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Application Research of Simulation Analysis Technology in the Construction of Smart City

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Abstract

Simulation analysis in smart cities is based on engineering and scientific issues, based on cybernetics, system theory, similar principles and information technology, and based on computers and various urban environment simulation software, fluid simulation software, and energy consumption simulation software as a tool, the mathematical model is used to simulate and analyze the light environment, thermal environment, acoustic environment, pollutant diffusion, traffic flow and evacuation of the entire city. The simulation analysis results have certain usability for the city's anticipated planning, design, and construction, and will directly affect the subsequent series of applications or decision-making processes.

Keywords: *smart city, simulation analysis, urban environment, mathematical model*

1. Introduction

The construction of smart cities has accumulated massive amounts of urban real-time operation and management data. However, judging from the status quo of urban management, many aspects of urban management are still at the stage of traditional experience, without complete basic data, lack of regular quantitative analysis and a sound dynamic management system, lack of comprehensive system analysis of the entire city. For many hidden dangers and problems, especially the unsystematic integration of resources involving different fields or related industries, and the lack of information-based auxiliary decision-making support methods to predict their development trends, etc., this has resulted in the industry data separation and information a series of problems such as fragmentation.

Simulation technology is based on similar principles, control theory, computer technology, information technology and professional technology in its application fields, using computers and various physical effect equipment as tools. Simulation technology is a comprehensive technology that uses system models to conduct dynamic experimental research on real or imagined systems. At present, most simulations are digital simulations, that is, computer simulations. With the improvement of computer computing power, the continuous development of simulation technology itself and the deepening of people's understanding of the application value of simulation technology, the application fields of simulation technology are becoming more and more extensive. Smart city simulation is one of the important branches. The application of simulation analysis technology guarantees the construction effect of the whole life cycle of the smart city.

The application of simulation technology in smart city construction mainly includes generating large-scale urban models; establishing or rebuilding urban landscapes and urban facilities; visual analysis of urban and environmental planning, etc.

There are two mainstream applications of simulation technology in smart city design: one is to focus on the city's three-dimensional visual simulation, which mainly realizes real-time roaming, multi-scheme comparison, and real-time adjustment of smart city design elements. It is useful for smart city design. The improvement of communication methods and means is of greater significance. Its greatest advantage is that it has a better visual effect, but its integration with information systems is weak. The other type is the city simulation system mainly based on the traditional geographic information system. Its biggest advantage is that it can be closely integrated with the geographic information system and facilitate the realization of various GIS practical functions in a three-dimensional virtual environment, but the visual effect is poor.

At present, the main development trends of smart city design simulation and visualization technology are mainly the following aspects:

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(1) Improve the technical simulation system and easy to use.

Although the desktop computer system itself is already fast, it still cannot provide high-quality images that can be easily used. Even with the fastest computer, we need to spend time waiting. Relevant planning departments conduct reviews, and urban planning departments with the latest GIS systems prefer to integrate modeling and visualization projects. At the same time, there is a lack of modeling and simulation software with intuitive and easy-to-use interfaces, because only in this way can practitioners use these technologies without difficulty. Therefore, improving the technology and simplicity of the simulation system will be a problem that needs to be studied and solved for a long time in the future.

(2) Systematic research of technology application.

The smart city simulation system is a complex giant system that integrates multiple technologies. It needs to integrate multiple subsystems such as a three-dimensional visualization system, a city analysis model system, a city information system, and a smart city design decision support system. It is very difficult to create and complete a model that is close to the real state and has actual predictive value. In the smart city simulation system, not only the system integration technology has major problems, but also the technical problems within each subsystem. For example, the collection and management of massive data, database connection technology, database management, model library technology, integration technology of model library system and urban geographic information system, computer expression of expert knowledge, and a series of problems.

(3) Research on reusability of urban analysis model and model design standardization.

The analysis model is an abstraction of the analysis method and operation process used to solve a certain problem. It can be used to solve similar problems or provide references for similar problems. There are some frequently encountered problems in smart city design. Establishing corresponding application analysis models and analysis research methods for these problems can improve the scientific of analysis and decision-making and reduce repetitive work. Currently, the establishment of smart city design models is still in the research and exploration stage. Many analysis models have not been fully realized, and the application of models is not popular enough, and a standardized and serialized city model system has not been formed. At the same time, if the city model leaves the computer, it is only a theoretical mathematical model. Due to the huge amount of calculation, it is unlikely to be applied to the actual planning and design process and some models cannot be solved without the computer.

