Construction and Thoughts of Intelligent "Three-Prevention" System in Shenzhen

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Abstract: Modern science and technology is a weapon against natural disasters. Shenzhen is a city of technology and innovation and we should endeavor to address flood control, drought relief and wind mitigation (named "three-prevention" in this context). In particular, we should vigorously promote the improvement of technology, and make use of modern information technologies such as big data, internet of things, cloud computing and artificial intelligence to create intelligent three-prevention system. This paper described in detail the characteristics and the construction status of the intelligent three-prevention system as well as the future development direction, in order to achieve the construction goals of the overall situation probing of the three-prevention, real-time decision-making assistance, flat command and control and urban resilience development. Since the intelligent three-prevention system's launch in April 2020, it has started more than 20 times of emergency response against typhoon and flood. The whole process functions of front-end intelligent perception, fine dynamic simulation, real-time forecast and early warning, emergency command and post-disaster assessment have been preliminarily realized.

1 Introduction

Shenzhen is located in the east coast of the Pearl River Delta in Guangdong Province. It is a special economic zone, a national economic center and an international city in China. With a large urban population and a developed economy, the city covers an area of 1997.47km^2, which has a permanent population of 13.44 million and a GDP of over 2.6 trillion in 2019[1-3]. Located in the south of the Tropic of Cancer and adjacent to the South China Sea, Shenzhen has a typical subtropical Marine climate and is one of the cities with the most severe meteorological disasters, such as typhoons and rainstorms [4-6]. According to incomplete statistics, from 2003 to 2019 alone, Shenzhen was affected by typhoons, rainstorms and other extreme weather events for more than 190 times, resulting in more than 95 deaths and missing persons, which caused a total direct economic loss of 2.6 billion [7-9]. Therefore, it is particularly important to strengthen flood control, drought relief and wind mitigation (called "three-prevention"). It also consolidates the emergency mechanism system through scientific construction, refined management and intelligent service to protect the life and property of citizens and the sustainable development of the city [10-16].

Modern science and technology is a sharp weapon to fight against natural disasters. Using modern science and technology to carry out information construction is the general trend of world economic and social development. It is also the key of China's industrial optimization and upgrading and the realization of industrialization and modernization. It is also an important means to resist natural disasters and build a resilient city. As early as 2009, IBM put forward the concept of "smart earth", and countries around the world have started to explore smart cities one after another. In 2017, in the report of the 19th National Congress of the Communist Party of China, China stressed the need to build a network power, a digital China and a smart society, taking the smart society as an important part of building an innovative country. In 2018, Shenzhen issued the overall plan for the construction of a new smart city, and pointed out the direction for the construction of a smart city in the fields of economic development, public services, social governance, etc. from the perspective of top-level design. "Shenzhen emergency management informatization development plan (2019-2022)" clearly required that relying on the cutting-edge technology of science to enable emergency management informatization and intellectualization, to create safe and efficient production space, to improve urban disaster protection capacity, and to take the lead in realizing the modernization of emergency management.

Under the great opportunity of the construction of the Guangdong-Hong Kong-Macao Greater Bay area and the socialist pilot demonstration area with Chinese characteristics, in face of frequent typhoons, rainstorms, floods and other natural disasters, Shenzhen has established an emergency management mechanism with scientific and technological strength and carried out

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emergency management of disasters with scientific and intelligent means. By using of big data, internet of things, cloud computing, artificial intelligence and other modern information technologies, a smart three-prevention system was created. Since its launch in April 2020, the three-prevention system has started more than 20 times of emergency response against typhoon and flood, including 1 response of third level and 6 responses of fifth level. The whole process functions of front-end intelligent perception, fine dynamic simulation, real-time forecast and early warning, emergency command and post-disaster assessment have been preliminarily realized.

2 Analysis on the characteristics and demands of three-prevention system in Shenzhen

2.1 Three-prevention work characteristics

Shenzhen is affected by multiple weather systems, such as the strong convection in spring, the dragon boat water, the heat convection in summer and typhoons. Therefore, it faces a great threat of strong wind, rainstorm, flood, storm surge and other natural disasters during flood seasons. The frequent occurrence of extreme weather such as typhoon and rainstorm, the heavy pressure of ensuring urban reservoirs safety during flood periods, the great intensity of urban development and construction, the numerous important economic targets, the frequent f population movements and the over-density of population, all of these factors lead to the great pressure of the three-prevention work in our city, and the urban emergency management is faced with severe challenges.

