

Planning and Development of Smart Cities Based on the Concept of Sustainable Development

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Abstract: Based on the idea of sustainable development, this paper explores the planning and development of smart cities. Cities face many issues as global urbanization picks up speed, including environmental pollution, resource depletion, traffic congestion, and social inequality. To address these challenges, the notion of sustainable development has become a guiding principle for many city policymakers, aiming to meet contemporary needs while safeguarding future development. Smart cities utilize advanced information and communication technology to enhance urban operational efficiency, improve resource management, and enhance residents' quality of life, thereby providing a more sustainable development model for cities. This paper focuses on the key areas of smart city planning, including energy utilization and environmental protection, smart transportation and urban mobility, smart city planning and land use, social equity, and community engagement. Using Shenzhen as a case study, the practical application of the notion of sustainable development in smart city construction is elucidated, providing valuable insights and practical references for future smart cities.

Keywords: Smart cities, sustainable development, planning and development, energy, smart transportation

1. Introduction

The rate of urbanization has increased globally at an unprecedented rate in the last few decades. However, along with urbanization, issues such as environmental pollution, resource depletion, traffic congestion, and social inequality have arisen due to blind expansion and economy-driven urban planning. Consequently, upgrading cities for sustainable development has become a crucial topic in urban planning. To address these challenges, the concept of sustainable development has become a guiding principle for many city policymakers, aiming to meet contemporary needs while safeguarding future development.

With advancements in big data and communication technology, the emergence of smart cities has become almost inevitable, offering new approaches to tackle challenges in sustainable development. Smart cities utilize advanced information and communication technology to enhance urban operational efficiency, improve resource management, and enhance residents' quality of life, thereby providing a more sustainable development model for cities. While smart cities are not equivalent to sustainable cities, they share common goals of environmental, economic, and social sustainability [1]. Through the digitization, automation, and data sharing of various urban systems, smart city

management is achieved. In the process of constructing smart cities, the principles of sustainable development are crucial in guiding smart city development and achieving its goals. Sustainable development promotes long-term planning in smart city construction, ensuring resource availability and considering both current and future generations' needs in infrastructure construction and service provision. These principles ensure that population and economic growth can address relative challenges by implementing systems such as intelligent transportation, renewable energy, energy-efficient buildings, and waste management, which are beneficial to environmental protection. Additionally, smart cities enhance social inclusivity and equity during construction. By leveraging technological advancements to provide equal services and opportunities to all residents, social inequality issues are significantly improved, creating a more inclusive urban environment, further promoting sustainable urban development, and entering into a positive feedback loop of mutual interaction.

Against this backdrop, this paper aims to review existing literature by exploring the planning and development of smart cities based on the sustainable development theory. It elucidates the fundamental concepts and characteristics of sustainable development and smart cities, determining how sustainable development principles integrate into smart city planning. Shenzhen is selected as a case study of a smart city to illustrate the practical application of sustainable development in smart city construction. Shenzhen, as a pioneer of China's reform and opening up, is renowned for its rapid economic development and innovation capabilities. In recent years, building smart cities has advanced significantly in Shenzhen, with the creation of digital infrastructure including huge data centers and the Internet of Things, intelligent traffic management such as smart traffic lights and bus dispatching, smart energy systems such as smart grids and smart homes, and digitized government and public services such as online applications and approvals, online payments, and data disclosure. By analyzing experiences and challenges in the fields of energy, transportation, environment, and social equity in smart cities, this paper provides valuable insights and practical references for future smart cities.

2. Sustainable Development

Originally stemming from the ecological realm, sustainable development referred to ecosystems that changed little over time [2]. As time progressed, this concept gradually extended to encompass environmental, social, and economic dimensions. People shifted focus from mere environmental conservation to emphasizing sustainable development, aiming for long-term fulfillment of human needs while achieving a balance between the environment and the economy. Various conceptual frameworks have emerged around sustainable development. For instance, the concept of ethical paradox posits an irreconcilable conflict between environmental protection and economic development [3]. In the realm of equity, sustainable development is regarded as a standard of environmental justice, encompassing environmental, socio-economic, social fairness, quality of life, social distribution, and democratic freedom [4]. In an unjust social environment, sustainable development is unlikely to occur. The concept of constant natural capital suggests that sustainable development relies on the principle of maintaining constant natural capital over time [5]. Additionally, there are various other perspectives on sustainable development definitions, but the theory of constant natural capital, rooted in ecological economics, is a widely recognized mainstream theory.