Figure 1-1 Simulation technology research and service system

2. Urban environment simulation analysis

2.1 Simulation analysis of urban heat island

Compared with traditional research methods, smart city simulation technology saves a lot of manpower and material resources. It can also complete experiments that cannot be done by traditional methods and fill in the blank areas of previous research methods. By using simulation technology to simulate the urban thermal environment under typical urban working conditions, we have a deeper understanding of a series of climatic factors such as the cause and distribution of the urban heat island effect and the wind speed, temperature, radiation temperature and atmospheric pressure which are closely related to the urban thermal environment. Using this research method, we can propose better solutions to improve the urban heat island effect and improve thermal comfort, and introduce such research methods into urban planning, and formulate corresponding urban climate environmental design guidelines for cities with different regions and climate characteristics. Furthermore, corresponding suggestions are made on the urban spatial distribution, ventilation corridors, park green space layout, etc., to provide reference opinions for the urban planning management department. Because numerical simulation can directly observe certain properties and phenomena, and can quickly obtain results under given conditions, it can be used for further evaluation and analysis of wind speed, temperature, atmospheric pressure, and other climatic factors that are closely related to the urban heat island effect. Through sensitivity experiments under different conditions, it is possible to quantitatively evaluate the magnitude of a single index change on the urban heat island effect and propose better and more reasonable solutions.

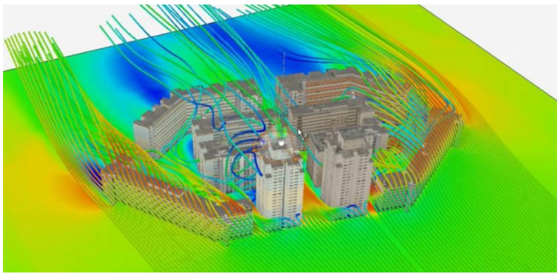

Figure 2-1 City wind speed map (changes with altitude)

2.2 Urban noise simulation analysis

Establish an urban noise simulation analysis model and use the Internet and the Internet of Things to link data with noise sources during urban operation, real-time transfer of noise impact information points that may be generated during urban operation and form an urban noise environmental assessment analysis auxiliary control management information platform. Realize the visualization of urban noise release, prediction, evaluation, and influence service cloud. The cloud can realize data collection, planning and design forecast evaluation, information release, and noise pollution control functions.

Establish a basic research model of urban noise simulation and collect and sort out the data from the urban noise simulation analysis model. Incorporate noise control technology methods, sound insulation structures for traffic noise, sound insulation structures for industrial areas, sound insulation structures for cultural, sports and entertainment, and sound insulation for green belts into the simulation research laboratory to conduct optimization research on urban noise control measures. Form a basic database and a simulation innovation research and development center. Provide forward-looking technical strategies for urban planning and design, urban environmental impact assessment, urban traffic management, urban environmental pollution control, and future urban construction and development.

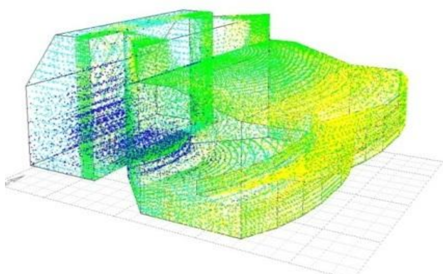

Figure 2-2 Urban noise analysis

2.3 City energy consumption simulation analysis

The main purpose of smart city building energy consumption simulation analysis is to achieve a comfortable and healthy optimal indoor environment with the lowest energy consumption. Use building energy analysis software to simulate and analyze the building thermal environment to obtain total building energy consumption: system energy consumption (including air conditioning, lighting, hot water, office, and equipment, etc.), indoor air comfort, carbon dioxide emissions, system capacity, temperature distribution, monthly thermal comfort, and other thermal performance parameters. By interpreting these simulation analysis results, the designer can understand and master the main thermal performance of the building, and on this basis, various comparisons and optimizations of the design plan can be made to arrive at the best plan. To improve the thermal environment of the building through architectural design methods. Through the comparative analysis of multiple schemes, the energy consumption, hourly heat gain and economic cost of the buildings under each scheme are obtained, and the most suitable urban building scheme is determined with consideration of economy and energy saving.