2.1.1 The extreme trend of wind and rainstorm

Under the background of global warming, the situations of wind and rain in our city presents an extreme development trend. Local, sudden and high-intensity extreme weather events occur frequently, and multiple disaster-causing factors are easy to appear at the same time, leading to the superposition and amplification of disaster effects.

Statistics show that the city is affected by 4 typhoons on average every year, with 8 typhoons at most. Since the founding of the People's Republic of China, there have been 15 typhoons directly landing in the city, including 5 typhoons with wind force of 12 or above. Since the reform and opening up policy, the frequency of typhoons affecting our city has increased by 26%, and the intensity has increased by 58%, and the typhoon season has increased by 10 days. There are 144.0 days of rainfall, 9.0 days of heavy rain and 2.2 days of heavy rain throughout the year. The rainfall in typhoon season accounted for 36% of the total rainfall, and that in flood season accounted for 85%. The rainfall in eastern Shenzhen was significantly higher than that in the west. In recent years, short-duration heavy rainfall has continuously broken records. In 2019, the extreme rainfall of 136.5 mm in one hour and 189.8 mm in two hours both reached the historical record.

2.1.2 The flood pressure of urban reservoirs is large

Due to the contradiction between the rapid urbanization process and the lack of developable area, the 155 reservoirs in Shenzhen are basically located in the urban area, and the downstream of the urban reservoirs have high population density, high economic level and high pressure of flood control. The intensity of development and construction in the downstream of urban reservoirs leads to insufficient flood discharge space. Considering the dense residential areas, commercial areas, industrial parks, and concentrated transportation, power, communication and other infrastructure, once a dam break occurs, it will cause unimaginable damage and consequences. The Meilin and Tiegang reservoirs in the center of the city have experienced danger in the history. Meilin reservoir, which is only 4.3 km far away from the center of Futian district, will affect 2 million people and result in inestimable economic losses, if the danger is not effectively controlled.

2.1.3 City security risks are high

The high exposure degree and strong vulnerability of the disaster bearing body in our city further increase the urban security risk, which is manifested in three aspects.

First, Shenzhen is densely populated with large transient population. In 2019, the actual managed population of Shenzhen was more than 20 million, with a population density of 6,653 people/km^2, far higher than that of Beijing and Shanghai. Hence, the same disaster may cause more serious losses in Shenzhen. The transient population is close to 8 million, with more than 3 million new arrivals every year. Particularly, the prevention awareness of typhoon and rainstorm disasters among people from inland areas is seriously insufficient.

Second, the intensity of urban development and construction has brought new risks. More than 1600 super high-rise buildings in the city are prone to curtain wall falling and other risks during typhoons. The underground space is large and deep and the subway station, high-speed railway station, shopping mall, parking lot and other sunken space are dense so the risk of rainwater backfill is large. At the same time, the high-density hardened pavement on the ground is easy to form runoff, and the pressure of urban drainage pipe network increases.

Third, the city has developed economy and many important economic targets. The Shenzhen liquefied natural gas (LNG) terminal is responsible for 60% of the natural gas supply in southern China, and any damage to the terminal could have a major impact on the province and the whole country. The Daya Bay Nuclear Power Station and Ling'ao Nuclear Power Station are located in areas with a high risk of storm surge, and the stable operation of nuclear power stations is even more important to the safety of the Guangdong-Hong Kong-Macao Greater Bay area.

2.2 Three-prevention work requirements

The trend of wind and rain in Shenzhen is developing towards extreme weather conditions. The large pressure of urban reservoirs during flood seasons, the high exposure and vulnerability of disaster bearing bodies, and the large risk of urban safety require strict treatment of the city's three-prevention work, which mainly includes the demands of top-level planning and design, application of intelligent scene, and public publicity services.

2.2.1 The top of planning and design requirements

The city emergency management informatization development planning (2019-2022) claimed that digital government should comprehensively considered the city emergency management which involved all aspects of the information construction factors, put forward the overall planning objectives and implementation path, flexibly use the municipal-planning and district-deployment mode, and strengthen municipal-district coordinate and linkage. Under the guidance of top-level planning and design, the construction of the intelligent three-prevention system needs to fully integrate the data of water affairs, meteorology, ocean, planning and natural resources, transportation, housing and construction, public security, emergency response and other parties, so as to realize the thorough perception of the three-prevention information in all directions, all objects and all indicators. We aim to establish unified data standards, deeply integrate scattered data resources and infrastructure, break the phenomenon of “data island”, gather and integrate diverse and heterogeneous data, and realize extensive data sharing and intelligent application.