Based on the theory of sustainable development, several fundamental principles need to be adhered to in practice. The most important principle is to protect the foundation of natural resources, ensuring the integrity of resources under normal delivery and usage patterns to preserve natural resources for future generations' sustainable development. Secondly, the essence of sustainable development is to ensure long-term better survival for humanity. Therefore, improving individual quality of life is equally important while considering the overall survival of humanity, ensuring fair distribution to

promote the benign development of society. Since the formation of human society, a significant amount of man-made assets has been left in history. In addition to protecting natural resources, sustainable development should also protect cultural capital [6].

3. Smart Cities

The term "smart city" first appeared in 1988 [7], but its meaning has evolved significantly over the past 20 years. Despite the ambiguity in its basic concept and definition, there is a general consensus that the construction of smart cities involves several key areas. According to the theory proposed by Niederer et al., Smart cities can be divided into two primary domains: the "soft" domain, which covers social, political, and economic aspects, and the "hard" domain, which includes energy, lighting, environment, transportation, architecture, healthcare, and public safety [8]. The framework for achieving smart cities primarily consists of the following application areas: resources, including natural resources and energy supply and management; transportation, focusing on intelligent transportation systems and the application of communication technologies in transportation management; urban infrastructure such as smart buildings; quality of life, covering education, healthcare, safety, and residents' well-being; governance, involving public electronic services, democratic participation, and administrative efficiency; and economic and social cohesion, among others [9,10]. A smart city is generally understood to be a contemporary urban setting that makes use of cutting-edge information and technology to boost resource management, operational effectiveness, and ultimately resident quality of life. The creation of a more sustainable and livable urban environment is the purpose of smart cities, which is in line with sustainable development.

4. Planning Focus of Smart Cities: A Case Study of Shenzhen

Shenzhen, as China's first established Special Economic Zone, swiftly transformed from a small fishing village into a crucial model city for China's economy. Its rapid economic development, innovative capacity, infrastructure, and societal culture have provided essential prerequisites for the city's rapid advancement. In 2018, Shenzhen unveiled the master plan for its new smart city initiative [11]. Over the years, with the advancement of big data and communication technologies, Shenzhen's favorable conditions and innovative cultural environment have provided fertile ground for the development of a pioneering smart city in China [12].

4.1. Energy Utilization and Environmental Protection

Smart city planning should prioritize the utilization of renewable energy and enhancing energy efficiency, as well as the efficient integration of both. For instance, utilizing solar energy for daytime power generation and using surplus electricity to electrolyze water at hydroelectric stations to produce hydrogen. Later, during peak electricity demand periods, the stored water and electrolyzed hydrogen can be used for power generation. Leveraging smart technology to monitor and manage energy usage helps in reducing energy consumption and carbon emissions. For example, during high winds, both thermal and wind power generation can be utilized simultaneously, as the strong winds rapidly disperse the emissions from thermal power plants away from urban areas.

Moreover, smart city planning should also emphasize environmental protection. For instance, planning green space areas in conjunction with population size ensures optimal greenery experience for residents while minimizing landscaping costs. Through smart city monitoring of waste sorting and pollution emissions, potential pollution incidents can be nipped in the bud, while also optimizing the allocation of sanitation workers, reducing urban cleaning costs, and enhancing city cleanliness and hygiene.

Currently, Shenzhen's energy utilization presents a diversified profile. Although traditional energy sources still serve as the foundation, in recent years, Shenzhen has actively promoted the development of clean energy, especially solar and wind power generation projects. The proportion of clean energy usage is gradually increasing. In addition to diverse energy development approaches, Shenzhen has implemented a series of energy conservation and emission reduction measures. These include promoting energy-saving technologies, implementing energy intelligent management systems, encouraging the use of public transportation and non-motorized vehicles, establishing building energy efficiency standards, and improving building energy efficiency.

Furthermore, in the power system, Shenzhen has actively promoted the construction of smart grids and widely deployed smart meters. Through remote monitoring, control, and optimization of the power grid and meters, electricity can be flexibly allocated based on real-time electricity demand and energy supply. Residents can monitor their own electricity usage, reduce waste, and enhance the stability and economy of the power grid system [13]. Through technological innovation and management measures, Shenzhen aims to reduce energy consumption and carbon emissions.

4.2. Smart Transportation and Urban Mobility

Smart city planning should optimize the urban transportation system by improving road design and efficiently allocating road resources during peak commuting hours through technological means. For example, movable road median lines can be remotely controlled to swiftly adjust the number of lanes. Navigation software can guide drivers to avoid congested routes and choose the fastest ones. Policies can encourage the use of clean energy vehicles and public transportation to reduce traffic congestion and emissions. Additionally, big data can influence urban planning to shorten commuting distances and allocate public transportation schedules based on passenger flow data, enhancing the efficiency of green travel far beyond driving private cars, which are both highly polluting and inefficient.

