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Sustainable Smart Cities Planning in Conjunction with Environment Governance

Yichen Sun[1,a,*]

[1]*University of Warwick, Coventry, United Kingdom, CV4 7AL*
a. sunyc666@gmail.com
**corresponding author*

Abstract: In the present age, many issues have been brought to the forefront with the development of cities, hence the concept of sustainable smart cities has been introduced. Based on the methodology of big data analytics and related technologies, this paper gives the planning for sustainable smart cities from several perspectives. Starting from the analysis of urban industries and architecture, this paper analyses the distribution of urban population, presents and analyses the use of renewable energy sources in cities and the use of advanced traffic systems through several successful cases, and introduces the application of internet technology at the end. Many perspectives in this paper start with examples from real cities, thus giving evaluations as well as suggestions for optimisation. The analyses of smart cities throughout the text also deal with environmental governance, aiming to make the topic of sustainable development realisable, so that the economy and environment of the smart cities in the future can be mutually reinforcing.

Keywords: Smart city, Sustainability, Environment governance

1. Introduction

In the rapid urbanisation process of today's society, some irrational planning has led to social problems and environmental pollution has become increasingly prominent. In such circumstances, the shift from traditional urban development models to sustainable smart cities has become a significant research issue, which has a process that includes the upgrading of industrial structures, the upgrading of urban planning, and the use of cleaner energy sources to promote more efficient economic development and environmental improvement, and this is the purpose of the study for which this paper is written. This paper analyses the spatial data of the city in several dimensions in order to derive the characteristics of the distribution of the data in different regions of the city. It covers a wide range of data on the city's industries, architecture, population, energy and environment, traffic and introduces the use of new Internet technologies. By collecting and analysing the data, it identifies the problems in these areas, and purposes targeted enhancement programmes, the monitoring of real-time data can help to identify shortcomings in the programme, so that it can be optimised continually. Thus to find practical development planning for sustainable smart cities in modern society, which can create a suitable living environment for urban citizens, balance environmental protection and urban development at the same time.

2. Urban industries, architecture analysis and environmental management

Cities are the gathering place for all kinds of production and life of human beings, and the planning of land use in each functional area of the city plays a vital role in the development of the city. However, due to the overdevelopment of contemporary cities and the irrational planning of industries, the environmental pollution brought about by urbanisation has become more and more prominent, and one of the major serious problems is air pollution, under these circumstances, the rational planning of urban construction and green space has become an important research object. EBM-DEA model, ArcGIS spatial analysis and the spatial Durbin model with different weight matrices can be used to investigate the evolution pattern of green efficiency of urban construction land and the spatial effects of industrial agglomeration and environmental regulations on it.

For the urban development, architecture is fundamental to all aspects. However, buildings can consume large amounts of resources and emit large amounts of pollutants during their construction and use phases, so how to reduce the resources consumed by buildings and their impact on the environment has become an important research issue nowadays. By using the Building Environmental Performance Assessment System BEPAS, the environmental impacts of buildings can be studied in terms of building materials, energy and water consumption during the use of the building, and building appurtenances. Calculations on 62 samples in Beijing show that in the materialisation phase, the environmental impact of high-rise buildings is higher than that of low-rise buildings, while the difference between residential and office buildings in terms of environmental impact is not significant. In the use phase, office buildings have significantly higher environmental impact values than residential buildings, and buildings with lifts also have a greater environmental impact. The use phase of a building's entire life cycle has the greatest environmental impact, accounting for more than 85% of the total, the vast majority of which is attributable to the consumption of electrical energy [1]. Therefore, in the process of urban building planning, it is necessary to plan the distribution of office buildings and residential buildings rationally, as well as the distribution of high-rise buildings and low-rise buildings, to control the ratios of office buildings and high-rise buildings, and promote green buildings, so that reduce the consumption of traditional energy resources by buildings by renewable energy sources. Such a planning scheme can achieve environmental protection, and reduce the emission of pollutants and greenhouse gases while ensuring economic benefits, which can mitigate global warming and achieve the concept of sustainable development.

