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Fire Risk Assessment and Emergency Route Decision Analysis Based on Big Data Platform—Example of Huizhou

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***Keywords* — Gaode Big Data Platform; Fire Risk Assessment; Emergency Route Decision Analysis; Analytic Hierarchy Process (AHP); Python**

Abstract — *With the process of urbanization, the frequency of fires is gradually increasing, and fire emergency work has become particularly important. This paper takes Huizhou City as an example and conducts a fire risk assessment based on the various conditions of the city using the Gaode big data platform. The analysis shows that the low-risk area within the Fourth Ring Road in Huicheng District is about 91.8%, the medium-risk area is about 6.72%, the secondary high-risk area is about 1.16%, and the high-risk area is about 0.31%. Meanwhile, we use Python code to calculate the decision analysis plan for fire emergency route selection. By collecting data on fire site locations, fire stations, and hospitals, combined with dynamic information such as road conditions and traffic flow, and utilizing the functions of the Gaode big data platform, route calculation and optimal path selection are carried out. This method will improve the efficiency of fire emergency response, reduce rescue time, and provide better assistance to the affected population.*

I. INTRODUCTION

Fire is a common natural disaster that poses a huge threat to the safety of people's lives and property. With the process of urbanization, the large gathering of population and buildings, and the increasing complexity of various conditions, the risk rate of urban fires is also gradually increasing. At the same time, it also increases the number of fire risk factors and the difficulty of fire prevention and control (Hao et al., 2023). For example, in 2021, China reported approximately 7,480,000 fires, with 1987 deaths and 2225 injuries, resulting in direct property damage exceeding 6.75 billion yuan (NFRA online, 2022). This threat is very serious in densely populated areas such as commercial and residential communities, so it is necessary to assess and control fire risks and improve urban fire safety. In order to maintain the fire safety of the city and reduce the harm of fire hazards, it is necessary to have an urban fire risk assessment and emergency strategy preparation. The former belongs to pre-assessment and preparation, and early understanding of the areas where risks may occur is necessary to plan and construct various basic disaster prevention facilities in order to understand where risks exist, what kind of risks, how to respond, and how to improve early management thinking. The latter considers how to deal with, evaluate, and prepare emergency measures in the event of a fire. Both thinking styles are indispensable and crucial for the decision-making and analysis of fire emergency measures.

Firstly, fire risk assessment is a fundamental means of identifying, analyzing, and evaluating the magnitude of fire risks through scientific methods to reduce and control fire consequences. It is an important component of fire science research (Fu, 2021) and a fundamental decision-making tool in the field of risk control and safety management. It provides potential risk information before a fire event occurs (Gao et al., 2023). Urban fire risk assessment is an important research topic that supports the scientific formulation of urban fire safety special planning and the refined management of fire safety. Urban fire risk assessment is an evolution of fire risk assessment in the fire protection profession, officially proposed by the national standard "Urban Fire Planning Specification" and identified as an important component of urban fire planning. The evaluation methods can generally be divided into three categories: qualitative, semi-quantitative, and quantitative (Zhang et al., 2006; Wei, 2019). At present, most cities in China use the qualitative evaluation method of "urban land classification and fire risk zoning" for fire risk assessment (Zhang, 2020), and some cities use the indicators selected by the evaluation index system research institute. Its purpose is to determine the relative fire risk in a city or a certain area of the city, establish the distribution of fires in the city area, and assist the government and fire departments in analyzing the current situation of fires. Meanwhile, it is to determine fire risks and acceptable levels, allocate fire rescue forces reasonably based on fire safety concerns and cost-benefit analysis, and guide urban fire system transformation and urban fire planning, ultimately reducing the level of fire risk in urban areas (Zhang et al., 2006). The technology of fire risk assessment in urban areas will promote more scientific and reasonable fire decision-making.

The traditional fire risk assessment mainly includes establishing an evaluation index system, determining indicator weights, and determining the fire risk level (Fu, 2021). Nevertheless, it involves many factors, and the sources of acquisition are complex, making it very difficult to accurately present its specific benefits. It is also often influenced by subjective and objective factors (Ketsakorn and Phangchandha, 2023). Currently, research on urban fire risk assessment often focuses on identifying key factors and evaluating models. The shortcomings of existing research are mainly reflected in data collection, indicator selection, and model selection (Hao et al., 2023). With the development of big data platforms and AI cloud computing, timely and dynamic evaluation methodologies are bound to usher in more cost-effective development prospects. This article attempts to collect Point of Interest (POI) data on fire risk sources, urban characteristics, and social prevention and control through Python, based on the background of Gaode big data. And combine the weight attribute value grading of YAHHP software to establish a risk assessment that is different from traditional methods. At the same time, use GIS visualization tools to present the level assessment classification and distribution of urban fire risk.

