Things (IoT), helps in sharing information with other connected devices and collecting information from others. Vehicles should be able to connect and communicate with other vehicles, with the transportation infrastructure, and with almost everything that is part of the communication networks. This may include traffic lights, construction site vehicles, emergency vehicles, pedestrians, cyclists, road signs (including speed signs), individuals directing traffic, accident scenes, obstructions, and many more. In situations, where the connectivity is not as pervasive as desired, autonomous aerial vehicles, such as drones, can bridge the gap by collecting and transporting information where it is needed (Shi et. al., 2018).

All vehicles can apply AI algorithms to the information gathered from their surroundings, identify possible decision options, and make transportation smarter. Autonomous vehicles have much to gain from artificial intelligence. They can use the collected information to train and be prepared to deal with any situation they may face. The factors that have propelled and continue to propel the successful performance of autonomous vehicles include access to

enormous amounts of data/information and greater processing or computing capabilities. The collection and use of data from sensors that are not in the direct line-of-sight is very helpful and impactful in making transportation safer. This combination of more data, more processing power, and the use of sophisticated AI algorithms, is leading to many beneficial outcomes including the following (Tong et. al., 2019 & Ma et. al., 2020):

- Citizens with physical limitations may be able to enjoy the benefits of transportation using autonomous vehicles without the need to drive. Transportation as a service will become a viable and popular option.
- Traffic management will adapt to the traffic conditions and the frequency of accidents will decrease leading to a significant reduction in fatalities. Smart cities will have the ability to manage traffic and deal with challenges such as parking-related difficulties, much more effectively.
- Consumers will have choices to put their travel time to some better and productive use.
- Traffic safety will increase due to cloud connectivity, the sensors embedded in the vehicles, and artificial intelligence. For instance, the sensors in a vehicle may be able to detect a sleepy driver, or a drunk driver and may not allow them to drive.

Citizens may reap many more benefits with the use of artificial intelligence in transportation including cost savings, better reliability, and increased safety. The concerns about the privacy of personal information will always be present.

4.3. The Role of AI in Smart Energy

As discussed earlier, the world population is rapidly growing. At the same time, a larger segment of the population is moving to cities. These trends will make cities more densely populated and city operations more complex. These

demographic shifts will certainly result in a higher energy demand. It is estimated that energy demand will increase by 40% during the next 25 years.

In managing energy demand and supply, it is important to know that the energy sector is also going through a transformational shift. Just a few decades ago, energy was mostly generated at large energy plants and distributed to consumers through what is called an energy grid. Lately, the energy grid has found several other distributed sources of energy such as windmills, and solar panels. To keep the energy losses to a minimum in the process of distribution, it is imperative to keep energy consumption as close to the energy generation as possible. This requires a sophisticated management strategy that keeps the energy flowing smoothly based on consumers' energy demands and the amount of energy being generated.

For addressing this challenge effectively, developing and maintaining a smart and efficient energy infrastructure using artificial intelligence becomes a necessity. A smart energy grid is expected to automatically adapt to the fluctuations in energy demand and energy supply and to make decisions about the paths of energy flow. Transformational shifts in the energy sector including the use of windmills, solar panels, and natural gas are expected to continue. Artificial intelligence's use will not only automate energy management processes but will also focus on its operational efficiencies. Remote monitoring and management of energy assets will become an integral part of the smart energy infrastructure. Such a system requires the frequent gathering of status information of the smart energy infrastructure to analyze and make decisions that are appropriate and relevant to providing the best possible service to the citizens of a smart city (Gungor et. al., 2012).

The use of smart meters that provide two-way communication between various household appliances and energy corporations through a pervasive communication network such as Internet of Things (IoT), can serve as an ideal platform to collect information about all the entities that are part of a

smart energy infrastructure. This information can be instrumental in enhancing the operational efficiency of a smart energy infrastructure with the help of artificial intelligence algorithms. This approach may lead to high-impact benefits including the following (Boiko, 2023):

- Automatic rerouting of the flow path of energy in situations such as large fluctuations in energy demand/supply, natural disasters, and accidents. This will minimize the outages, and provide reliable and efficient restoration of energy services.
- Making automatic energy distribution decisions based on consumer demands and availability of energy from a distributed set of energy sources.
- Automatically conducting inspections of all elements of smart energy infrastructure (could possibly using connected but autonomous aerial vehicles or drones) and possibly mitigating most if not all the problems detected.
- Tracking the health of energy sources and the energy distribution system and suggesting appropriate preventive maintenance as needed to minimize outages.

A smart energy infrastructure using artificial intelligence in managing its operations will be very beneficial to the energy companies as well as to the consumers. The citizens of a smart city will have stable and cost-effective access to the energy.

4.4. The Role of AI in Smart Agriculture

A major challenge associated with the growing world population is ensuring adequate food and water supply. This challenge is multifaceted because the shifting population demographics not only increase demand for food, but at the same the agricultural land shrinks. Thus, there is an urgency to use all the available technologies to make agricultural processes as efficient as possible

to have adequate food production. The trends show that during the next few decades, about 70% of the world population will decide to live in urban settings, agricultural land will shrink, and the agricultural workforce will also reduce. The availability of adequate drinking water for the growing population is another major challenge that must be addressed. Demand for the drinking water is expected to steadily increase as the population grows. At the same time, water is also needed for agriculture. A United Nations report (UNESCO, 2022) indicates that an average of 70% of the available groundwater is used for agriculture. In some countries, this percentage is much higher. Emerging technologies including drones (Mogili et. al., 2018), and artificial intelligence (Banthia et. al., 2022), can certainly help address these challenges.