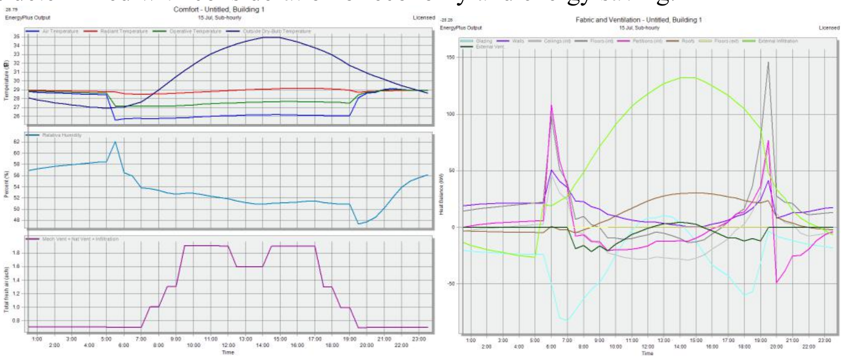

Figure 2-3 (a) Simulation analysis of building thermal comfort
Figure 2-3(b) Simulation analysis of building heat balance

Building energy simulation analysis mainly includes three items: building energy structure analysis, building hourly energy consumption analysis, and energy saving potential analysis. Specific implementation technical indicators include comprehensive energy consumption (CEC) analysis, unit output/value energy consumption analysis (UOP/UOV), carbon emission (CE) analysis, unit output/value carbon emission analysis (CEUOP/CEUOV).

a) Analysis of building energy consumption structure: Building energy consumption mainly includes air conditioning system energy consumption, lighting system energy consumption, domestic hot water system, equipment system energy consumption, etc. It focuses on the energy consumption of various parts of the air conditioning system, including the energy consumption of cold and hot water units, cooling (freezing) water pumps, cooling towers and terminal equipment, and compares and analyzes the proportion of each energy consumption to the total energy consumption and optimization potential.

b) Hourly energy consumption analysis of buildings: The simulation analysis results show the energy consumption of each system of office buildings in winter and summer year by year (month by month, day by day), analyze the law of energy consumption distribution, and formulate more reasonable equipment operating hours.

c) Energy-saving potential analysis: Air-conditioning, lighting and equipment constitute the three major energy consumption systems of the building. According to the analysis of the annual operation records of the air-conditioning system and other energy-consuming equipment and other relevant data, it is found that the air-conditioning system has great energy-saving potential in the design, operation and management, mainly including office building envelope insulation materials and air-conditioning system forms , Air conditioning temperature, operating mode, constant/variable flow pump and cooling and heating source matching performance parameters optimization.

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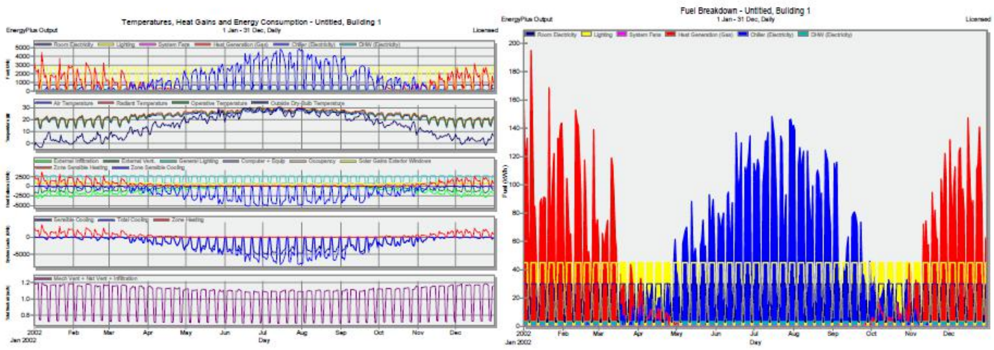

Figure 2-4 (a) Temporary monthly simulation analysis results
Figure 2-4 (b) The simulation analysis results of monthly total forecast of buildings