Secondly, in the management of urban fires, another important issue is how to quickly and accurately choose the best emergency path after a fire occurs, effectively and quickly eliminate the fire, and carry out personnel rescue, which is an important link to ensuring the safety of people's lives and property. With the rapid development of big data technology, the decision analysis of fire emergency route selection has gradually attracted the attention of academia and engineering practice.

In previous studies, the selection of fire emergency routes mainly relied on experience and manual judgment, which have certain limitations. With the rapid development of big data technology, the rich data resources provided by the Gaode big data platform can be utilized, combined with decision analysis methods, to solve the problems encountered in fire emergency route selection. It is an innovative combination of technology and thinking. The Gaode big data platform has timely and dynamic data on road information, traffic flow, pedestrian flow, and other information across the country. The analysis and mining of these data will provide more accurate and realistic decision support.

Based on the above perspectives, the main purpose of this study is to explore how to utilize the diverse, timely, dynamic, and abundant data sources provided by big data platforms. Through Python programming tools, the decision analysis method for fire emergency route selection, the establishment of fire risk assessment, and the level distribution range were explored. Taking Huicheng District in Huizhou as an example, it is hoped that through the application of this method, accurate risk management mechanisms can be established in daily life. When disasters occur, it can effectively improve the efficiency of fire emergency rescue and reduce rescue time, providing timely and effective assistance to the affected population.

II. STUDY AREA AND DATA SOURCES

2.1 Study Area

Huicheng District, under the jurisdiction of Huizhou City, Guangdong Province, is located in the middle and lower reaches of the Dongjiang River and the eastern part of the Pearl River Delta, with a total area of 1170.6 square kilometers. The development intensity is low, especially in the northern mountainous areas, which are basically undeveloped. It is jurisdiction over 10 streets, 8 towns, and 3 township-level units. As of November 2020, the permanent population of Huicheng District was 1.559 million. The population density in 2021 is 1347 people/square kilometer, ranking at the middle level of the Greater Bay Area (26th). Generally speaking, the population density of livable cities is generally 1000 to 3000 people per square kilometer, with over 4000 people belonging to high-density cities. It can be seen that Huicheng District is a livable city with an average annual temperature of 22.5 °C, which is consistent with the same period of the year (1991–2020). The annual extreme minimum temperature of 4.5 °C occurred on February 21st. The annual extreme maximum temperature is 38.7 °C.

Huicheng District has a good transportation location advantage. To the north is Heyuan City, and to the southwest are Dongguan and Shenzhen City. It is the hub gateway of the Greater Bay Area, connecting eastern Guangdong, northern Guangdong, and the Fujian Jiangxi region. Within the jurisdiction, there are 6 expressways, 2 high-speed railways, 2 urban rails, and the Beijing Kowloon Railway passing through the area. Pingtan Airport and Huizhou Port are within easy reach, and the three-dimensional transportation network of sea, land, and air is accessible in all directions. It takes 30 minutes to directly reach Guangzhou and Shenzhen, fully integrating into the one-hour living circle of the Greater Bay Area. Compared with other counties and districts in the Greater

Bay Area, it has the position and advantages of an important transportation hub in the eastern part of the Greater Bay Area.

The tertiary industrial structure of Huicheng District is 3.4: 29.4: 67.1. In recent years, it has continuously promoted industrial development and continuously optimized the industrial structure, and the commercial and trade industries are large but not strong. The proportion of modern service industries is not high, and traditional service industries such as wholesale and retail are still the main ones. The level of public service facility investment and construction is constantly improving. The proportion of infrastructure investment in fixed asset investments will rise from 24.83% to 28.13% in 2022. The city's energy level is constantly rising. It is high time to give full play to the advantages of the central city, gather talents from all sides, and build a regional consumption center.

The analysis scope of this study is within the Fourth Ring Road area of Huicheng District, Huizhou City (enclosed by the Guanglong Expressway, Jiguang Expressway, and Changsheng Expressway) (Figure 1), which is an important dense area and main activity area of the city. It also shows that its potential risks are significant and worthy of attention.