2.2.2 The requirements of smart scene application

Smart scene application is a reflection of the “wise” in three-prevention system in Shenzhen. The key of intelligent three-prevention system is that using big data, internet of things, cloud computing, artificial intelligence, the use of Mobile Internet and other modern information technology, to make government supervision, social management more accurate, more efficient, more scientific, the operation of emergency disposal faster, and convenient service more friendly. Intelligent three-prevention system should be based on multi-source remote sensing equipment, the internet of things sensor, camera and other hardware to thoroughly perceive the storm and flood situation. Based on monitoring data and surveillance videos, we applied big data analysis, image recognition, video semantic computing and other technologies to realize the prediction and early warning of typhoon, rainstorm, flood, storm surge and their derived disasters, and widely shares the early warning and response information, so as to provide efficient and convenient services for social management. Based on artificial intelligence, cloud computing technology, scenario simulation decision aided model is established. Through deep learning and machine learning methods, it can improve the quality of the model, realize intelligent deduction of disaster situation, and output accurate and reliable data which has guiding significance. It also provides intelligence services to disaster risk analysis and realize scientific decision in the efficient command, comprehensive and rapid post-disaster assessment analysis.

2.2.3 The requirements for publicity services

Cities are built by and for people. It is urgent to strengthen the publicity of the three-prevention work, raise the public awareness of disaster prevention and reduction, and develop refined, personalized and interactive public services. An emergency-response information application platform directly facing the public should be established to solve problems such as the public's inability to use it and the difficulty in understanding professional terms. We aim to break through terminal equipment barriers of cities, districts, streets and communities, realize intelligent information push service based on user location and personalized customized needs, improve the practicability, scientific universality and readability of the three-prevention information, and promote the construction of human-oriented intelligent service.

3 Construction and functional characteristics of intelligent three-prevention system

3.1 System construction

In order to meet the requirements of the above three-prevention work, we have built an intelligent three-prevention system. The system adopts modern information technologies such as JavaEE technology architecture based on MVC, second-generation SOA architecture based on cloud computing, Web Service technology to develop and construct, and is deployed on the government extranet based on the government cloud. The system is based on the established big database of the three prevention, builds the application platform of the three-prevention, develops the mobile application program of Shenzhen Emergency Management and the WeChat applet of three-prevention, and finally builds the command deployment platform of the three-prevention that integrates monitoring and early warning, auxiliary decision-making, command and dispatch, on-duty management and other functions, finally form the whole process of the three-prevention service system with pre-warning, decision-making and command, and evaluation and analysis.

The intelligent three-prevention system is mainly composed of four parts: intelligent perception system, information infrastructure, three-prevention large database, intelligent application and terminal (Figure 1). Based on the above four-layer framework and supported by the standard system and the operation-maintenance support system, a complete intelligent prevention deployment command platform is constructed. In the three-prevention work, the intelligent interaction of

human, technology and material has been realized, which provides timely, accurate and convenient decision-making basis and visual, scientific and intelligent service for natural disaster risk assessment, office management and other important work.