Shenzhen has implemented a series of measures to improve traffic operation efficiency, reduce congestion, and enhance traffic service levels. Intelligent traffic signal control has been achieved, wherein traffic signals at different locations are adjusted based on real-time traffic flow and road conditions using timing algorithms and intelligent controllers, optimizing traffic flow [11]. Shenzhen has also established intelligent bus dispatching and navigation systems, reducing passenger wait times and road congestion by transmitting Global Position System (GPS) location data to dispatching platforms. The navigation system can plan the optimal route, reducing both travel time and energy consumption. Furthermore, Shenzhen's smart parking system makes use of technologies like intelligent payment and parking space identification to manage parking spaces in real time, enhancing both the user experience and parking efficiency.

4.3. Smart City Planning and Land Use

Smart city planning should make efficient use of land resources, achieving intelligent allocation and efficient utilization of urban space. By studying the data on urban residents' daily behaviors, cities can be planned into relatively independent and comprehensive small areas where residents can fulfill major urban functions such as living, working, leisure, education, and healthcare within their vicinity. This approach helps avoid long-distance commuting and issues related to accessing schools, workplaces, and healthcare facilities due to inefficient urban resource allocation, ultimately addressing the significant problem of resource waste caused by transportation. Shenzhen's overall planning for smart cities is based on spatial layout, land use structure, transportation networks, public facilities, and other planning objectives. For instance, it involves the renovation and transformation of old urban areas, optimizing urban spatial layout and functional configuration, and equipping corresponding smart infrastructure to enhance land use efficiency and improve residents' living

environment. Smart city construction is also reliant on ecological environment protection, leading Shenzhen to increase the number of green spaces and ecological conservation areas in its urban planning. This not only improves the ecological environment but also provides space for recreational activities and children's education. In terms of industrial layout, Shenzhen further optimizes industrial structure and development clusters. For example, high-tech industries are concentrated in Nanshan District and Longgang District, financial services are concentrated in Futian District, and manufacturing industries are concentrated in Bao'an District. This industry layout based on advantages and clusters maximizes resource advantages and technological innovation.

4.4. Social Equity and Community Engagement

Smart city planning should consider the needs of all social groups to promote social equity and inclusive development. Particularly for vulnerable groups such as the elderly and the disabled, targeted resource allocation through intelligent means should be implemented to provide them with specific resources. Furthermore, through specialized planning, certain eligible vulnerable groups can be concentrated in specific areas with enhanced public facilities tailored to their needs, ensuring their convenience comparable to other citizens. In other areas, targeted resource allocation based on big data can reduce unnecessary costs. Additionally, improving technology and enhancing the personal convenience of vulnerable groups can significantly reduce the investment in barrier-free facilities in urban construction. For example, wearable devices for the visually impaired can enable them to use most urban facilities relying on auditory and tactile senses, while wearable exoskeletons can enable mobility-impaired individuals to use stairs like ordinary people, thereby reducing the need for barrier-free pathways in urban architecture. Shenzhen enhances social equity through the construction of smart cities. The city has implemented an intelligent social service system covering education, healthcare, employment, social security, etc., allowing citizens to access information more conveniently through the government's intelligent platform and handle corresponding services online, thus reducing the threshold for social services and improving their universality and equality. Shenzhen has also established numerous smart communities, which initially involve network infrastructure and smart devices. Currently, Shenzhen boasts a wireless broadband coverage rate of up to 98% [12]. After establishing the initial infrastructure, intelligent management systems are implemented. Through big data and smart technology, interaction among residents is promoted, enhancing community harmony and residents' sense of well-being.

5. Challenges

5.1. Social Challenges

Technological Divide: The development of smart cities may exacerbate the technological gap, meaning those who lack access to or familiarity with digital technologies may become marginalized. This gap is especially pronounced for elderly individuals and persons with disabilities, and the adaptive programs implemented by smart cities for these vulnerable groups may incur additional costs and increase technological complexity.

Privacy and Security: Smart cities require extensive data collection and processing, thus privacy and data security become significant challenges. Balancing the utilization of data with the protection of personal privacy is crucial. Once facing systematic attacks or disruptions, the resilience of more sophisticated devices diminishes, posing greater challenges for cities.

Social Inclusivity: The development of smart cities needs to consider the needs of all societal groups, ensuring participation and benefits for various communities.

Social Problems Resulting from Unequal Resource Allocation: While smart cities bring numerous benefits, they may also cause relative resource scarcity in other non-smart cities or rural areas, leading

to dissatisfaction among the latter. Ensuring the equitable distribution of smart city resources will require careful consideration from national governments and policymakers.