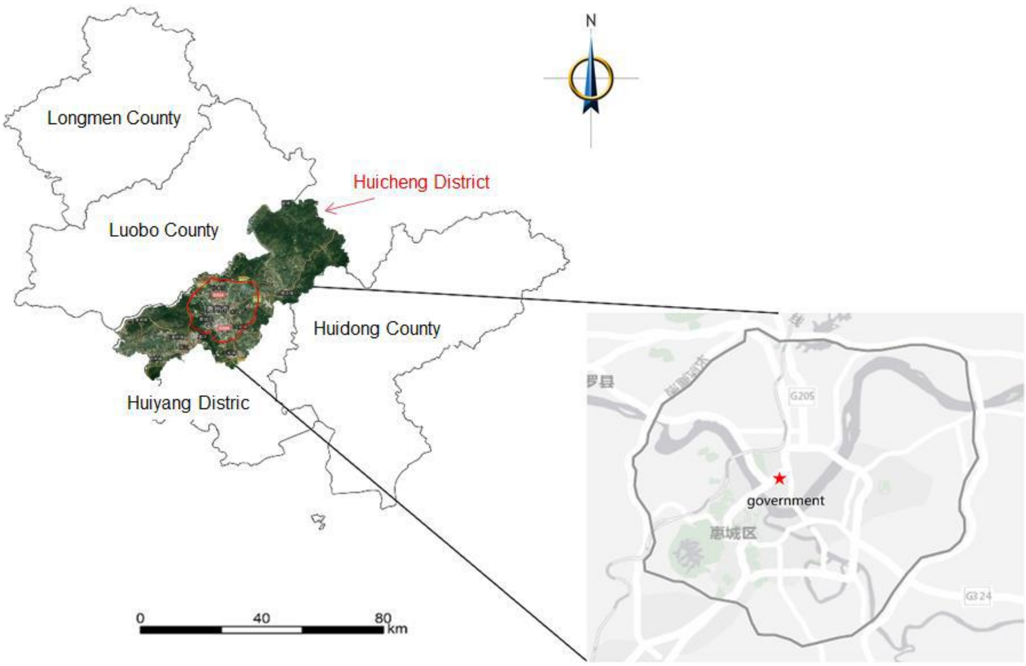

Fig.1 Study Area Scope Map of Huicheng District, Huizhou

III. MATERIALS AND METHODS

3.1 Data Acquisition

This study called the request module through Python 3.8 to collect POI information data from the Gaode big data platform. Based on the research purpose, obtain POI data from three major categories: fire risk sources, urban characteristics, and social prevention and control. Among them are: fire risk sources encompassing large gas facilities, gas stations, and flammability; urban characteristics encompassing population density and fire rescue efficiency; and social prevention and control encompassing medical institutions..

3.2 Methods

The concept of this study is mainly based on the application of the Gaode big data platform. Firstly, the AHP method is used to construct a hierarchical structure and assign weights using Yaahp software in order to obtain the fire risk level distribution map of Huizhou Huicheng

District and establish a decision-making and control knowledge map for urban fire management. Secondly, the decision support route selection scheme for emergency rescue resources and handling in case of fire is carried out through Python algorithms. By coupling the two, a decision-making framework for the urban fire emergency decision-making system can be established (Figure 2).

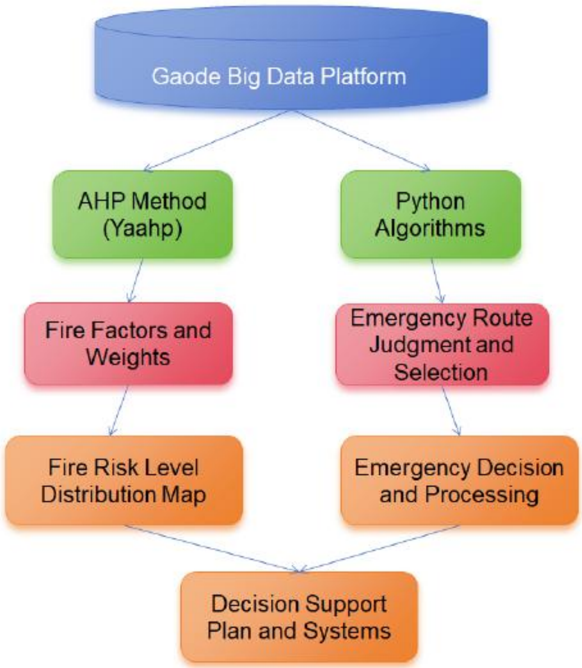

Fig.2 The Decision-making Framework of This Study

3.2.1. Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) refers to a decision-making method that decomposes elements that are always related to decision-making into levels such as goals, criteria, and solutions and conducts qualitative and quantitative analysis on this basis. This method is a hierarchical weight decision analysis method proposed by American operations researcher Professor Saaty from the University of Pittsburgh in the early 1970s, applying network system theory and multi-objective comprehensive evaluation methods to the study of "power distribution based on the contribution of various industrial sectors to national welfare" for the US Department of Defense (Alrawad et al., 2023).

The AHP decomposes decision-making problems into different hierarchical structures in the order of overall objectives, sub-objectives at each level, evaluation criteria, and specific alternative investment plans. Then, by solving the eigenvectors of the judgment matrix, the priority weights of each element at each level to a certain element at the previous level are obtained. Finally, the weighted sum method is used to gradually merge the final weights of each alternative plan into the overall objective. The one with the highest final weight is the optimal solution (Figure 3).