In addition, the digital twin model, as an advanced tool for smart city planning, provides a platform for experimentation and prediction for urban decision-makers. By establishing a digital twin model of the city and utilising virtual simulation technology to test the effects of different planning scenarios, it offers a scientific basis for future urban development. The digital twin model is capable of simulating various aspects of the city, including buildings, infrastructure, the environment, and population movements. The establishment of the digital twin model relies on the input of a substantial amount of actual urban data.

Currently, Singapore serves as a typical case where the digital twin model has been successfully applied. Through digital twin technology, the city has established a virtual city model that can simulate changes and developments in real-time. For example, planners can predict the impact of new infrastructure construction on traffic, energy, and the environment through the model, optimising planning scenarios. The digital twin model has become a core tool in Singapore's urban planning, providing a scientific basis for sustainable development. By implementing smart energy management systems and establishing digital twin models, cities can understand and address energy challenges better, while scientifically planning the future development of the city [2]. Digital twin models offer various advantages in urban environmental management. Firstly, they enable precise environmental monitoring, providing high-resolution environmental data such as air quality, noise, and water quality

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to identify and address environmental issues promptly. Secondly, they facilitate more accurate sustainable development planning by simulating the impact of different planning decisions on the environment. Digital twin models assist city planners in formulating sustainable development strategies to minimise adverse environmental impacts. Thirdly, they enhance emergency response and management capabilities by providing disaster simulations and emergency response plans, strengthening a city's ability to manage emergencies such as fires, earthquakes, and floods [3]. Fourthly, they optimise resource utilisation more effectively by optimising data related to energy, water resources, and transportation, helping to reduce resource consumption, improve resource efficiency, and promote environmental sustainability.

It is noteworthy that digital twin models also pose four technical challenges in smart city planning, namely, data integration and quality, model complexity and computational resource requirements, real-time updates and synchronisation, and privacy and security. Firstly, due to the specificity of each city's situation, acquiring high-quality real-time data from various aspects of the city and integrating information from different data sources to construct accurate and comprehensive digital twin models is currently challenging. This issue is difficult to address as various departments control and coordinate different data sources in a city, making it challenging to grant developers full access. Additionally, disparities in the format, standards, and update frequencies of different data sources can lead to inconsistent data quality, potentially reducing model accuracy [4]. Secondly, creating detailed and comprehensive digital twin-city models requires substantial computational resources, including high-performance computing and storage capabilities. This poses a significant challenge for some developing countries or underdeveloped regions, limiting the quality of their models. Furthermore, maintaining real-time and detailed accuracy on a large scale within a city imposes high demands on computational capabilities, potentially constrained by hardware and cost limitations. Full coordination and support from decision-makers are necessary in the economic aspect, making widespread implementation challenging for every city [5]. Thirdly, cities are dynamic, requiring real-time updates to digital twin models while ensuring synchronisation among different components to reflect the actual urban state. Synchronising digital twin models with the real city poses challenges in rapidly updating real-time data and dynamically adjusting models. Fourthly, integrating privacy protection measures into digital twin models to balance the conflict between data sharing and individual privacy is a complex and crucial issue [6]. Therefore, ensuring the privacy and security of data is essential when obtaining information about the behaviour and lifestyle of urban citizens to prevent misuse and violation of personal privacy.

3. Analysis of urban population

The development of a city is always centred on people, so it is necessary to study the distribution of a city's population. In the course of the study, by using geo-detectors and applying geographically weighted regressions combined with demographic data provided by various parties, the spatial distribution of a city's population can be obtained. In Nanjing, China, for example, distance from the city centre is negatively correlated with the spatial distribution of the population, while the number of jobs, the mix of land use and the average house price is positively correlated with the spatial distribution of the population. However, when this aspect of distance from the city centre is examined in more detail, it is found that within a certain distance from the city centre, the residential population increases as the distance to the city centre increases, the major part of the reason for this is that housing prices in the city centre are so high that many people are willing to accept commuting further than is reasonable to reduce the cost of living [7]. This case demonstrates the need to take measures to keep housing prices within a reasonable range during urban development, and it will lead to a more rational distribution of population across the city.