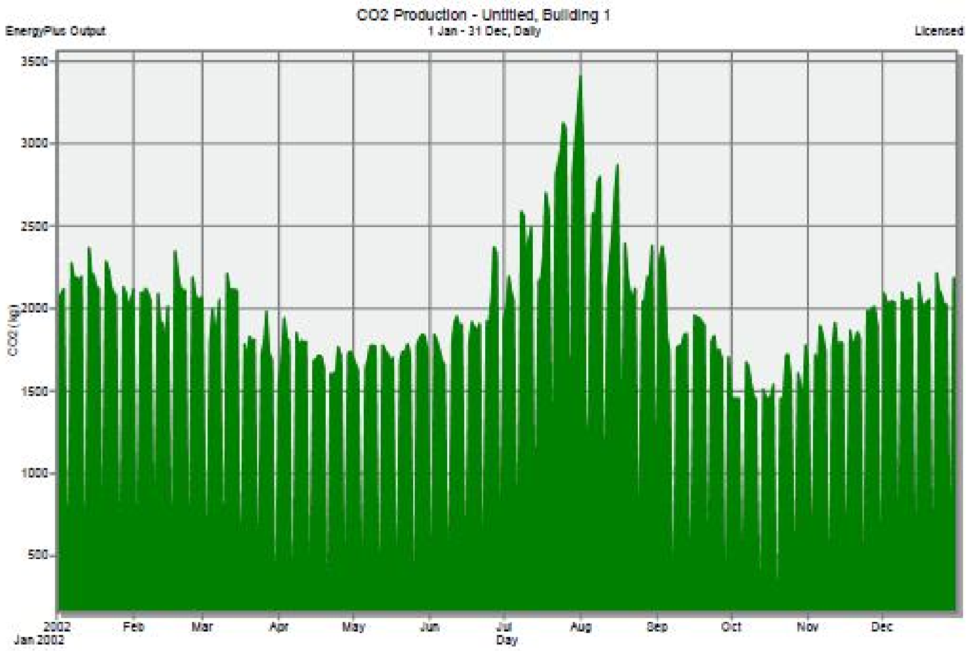

Figure 2-5 Simulation analysis results of monthly CO2 emissions from buildings

The energy metering center is used as the data support for building energy consumption design simulation and building energy consumption simulation software is used as a calculation tool, and finally the building energy consumption design simulation and visualization are realized. At the same time, it provides energy users and cities with actual energy consumption status and comprehensive energy consumption indicators to achieve urban energy consumption reduction and efficiency increase, and to improve energy measurement and energy conservation management.

2.4 Simulation analysis of urban wind farm environment

With the rapid development of cities in our country, the scale of cities is getting larger and larger, and the problem of urban wind farms is becoming increasingly prominent. The wind environment outside the building involves the safety and comfort of pedestrians, residential climate, residents' health, green buildings and energy conservation, the diffusion of pollutants, and air self-purification. Therefore, the research on the outdoor wind environment of buildings becomes more and more important. The research of smart city wind environment is based on CFD simulation and visualization technology.

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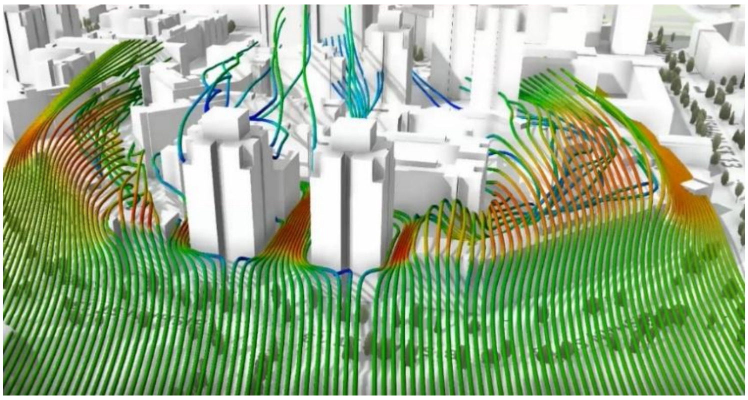

Figure 2-6 Simulation analysis of urban wind environment

2.5 Simulation analysis of urban underground space disaster prevention system

Emergency rescue for underground space disasters is a highly professional work. Experiences at home and abroad have shown that, compared with ground rescue, effective command and management can play a very crucial role in the full utilization of emergency rescue effectiveness in large underground spaces. Using advanced virtual simulation visualization technology, it can provide emergency rescuers with a drill environment very similar to the real disaster scene in the complex underground space. On the one hand, this kind of exercise environment is very close to the real world, so that the trainees can get a real experience in terms of sight, hearing, and touch. Emergency management personnel can be immersed in this kind of drill environment and receive a full range of exercises similar to actual combat, such as vision, hearing, touch, and command, thereby improving the effectiveness of the drill. On the other hand, virtual simulation visualization technology can construct many virtual environments beyond the real world.