This study uses Yaahp (Yet Another AHP) software for the processing and construction of the analytical hierarchy process. It is AHP software designed by Beijing Xinshengyun Software Technology Co., Ltd. This software provides convenient functions such as hierarchical model construction, judgment matrix data input, sorting weight calculation, and calculation data export. The design goal is that users only need to have preliminary knowledge of the AHP and do not need to understand various details of AHP calculations in order to make decisions using the AHP. Using Yaahp to assist decision-making, users only need to pay attention to the decision-making problem itself. With the model construction function provided by the software, they can organize their ideas and complete a hierarchical model of the decision-making problem. Then, Yaahp is used to fill in the pairwise comparison data in the judgment matrix. The software automatically calculates the ranking weights of various decision-making schemes based on the hierarchical model and judgment matrix.

3.2.2 Python

Python was designed in the early 1990s by Gido van Rossum of the National Center for Mathematics and Computer Science in the Netherlands as an alternative to the language ABC. Python provides efficient, advanced data structures as well as simple and effective object-oriented programming. Python syntax and dynamic typing, as well as the nature of interpretive languages, make it the programming language for writing scripts and rapidly developing applications on most platforms.

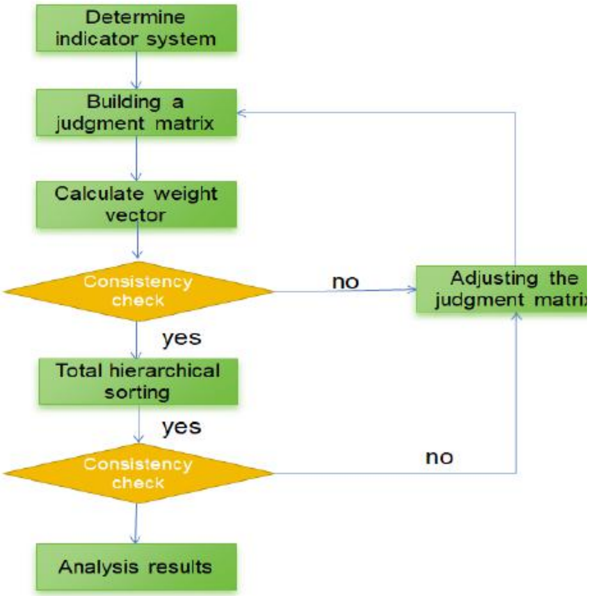

Fig.3 Process Flow of Processing Program Judgment by AHP

What can Python do? With the advent of the AI era, the Python language can provide diverse applications such as web development, web crawlers, data science, automated operations and maintenance, database programming, network programming, graphic processing, mathematical processing, text processing, multimedia applications, artificial intelligence, and automated testing. Among them are the Internet of Things and robot control. Web development can be combined with Python, HTML, CSS, JavaScript, databases, and other applications to develop a website. In addition, data science includes machine learning, data analysis, and data visualization. In addition, Python can be used for machine learning, which can research artificial intelligence (AI), robotics, language recognition, image recognition, natural language processing, expert systems (ES), as well as data analysis and visualization.

This study is based on the data source of the big data platform, using Python as a tool to form a decision support rule program, combined with dynamic and timely data, to form a judgment decision plan, and using GIS as a visual display tool to generate emergency decision-making (Li and Wang, 2023) (Figure 4).