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The production and living of urban residents generates a large amount of waste, which puts a great deal of pressure on the environment and needs to be disposed of properly. The time series cluster analysis by the K-mean algorithm can get the change of domestic waste removal volume over time in different cities in China, and it can be found that the domestic waste removal volume in most of the cities is increasing. Using the random forest regression model, the Mean Square Error MSE can be calculated based on the values obtained, and the factors with a large increase in MSE have a greater impact on the regression results, and hence are more significant for the model. It can be found that the built-up area and the number of people in the urban area have a high degree of influence on the amount of domestic waste transported in the urban area, while the influence of the factors might be different with the changes in the region [8].

Taking a comprehensive look at the distribution of the urban population and the corresponding amount of domestic waste can derive some inspiration for urban upgrading. In the construction of smart cities, it is necessary to plan the number of people expected to be accommodated in each area rationally, for example, keep a certain proportion of high-rise buildings and low-rise buildings in urban areas, reduce the density of buildings and ensure that low-rise buildings are the mainstay in suburban areas, while planning adequate parks in any area. It is also important to ensure that infrastructure is in place and that roads and undergrounds are built to shorten commuting times so that housing prices in different parts of the city are kept within reasonable limits. In this process, it is necessary to control the size of the built-up area, planning a certain area of green space as a buffer zone, so that the amount of rubbish in the area will not be too large to maintain the carrying capacity of the environment. Such planning can make the population density of the city more reasonable and liveable, thus promoting the improvement of the living standard of urban residents.

4. Urban energy and traffic management

Under the framework of building a smart city and against the backdrop of acquiring dynamic population information, the implementation of a smart energy management system is a crucial component to ensure the sustainable development of cities. Through the monitoring of urban energy consumption using population data models, particular attention is given to electricity, water resources, and renewable energy [9]. Leveraging smart energy systems, cities can monitor and analyse energy consumption in real-time, enabling more effective energy allocation, enhancing energy utilisation efficiency, and mitigating environmental burdens.

Currently, the smart energy management system, based on real-time monitoring of population data, has achieved standardisation in the realm of intelligent transportation. It optimises energy utilisation by comprehensively controlling urban traffic conditions. The key practices and methods of this system can be categorised into four main components: data sourcing and integration, real-time mobility monitoring, traffic signal optimisation and congestion prediction and route planning. The system relies on diverse data sources, including mobile devices, traffic cameras, and geomagnetic sensors, to capture real-time data on population movements and traffic conditions [9]. By establishing a standardised data integration platform, information from various sources is consolidated into a comprehensive urban traffic database. Advanced big data analytics techniques are employed to monitor the real-time movement of people within the city. Utilising location data from mobile devices and real-time images captured by traffic cameras, the system generates population density heat maps and real-time traffic flow diagrams. This information provides city managers with immediate insights into the current traffic conditions. The system leverages big data analytics results to intelligently adjust the traffic signal control systems at intersections. By analysing historical traffic data and real-time mobility information, the timing of traffic signals is dynamically adjusted to accommodate fluctuations in different time periods and traffic volumes. This real-time optimisation contributes to alleviating traffic congestion and improving intersection efficiency. Big data analysis is also applied

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to predict the likelihood of traffic congestion. Combining historical data with real-time information, the system can proactively identify potential congestion areas and provide warnings to drivers and city traffic managers. Additionally, intelligent route planning services based on real-time data assist drivers in selecting the optimal routes, reducing travel time [10].

These integrated practices and methods underscore the capability of the system to enhance urban mobility by providing accurate, real-time information and implementing data-driven strategies for traffic management. A notable example of a smart energy system is Copenhagen, Denmark [11]. By deploying smart meters, intelligent grids, and real-time monitoring systems, Copenhagen has successfully achieved a real-time balance in energy supply and demand. Urban planners can adjust electricity generation and distribution based on actual needs and weather forecasts, ensuring the satisfaction of the city's energy demand during peak periods while maximising the utilisation of renewable energy.

Copenhagen has effectively utilised devices such as smart meters and sensors to monitor the use of electricity and water resources in real-time, based on real-time energy data and population movement data. Through data analysis, the city can precisely understand peak and off-peak periods of energy consumption, optimising the energy supply chain accordingly and improving the efficiency of renewable energy utilisation. The smart grid monitoring in Copenhagen indicates that the city has achieved over 70% utilisation of renewable energy, with a significant increase in the share of wind and solar energy [11]. Guided by real-time data, the city is better able to integrate renewable energy into the power grid.