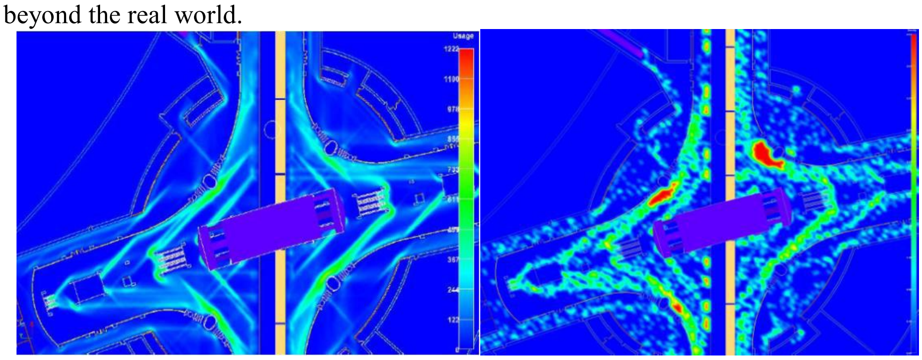

Figure 2-7 Distribution of personnel in an emergency

Figure 2-8 Fire simulation analysis

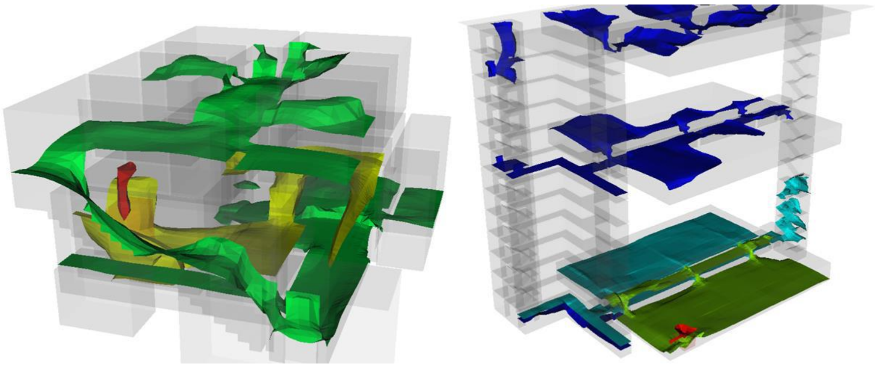

Figure 2-9 Smoke analysis

2.6 Simulation analysis of urban emergency evacuation

With the gradual increase of large and complex structures in the city, due to the particularity of the building structure, the complexity of the use of functions, the installation and use of various functional equipment, and the large area gathering of people, the factors and possibilities of building fire accidents have increased significantly, and fire hazards have become increasingly serious. Due to the suddenness, randomness and uncertainty of major disasters or emergency accidents, as well as the randomness and fuzzy nature of personnel behavior, it is very difficult to conduct quantitative analysis and experimental simulation of personnel emergency evacuation behavior. With the development of computer technology, simulation using computers has become an important tool for fire research.

When disasters such as fires and earthquakes occur, densely populated cities become the most threatened places. The functions and structures of high-rise and comprehensive buildings are becoming more complicated. Therefore, how to improve the ability of such public buildings to defend against emergencies is an important topic in the field of urban earthquake prevention and disaster reduction. Through computer simulation, different prediction models can be used to predict the evacuation start time, evacuation action time and available safe evacuation time. The process of visual simulation provides an intuitive evaluation basis and provides more accurate and intuitive information for performance-based evacuation design and performance-based fire protection design. The fire department can use simulation software to evaluate the evacuation performance of various types of buildings, combined with the design of the road network around the building, quickly disperse the internal population and traffic to a safe area, and help the relevant departments in urban construction and urban disaster prevention planning provides scientific basis.

Based on computer simulation technology, the combination of STEPS, building EXODUS, CFD and SMARTFIRE software can simulate the emergency situations in various buildings, tunnels, and other environments in the city. With personnel evacuation dynamics as the core of calculation, calculation methods such as optimization models, simulation models, and risk assessment models are established.