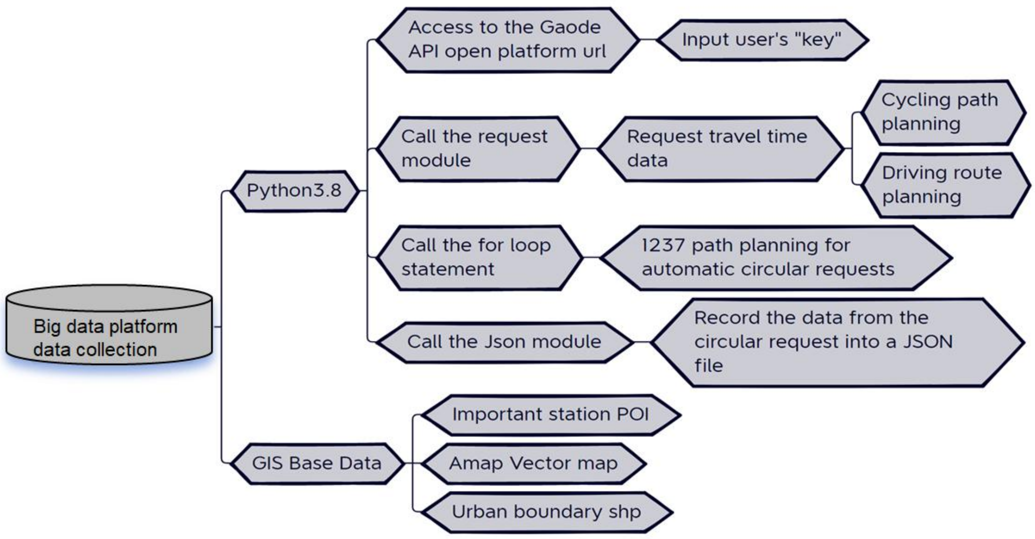

Fig.4 Python and GIS base processing

3.2.3 Algorithms Construction

This study uses the Python language as a tool, based on the decision support concept of event occurrence, to simulate and think about the handling methods when a fire occurs. Firstly, based on the data content of big data, search for nearby fire stations and calculate the distance, time, road conditions, traffic flow, traffic lights, and other related conditions between the stations and the event location to find the optimal fire station and time path. Provide a fire brigade to arrive at the scene as soon as possible for rescue. If a wounded person needs to be rescued, the search and condition calculation of the hospital site must also consider various dynamic conditions of path selection to improve the efficiency of rescue (Figure 5).

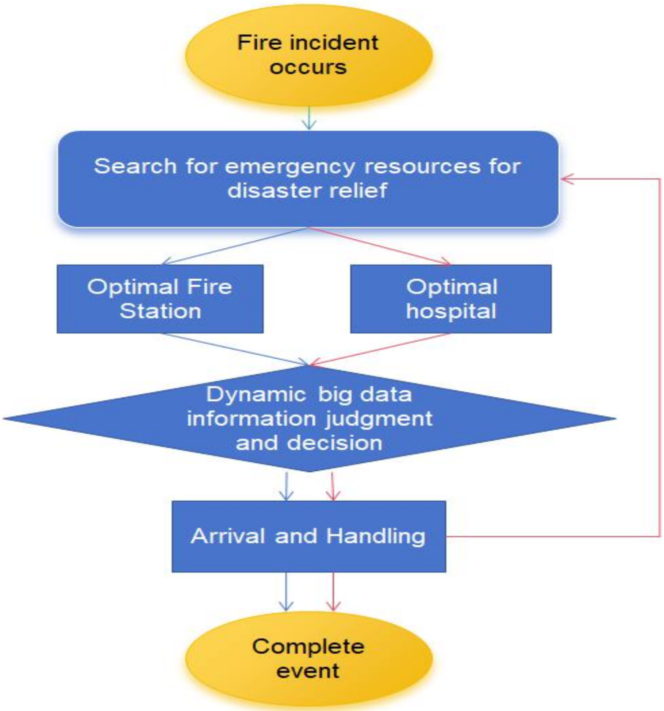

Fig.5 Thinking Process for Emergency Decision-making

IV. ANALYSIS AND RESULTS

4.1 Fire Risk Level Assessment

4.1.1 AHP Analysis

This study use Yaahp software to evaluate and grade the POI data of three major categories, including fire risk sources, urban characteristics, and social prevention and control, as well as six subcategory indicators (such as large gas facilities, gas stations, flammability, population density, fire rescue efficiency, and medical institutions) (Figure 6), and establish weight values (Figure 7), which are 0.178, 0.022, 0.052, 0.106, 0.2, and 0.041, respectively. And using GIS buffer analysis, point density analysis, and grading based on element weight attribute values, the impact of each element on fire risk assessment can be visually displayed in the grid through color separation (Figure 8).