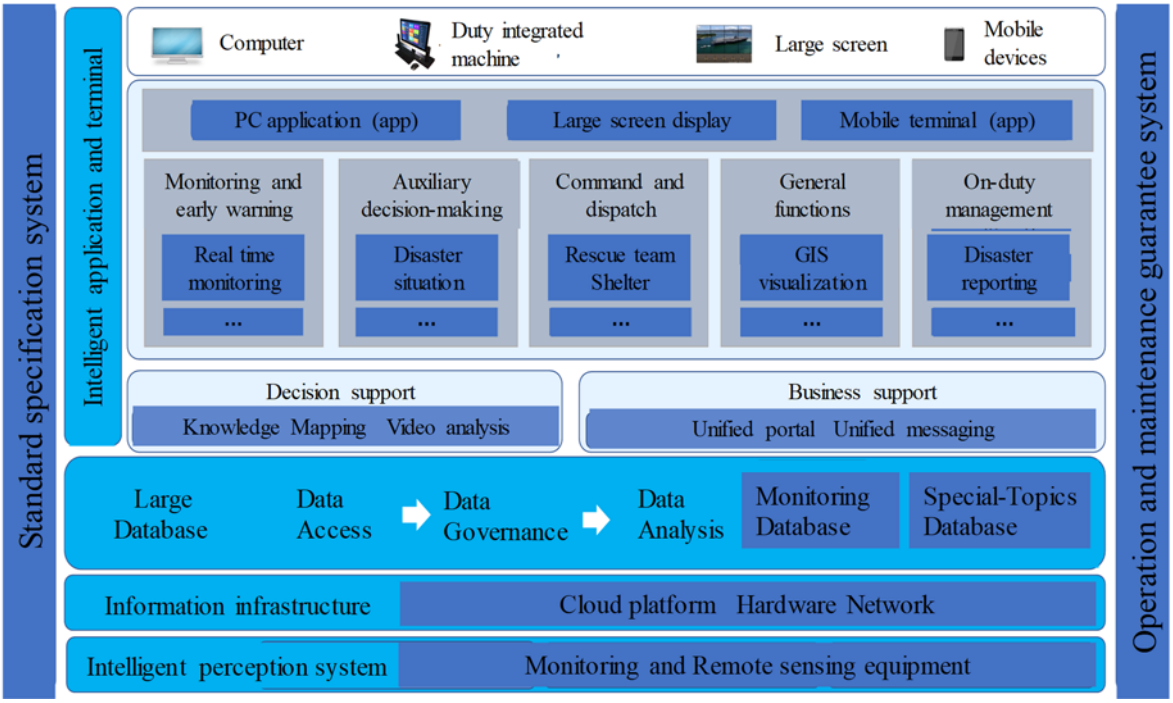

Figure 1. Composition of intelligent three-prevention system in Shenzhen

3.2 Functional features

According to the above system architecture, the first phase of Shenzhen intelligent three-prevention system has realized seven functions: monitoring and early warning, auxiliary decision-making, command and dispatch, on-duty management, one-map display, mobile application and system management. The specific functional structure is shown in Figure 2. Through the operation of the intelligent defense application system interface (Figure 3), the seven functions can be flexibly invoked, and the total elements of the three-prevention can be displayed in one-map to realize the overall situation probing. Based on monitoring and early warning information, statistical analysis of data and risk assessment of the model, disaster situation research and judgment can be carried out to realize real-time decision-making assistance. The communication network, terminal and application based on the integration of sky-air-land, and the integration of emergency resources such as various responsible persons and rescue teams, can realize the command and control of disaster disposal.

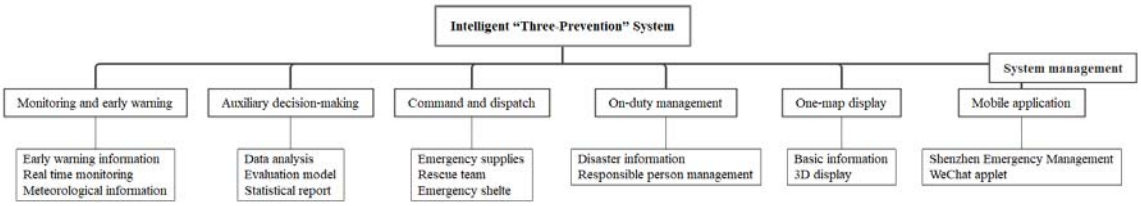

Figure 2. Functional structure of intelligent three-prevention system in Shenzhen