Set up fire scenes, describe fire events and obtain building information to construct fire sites, set fire sources and related parameters, set material performance parameters and indoor home components information in the fire site, and simulate output fire temperature field, velocity field and the type and concentration of fire gas, then assess the fire hazard, and formulate fire safety measures. By studying the impact of roads, building spacing, layout, number of evacuation openings, location and width in fire, the simulation can find out the shortcomings in building and road network design in advance, and further, provide technical support for planning design, architectural design, and fire protection design.

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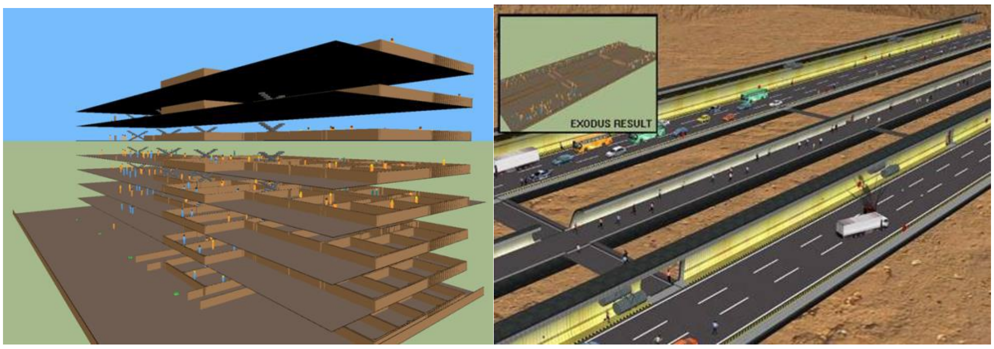

Figure 2-10 Evacuation model

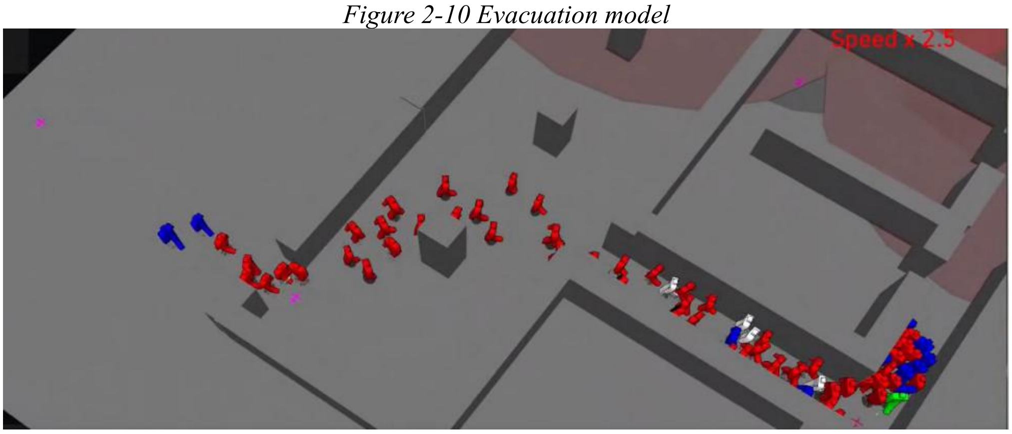

Figure 2-11 Analysis of the evacuation plan

3. Conclusion

The complexity of planning, design, and construction of smart city construction and the unverifiable nature of actual practice require that the simulation and visualization of smart city design and operation must be strengthened in the information world. The massive basic data accumulated in the construction of smart cities provides a data source for the development of urban planning and design simulation analysis. At present, the application of smart city simulation is in its infancy in China, but it is undoubtedly the most valuable research direction in the process of smart city construction. At the same time, it is also the key to solving the problem of model reusability and ensuring standardized simulation.

The existing modeling and simulation work are basically to establish specific simulation models for specific problems. Researchers often use specific simulation methods for specific models, and even use certain simplified methods and techniques to build simulation models, but rarely consider the versatility and reusability of simulation models. In the implementation of smart city simulation, due to factors such as the software itself and the knowledge and experience of the operator, the simulation results will vary greatly, and the credibility of the simulation is difficult to guarantee. The accuracy and research depth of simulation models built for different functional requirements are uneven, and they lack uniform standards and specifications.

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