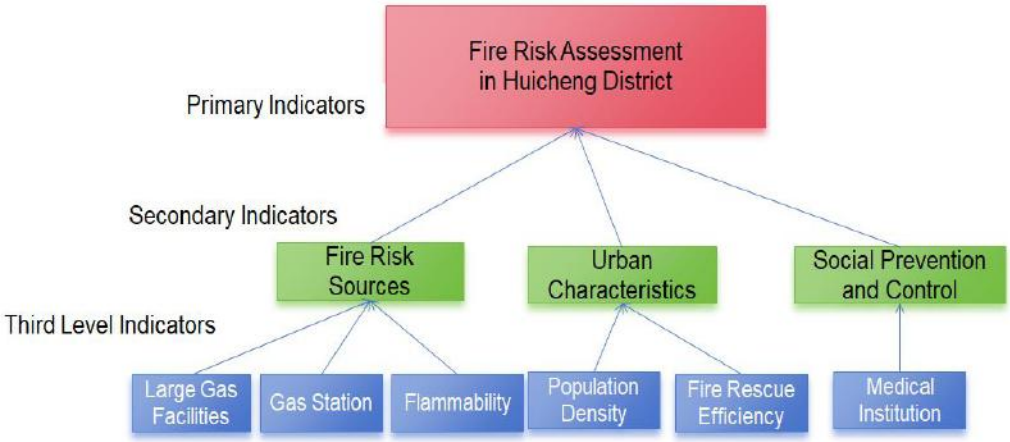

Fig.6 Index Evaluations for AHP Analysis

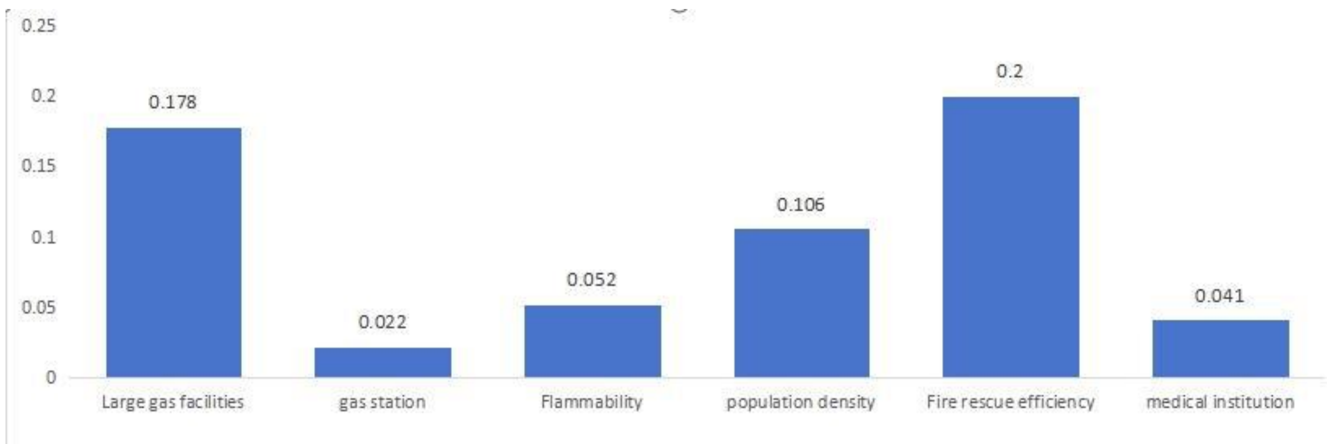

Fig.7 Indicator Weight Table by Yaahp

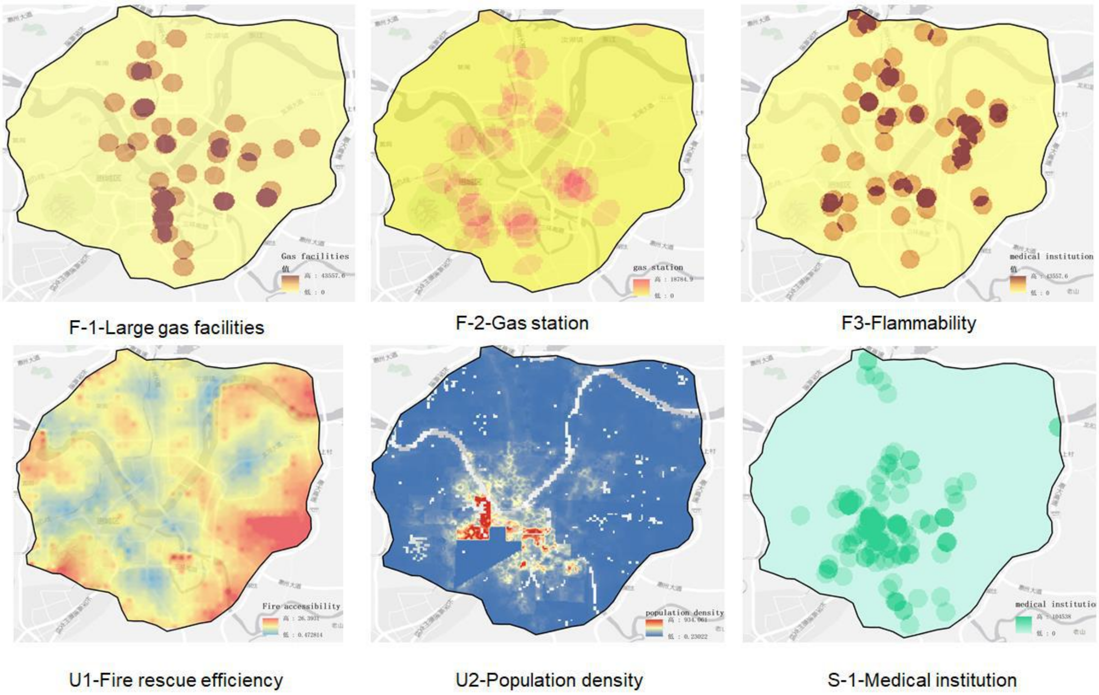

Fig.8: Evaluation and Grading Status of Six Subclass Indicators

Note: F-2, F-2, F3 are Fire Risk Sources; U-1, U2 are Urban Characteristics; S-1 is Social Prevention and Control