5. Application of internet technology in sustainable smart cities

Smart cities can be implemented with the use of modern information technologies, including Internet of Things (IoT) applications. Putting IoT to practical use in smart cities connects devices in homes and cities to the Internet and deploys many sensors in different places to collect and analyse data. In analysing IoT big data it is necessary to establish an architecture and implementation model and analyse it in layers. Vehicle traffic information, environmental pollution monitoring and security monitoring are included for smart cities. In vehicle traffic data analysis, the density of vehicles in each time period needs to be analysed by region to get the current traffic intensity. At this point the smart city can derive the optimal route and calculate the time required to make people's travelling more efficient and help the concerned government department to control the traffic. These methods can develop smart cities as well as provide ideas for urban planning by analysing simple IoT-based smart city datasets [12]. Taken together, the application of the Internet of Things (IoT) can bring great help to the operation of smart cities, which can collect and analyse real-time data more accurately and integrate a variety of devices. Thus the application can also realise the interconnection of everything, optimise all aspects of the city constantly, which forms a virtuous circle, thereby promoting the intelligence of the city and making it high-quality.

New smart city construction can be realised through IoT-based CIM City Intelligence Model platforms. The CIM can be obtained by combining IoT, BIM and GIS to collect and process urban data, while BIM is Building Information Modelling that is used in urban engineering and construction, and GIS is a Geographic Information System that can derive data on various aspects of the city through spatial and geographic coordinates. CIM-related technologies are being used in Suzhou, China. By collecting and analysing the temporal and spatial data of Suzhou, a multifaceted 3D data model can be constructed to guide the construction of a smart city, which makes the government more efficient and scientific in urban management and public services. The importance of sustainability also becomes prominent in such smart city designs. A sustainable smart city uses technology as a tool to address issues related to the 'people-environment-society-economy-culture' system, and centred on people. A sustainable design system for smart cities can be realised in four dimensions:

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management, space, resources and platform. Using these methods, combined with relevant data, a CIM information collection and processing model can be obtained to improve the sustainable development system of the smart city [13]. Therefore, modelling and processing big data through the Internet has become an important part of the construction of new smart cities. This allows data from all areas to be linked together so that problems can be identified and solutions can be optimised in a short period of time. At the same time, there is still a lot of room for improvement in this area as well. With the advancement of Internet technology and the updating of programming languages, data models can continue to be optimised and thus become more efficient and accurate, making the smart city smarter and have a higher level of development.

In addition to the Internet of Things (IoT) technology, 5G technology is gradually being applied to the construction of smart cities. 5G technology, as the fifth generation of mobile communication technology, offers higher bandwidth, lower latency, and greater connection density. It supports high-speed and reliable communication among a large number of IoT devices, enabling faster data transfer speeds, real-time monitoring, and decision-making. It better supports the intelligence of various aspects of the city by facilitating the connection of IoT devices on a large scale. Its advantages in environmental management and resource utilisation include more precise environmental monitoring, aiding in the prevention of natural disasters, optimising resource usage, and providing efficient communication infrastructure to drive innovation in energy management and environmental protection. Currently, Wuxi, China, serves as a successful example of a city utilising 5G technology, achieving intelligent optimisation of traffic signals and improving intersection traffic efficiency. However, challenges such as base station density, construction costs, security, and privacy issues associated with large-scale connectivity need to be addressed [14].

Furthermore, the application of Artificial Intelligence (AI) and machine learning in urban management, including data analysis, predictive modelling, and automated decision systems, enhances the intelligence of city operations, optimises resource allocation and services, and achieves more efficient traffic flow management, safety monitoring, and urban planning. However, scholars have pointed out that data privacy and ethical concerns require further discussion during implementation, particularly in handling massive urban data and ensuring privacy and security. Additionally, algorithm design and model training pose significant challenges in complex urban environments [15].

Edge computing, a method allowing real-time data processing near data sources to reduce transmission latency, finds widespread application in smart city construction. For city developers, it enables faster response times, especially for real-time decision-making applications, reduces reliance on central cloud servers, and enhances system stability. This approach, which reduces data transmission, significantly lowers energy consumption, making it an exemplary eco-friendly smart city technology. In Shanghai, China, for example, edge computing is used in intelligent traffic light control, enhancing the flexibility of signal regulation. However, the limited resources of edge devices necessitate addressing management issues related to computation and storage resources [16].