5.2. Economic Challenges

Technological Costs: Constructing smart cities requires substantial financial investment, including costs for infrastructure development, technological innovation, and maintenance. When the investment in smart cities exceeds their potential output, or even when their cost-effectiveness ratio falls below that of conventional non-smart cities, the economic challenges of smart cities become significant. Moreover, the maintenance and operational costs of more sophisticated and advanced infrastructure are higher. This necessitates the involvement of more highly skilled personnel for further development, maintenance, and updates, thereby creating more job opportunities. However, it may also lead to increased unemployment in low-skilled positions.

Pace of Technological Advancements: Rapid technological advancements may render smart city infrastructure obsolete quickly, necessitating continuous investment for updates and upgrades. As technology progresses, the investment required may increase, potentially even substantially. However, there might not be sufficient returns on investment at that point. The pace of technological advancements in smart cities will eventually begin to slow down, similar to the semiconductor industry's Moore's Law. At this juncture, increasing investment or maintaining current levels becomes a greater challenge for policymakers and investors. Economic stagnation or other pressing priorities could lead to reduced or canceled investments, akin to the reduction in aerospace investments in the United States after the Cold War.

Employment Transformation: The development of smart cities may lead to the disappearance of jobs in traditional industries, necessitating measures to assist affected populations in transitioning and retraining. The development of smart cities itself involves the replacement of many ordinary positions and middle to high-level positions with machines, big data, computers, and other technologies. While this may create additional job opportunities for individuals with specialized skills related to smart cities, it may also lead to an increase in unemployment due to the replacement of ordinary positions by smart city technologies. Moreover, the efficiency brought about by smart cities may reduce employment opportunities in certain sectors. Even if proper solutions are implemented, they may lead to other negative consequences. For instance, in many European countries with high welfare systems, the increase in minimum wages for ordinary individuals and the expansion of social welfare benefits for the unemployed have led to insufficient staffing for urban operations. Many people choose to stay at home and receive social welfare benefits rather than seeking employment, which contradicts the core principle of efficiency improvement and waste reduction in smart cities. If smart cities create greater value through more efficient technologies, allowing ordinary individuals to enjoy high social welfare benefits even without working, it would indeed be a positive development. However, if this trend spirals out of control, it could lead to another extreme, where everyone opts for the simpler option of not working and receiving welfare benefits. Even capable individuals might choose less challenging jobs. This situation poses an awkward dilemma where high-paying, high-challenge jobs remain unfilled, despite offering attractive compensation.

5.3. Challenges and Opportunities in Data Management

Big Data Management: Smart cities will generate vast amounts of data, such as traffic flow, environmental monitoring, and citizen behavior. Effectively managing and analyzing this data poses a challenge but also provides more information support for urban management and decision-making. Big data will bring enormous data and computational volume. Without advanced technology and effective implementation plans, algorithms may become ineffective. This not only makes big data a

significant computational burden, consuming energy, talent, and computing power, but also leads to decreased efficiency. Therefore, rash management of big data in the absence of adequate technology may lead to significant disasters.

Data Exploitation: Guarding against data exploitation is crucial. Data will become a new important social and business resource. Governments, businesses, and individuals who control data and data analysis will influence the majority of ordinary people's consumption decisions, and even their daily lives [14]. Therefore, if governments, businesses, or individuals fail to adhere to relevant ethical standards and regulations, or if governments do not promptly enact policies to protect the data security of ordinary people and uphold fair rights and interests, it can result in significant exploitation in the new era. This includes attention exploitation, consumption decision exploitation, and mental exploitation. For example, many smartphone apps nowadays have sparked an economic phenomenon known as the attention economy. The attention economy primarily involves the consumption of information [15]. These apps employ various tactics, such as short videos and other attention-grabbing methods, to gain users' time and attention on their platforms. However, this attention may not generate sufficient value for users. Instead, the data and traffic generated by attracting users' attention become essential bargaining chips for these companies to attract investment and convert commercial traffic.

6. Conclusion

The planning and development of smart cities based on the notion of sustainable development are important trends in urbanization today. Through measures such as rational resource utilization, optimized transportation, and enhanced social equity, smart cities can achieve a more efficient, environmentally friendly, and livable urban environment. As a model of smart city construction, Shenzhen continuously explores and practices the integration of sustainable development with smart cities, providing valuable experience and insights for other cities. However, smart city construction still faces many challenges, including technical standards, privacy protection, data security, etc., which require concerted efforts from governments, enterprises, and society to promote smart city construction towards a more sustainable and mutually beneficial future.

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