4.1.2 Risk Level Classification and Visualization

After overlaying the above three-level indicator data, ArcGIS software is used to classify the evaluation results into four levels: low-risk, medium-risk, secondary high-risk, and high-risk. The evaluation results are combined with GIS for visual display. Finally, based on the comprehensive calculation results of fire risks in each sub-region, the fire risks of each evaluation grid unit in Huicheng District are divided into four levels to demonstrate their spatial distribution patterns (Figure 9).

According to statistics, about 91.8% of the low-risk area, 6.72% of the medium-risk area, 1.16% of the secondary high-risk area, and 0.31% of the high-risk area are within the Fourth Ring Road in Huicheng District. Based on the visualized spatial distribution pattern, the secondary high-risk areas and high-risk areas are mainly concentrated in Henan-An Street, and there are also some secondary high-risk areas in Jiangbei Street and Shuikou Street.

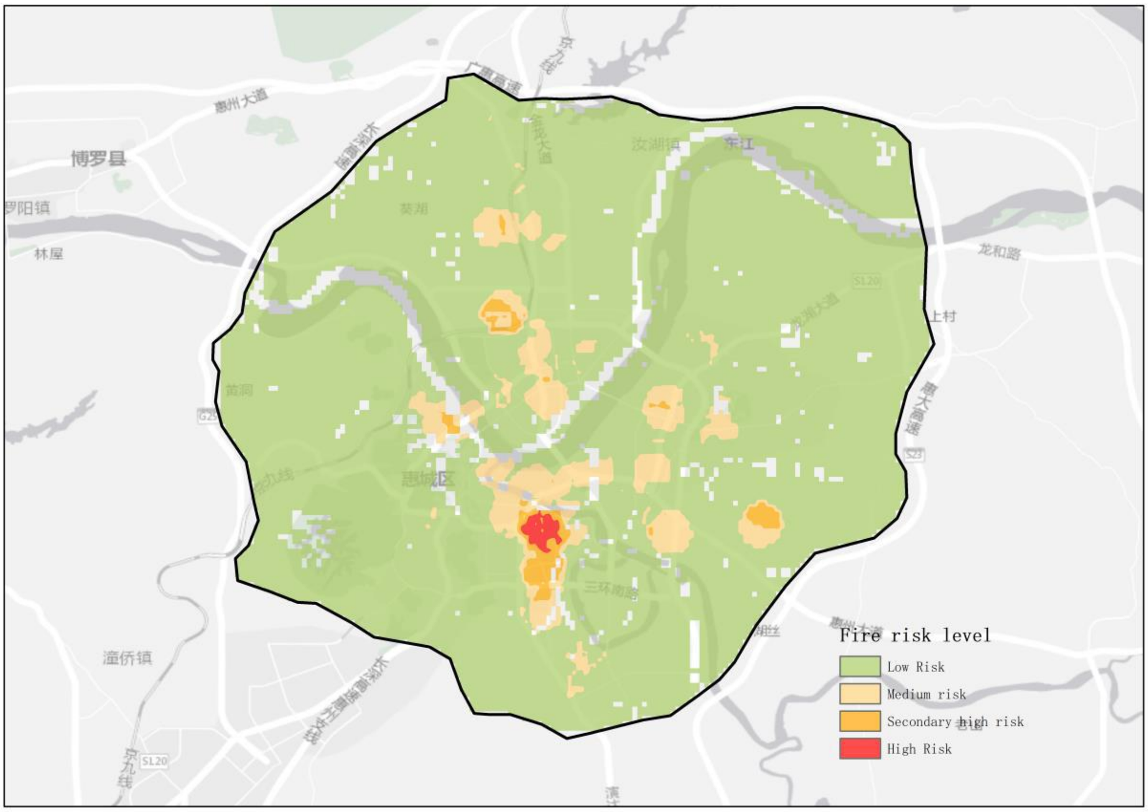

Fig.9 Distributions of Fire Risk Levels in Huicheng District

4.2 Emergency Decision Analysis of Events

In this case, assuming a fire occurs in a high-risk area of Henan-An Street, based on the calculation rule of decision support, the neighboring fire stations are determined (Figure 10). The figure shows four nearby fire stations. Through dynamic and timely data from the big data platform, the distance, time, road conditions, traffic flow, traffic lights, and other related conditions between the locations are calculated. The time is determined by “distance * speed” and traffic lights are comprehensively considered. The results obtained from timely data calculations, such as traffic factors, the calculation in this case shows that the nearest point is the fire brigade on the south bank of the river. It can quickly reach the fire site for rescue in about 5 minutes through Yanda Avenue and be sent to the nearest Xiapu People's Hospital in Huizhou City.