The use of drones has brought significant automation to the field of agriculture to improve the agricultural processes and this trend is expected to continue as new technologies emerge. It is anticipated that the use of artificial intelligence in agricultural processes will increase steadily and steeply. For these technologies to be effective, there must be an elaborate fleet of drones, a mesh of sensor networks, and/or Internet of Things (IoT) to collect relevant data and to automatically monitor the agricultural aspects and processes from cultivation to harvesting. The collected data may include information about the soil condition, irrigation needs, crops' health, and need for fertilizer/pesticide etc. The data can be analyzed and used for making decisions, and their implementation to achieve an optimal environment for crops to thrive, and to achieve the best possible outcomes (Qazi et. al., 2022). These decisions include the use of irrigation, application of pesticides, and application of fertilizer based on need. Such an environment will save resources (including groundwater) and produce better and healthier crops. These technologies can also be used very effectively in managing greenhouses for growing the same crop multiple times a year thus meeting the increased demand for food. The use of emerging technologies such as

artificial intelligence and automation in agriculture, will address the challenges discussed earlier, and is expected to have the following outcomes:

- Artificial intelligence combined with computer vision and image processing, can be used very effectively to monitor and mitigate weeds or other adverse conditions, for healthier crops. The same approach can be used to automate the process of harvesting.
- Irrigation can be controlled precisely and used only when needed, resulting in tremendous conservation of assets including water.
- The entire agriculture process can be automated. One can remotely manage the entire agricultural cycle including soil preparation, cultivation, monitoring, harvesting, packing, and shipping without visiting the farm.
- Sensors networks and communication networks can keep an eye on the food items being transported to make sure the shipping containers maintain a conducive climate for the items to stay fresh and not become contaminated while in transition.

Artificial intelligence can revolutionize the agricultural process, making it more efficient, cost-effective, and eco-friendly. From planting and harvesting to storage and transportation, AI-powered solutions can help farmers optimize their operations and produce healthier, safer, and abundant food for the world population. This is very relevant to keeping the citizens of smart cities as healthy and safe as possible. This applies to entire range of population from newborns to elderly.

5. The Impact of AI on Smart Cities

The role of artificial intelligence in smart cities is not limited to just healthcare, transportation, energy, and agriculture. There are numerous other significant applications that leverage AI, such as city planning, law

enforcement, security, waste management, environment, education, and government services. These applications involve collecting relevant information, analyzing it, applying AI algorithms, identifying patterns, making automatic decisions, and implementing them. As this process continues, the applications of AI keep improving in terms of efficiency and effectiveness, leading to better quality of life of citizens of smart cities. The profound impact of AI in current and future smart cities is undeniable.

With all the benefits, opportunities, and conveniences that artificial intelligence brings to the society, associated with AI are some challenges and concerns. The biggest concerns that citizens of smart city share include security of personal information and the "fear of unknown". These have always been the concerns with the introduction of new technologies. Society was even hesitant about using telephones when that technology was first deployed. With time these fears fade away and the advantages as well as the conveniences that new technologies provide become attractive. Concerns about the personal information falling in the hands of unauthorized and misguided individuals are real. However, attempts to maliciously access personal information about individuals, are being detected and mitigated effectively with the use of artificial intelligence. Another concern with the deployment of new technologies such as artificial intelligence is the future of workforce and machines taking away human jobs. We recall such fears when robots were introduced in assembly lines of manufacturing industries. These fears are real to some extent, and we have seen that with the mechanization of agricultural processes. The fears associated with the use of artificial intelligence and resulting automation, are no exception. However, looking from another perspective, introducing new technologies will clearly disturb the ecosystem of workforce. Some jobs will certainly disappear. At the same time new jobs will be needed and created to address the needs that emerge from the introduction of new technologies. For instance, the jobs at Google, Amazon, or Facebook, did not exist a few decades ago. They were created as the new technologies were deployed. With the broad introduction of artificial

intelligence, it is expected that each such disruption will result in a slightly adjusted ecosystem of workforce requiring new skillsets.

The best we can do at this stage is to put artificial intelligence to a good use to serve humanity and find ways to coexist with AI developments. At the same time, let us hope that with all the impressive enhancements in artificial intelligence, we humans can stay in control and avoid any potential pitfalls.

6. Conclusions

Artificial intelligence (AI) continues to have an enormous impact on all aspects of our lives. This trend is expected to keep growing. This paper discusses the impact of AI on current as well as future smart cities. The paper starts with transformational demographic shifts that have been happening for the past several decades, the emergence of technologies, and how we, as society, are adjusting to these shifts. With the implementation of AI in various services, the systems around us are becoming smarter and the automation is on the rise. These systems depend on the relevant data (past as well as current) and analysis of the data, allowing AI to make smarter decisions. Pervasive communication technologies such as sensor networks and Internet of Things (IoT) present as ideal platforms in the process of data collection. Smart cities use all the available technologies to improve the quality of life of their citizens. Although, there are numerous applications of artificial intelligence in smart cities, this paper has selected four applications that are very relevant to smart cities. These applications are smart healthcare, smart transportation, smart energy, and smart agriculture. For these applications, the paper discusses how AI can be extremely beneficial is improving efficiency of operations, offering cost-effective solutions, and supporting healthier and happier communities. The paper has also discussed some of the challenges and opportunities as the impact of artificial intelligence continues to grow in all aspects of our lives.

7. Acknowledgments

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