Lastly, blockchain technology, as a distributed and tamper-resistant data storage method, ensures the security and trustworthiness of data. In smart city construction, it provides decentralised data storage and management, enhancing data transparency and trust [17]. Dubai, UAE, has applied blockchain technology to improve land registration and real estate, increasing the transparency of environmental monitoring and carbon trading, preventing the tampering of environmental data, and facilitating the trade and management of renewable energy. Dubai has introduced blockchain technology in the real estate sector to enhance the transparency and efficiency of land registration [18]. By establishing a decentralised blockchain system, stakeholders such as real estate developers, government agencies, and financial institutions share a unified database, thereby reducing the risks of improper registration and disputes. This initiative has yielded significant advantages. Firstly, the

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improved transparency has clarified land ownership and transactions, thereby reducing the likelihood of disputes. Secondly, by eliminating intermediary steps, transaction speeds have greatly increased, accompanied by a corresponding reduction in associated costs. In terms of environmental management and resource utilisation, the digitisation of land registration has minimised paper usage, contributing to the city's progression towards a more environmentally sustainable direction [17].

However, the widespread adoption of this technology faces challenges related to standardisation and interoperability, necessitating collaborative efforts to establish and adhere to relevant standards. Additionally, the Dubai government actively promotes the blockchainisation of government services, encompassing areas such as identity authentication, health records, and education credentials [18]. The objectives of these applications include enhancing data security, reliability, and accessibility. The introduction of blockchain technology enhances data security, ensuring the privacy of personal information. Simultaneously, the digitisation of government service processes improves efficiency, providing citizens with faster and more convenient services. Nevertheless, overcoming challenges related to promotion and acceptance is necessary for the widespread adoption of these services.

Furthermore, Dubai has propelled the use of blockchain technology to optimise trade and logistics processes. By establishing a shared, decentralised trade platform, Dubai facilitates the efficient conduct of cross-border trade. In the realm of trade, the application of blockchain technology reduces fraud and disputes, enhancing the credibility of transactions [18]. In logistics, real-time, shared information aids in optimising the logistics process, reducing delivery times. These transformations also have positive implications for environmental management and resource utilisation. Blockchain technology assists in optimising the supply chain by tracking material sources and transportation processes, thereby reducing resource wastage. However, this application faces challenges, including issues related to international standardisation, necessitating the formulation of international standards to promote the cross-border application of blockchain [19].

In summary, Dubai's successful application of blockchain technology exemplifies an advanced level of smart city development. Despite encountering some challenges, these cases provide valuable experiences for other cities, encouraging more locations to engage in smart city construction and innovation.

6. Conclusion

Urban planning is a long-term process, often measured in years. Therefore, in the construction of smart cities, it is also possible to optimise the programme and propose new plans continuously, thus enabling the city to reach a higher level, and such ideas are present throughout the paper. This paper introduces and evaluates a variety of statistical methods for analysing urban data, analyses the problems of modern cities from a variety of perspectives, and provides recommendations for the construction of future smart cities on this basis. The upgrading of the city's industrial, architectural and transport planning, as well as the extensive use of renewable energies, can contribute to a higher quality of sustainable development while improving the urban environment. Additionally, through the combination of IoT, 5G, AI and machine learning, blockchain and big data technologies, urban infrastructure can be intelligently monitored and managed, and with the support of a large amount of data, analysis can be used to more accurately understand the use of information and the environmental situation of the city, so that it can be more targeted to the optimisation of the city [20]. In the era of the Internet and big data, the relevant technology should be widely used in combination with the actual situation of the city in all aspects based on the huge amount of data, and this is also the core of the smart city construction and development. Another important point is that smart cities are always people-centred, aiming to increase people's productivity, reduce commuting time and improve the living environment, thereby enhancing the quality of life for all. Sustainable smart cities will become mainstream in future urban regeneration and will be improved by local conditions, as well as

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promoting social development. In sustainable smart cities, high levels of economic development and environmental enhancement can be realised together.

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