Based on the above, the area is located in a high-risk area, and the required rescue time during normal and peak hours is also different. During peak hours, the traffic flow will be relatively high, and fire trucks will run slowly. This is a dynamic difference in the spatio-temporal accessibility of transportation, not a fixed value. Through dynamic big data calculations, the timeliness and accuracy obtained will be more accurate than traditional decision-making based solely on road length. So, although it appears that the support fire station for rescue is far from the fire scene in this example, after comprehensive calculation of various data conditions, it shows that its rescue service time is the shortest.

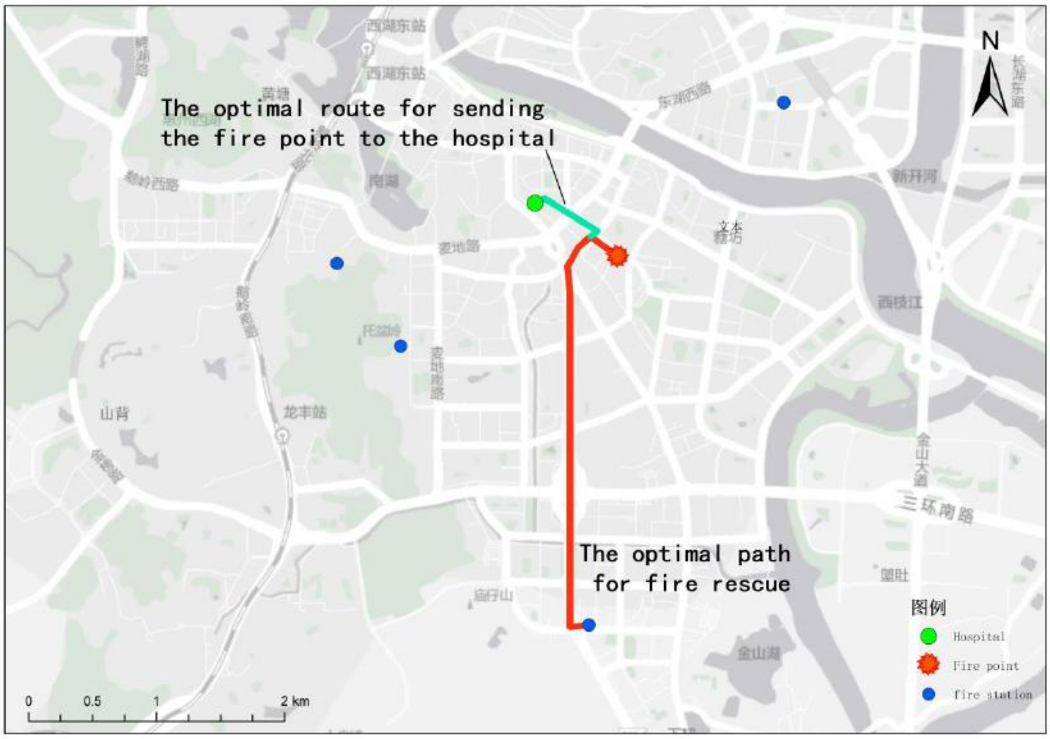

Fig.10: Case study of optimal path selection for fire emergency rescue

V. CONCLUSIONS

This study mainly focuses on the analysis of urban fire risk and emergency decision-making management. Based on the dynamic data of big data platforms, AHP evaluation is used to establish the level of urban fire risk, which serves as the basis for decision-making conditions for fire backup management in daily life. And use the Python language for data integration, calculation, and dynamic analysis. Firstly, search for nearby fire stations and hospitals based on the location of the fire and calculate the optimal route to improve the efficiency of fire emergency response. Secondly, considering the road conditions, traffic flow, and other information in real situations, utilizing the functions of the Gaode big data platform for route calculation and selection ensures that rescue operations can quickly reach the fire scene and escort the injured to the hospital.

In the era of big data and AI, all decision analysis and calculations should rely more on timely and dynamic big data sources to form more effective decision plans through the true form of data in order to approach the actual situation more closely and achieve the timeliness and effectiveness of decision-making. Through the analysis framework proposed by this study, the concept and analytical benefits of emergency decision support are demonstrated, which can enhance the actual effectiveness of fire prevention and provide reference for future relevant departments to establish relevant decision-making systems.

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