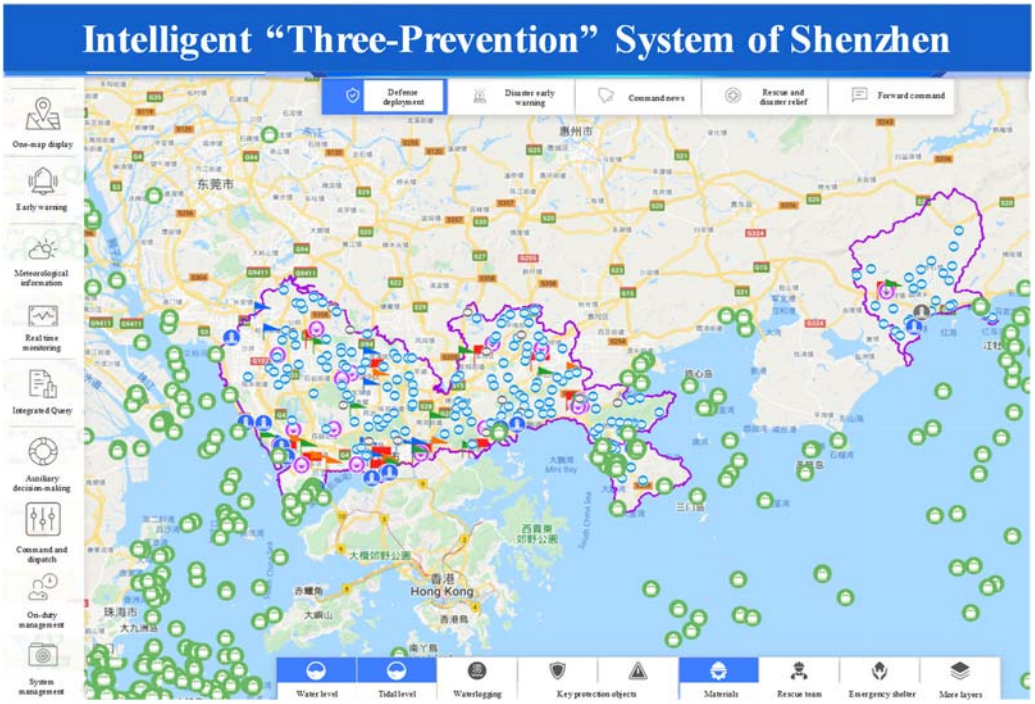

Figure 3. Operational interface of Shenzhen intelligent three-prevention application platform

Through real-time monitoring of river and rain conditions, tide level, waterlogging and other data as well as the satellite cloud images, radar images, rainfall distribution, wind speed distribution, tidal forecast, warning signals, meteorological broadcast and other information pushed by the meteorological platform, the monitoring and early warning function can be used for early warning of events such as rainstorm, typhoon, storm surge and sea waves. The system interface can scroll to display the early warning signals of relevant events, including the information of event level, and release time of the early warning signals, as well as the public defense guidance.

The assistant decision making function adopts multi-source data analysis and mathematical model simulation, which can study and judge the risks of many scenarios such as typhoon wind field, rainstorm waterlogging, storm surge, dam break flood, etc., and provide quantitative, dynamic and three-dimensional simulation decision support information for disaster prevention and reduction command work such as pre-disaster response, in-disaster disposal and post-disaster assessment.

The command and dispatch function brings together the emergency support resources of the whole city. Combined with a picture display, the information of key protection objects, key defense risk points, three-prevention materials, rescue teams, emergency shelters and other information can be presented in detail. Combined with early warning signal to start the relevant contingency plans, with reference to the emergency response plan regulations and guidance on the defensive, three-prevention headquarters are able to scientifically and reasonably dispatch regional responsible persons, rescue teams to carry out work, transfer threatened people into shelters, to avoid dangerous situations by calling video fusion, telephone and other communication functions.

The on-duty management function can realize the three-prevention work of rainstorm news, typhoon news, automatic publishing, statistics and related processing of rainstorm disaster information. Moreover, it can manage and maintain the information of more than 50,000 people responsible for the three-prevention and realize the import and visual editing of responsibility information. The disaster reporting function connects with the three-prevention reporting mobile terminals, which can summarize and upload the disaster information reported by districts, streets and the masses to the platform.

One-map display function can be used to overlay the information of water and rain situation, water accumulation, tide level, materials, emergency shelter, emergency rescue team, flood damage works, waterlogging prone points, pipe network and other basic geographical information on the layer containing terrain, road, water system, architecture and other basic geographical information, basically realizing the full management and full perception of the three-prevention elements. At the same time, it can call the historical videos and real-time monitoring videos of key points from water, marine, public security and other departments, so as to facilitate the commander of the three-prevention teams to grasp the real evolution of the situation on the scene, and also facilitate the daily inspection and supervision of key areas.

Mobile applications include the Shenzhen Emergency Management mobile application (Figure 4) and the intelligent three-prevention WeChat applet (Figure 5). Shenzhen Emergency Management mobile application is installed and used by all responsible persons for the three prevention work in Shenzhen. It realizes four functions: quick release of defense deployment, timely response of

disaster warning, communication of video consultation system, and timely feedback of disaster situation report. It has realized the direct connection and command and dispatch to the person and got through the last "one kilometer" of emergency command, ensured that the front-line situation was sent back to the command center in time, and the command instructions were uploaded and distributed, and the whole process was recorded, providing strong support for the rapid response. The three-prevention WeChat applet is tailored for Shenzhen citizens and provide early warning signal, the typhoon condition information, and have the function that reported the situation anytime and anywhere, further enhance the elaborating ability for fixed-point targeted people, and the key to solve the insufficient public understanding of disasters, weak awareness of disaster prevention and reduction, lack of reporting channel problems. It accomplishes early warning in time, high efficiency, wide audience. And good conditions have been created to minimize the loss and impact of emergencies.

System management functions mainly includes the management of the menu, roles and permissions and map configuration, can adjust menu sequence, menu items, roles and permissions can be added, deleted, modified, queried. At the same time, the map service address can be added to the system and the map can be added, deleted, modified and other operations.

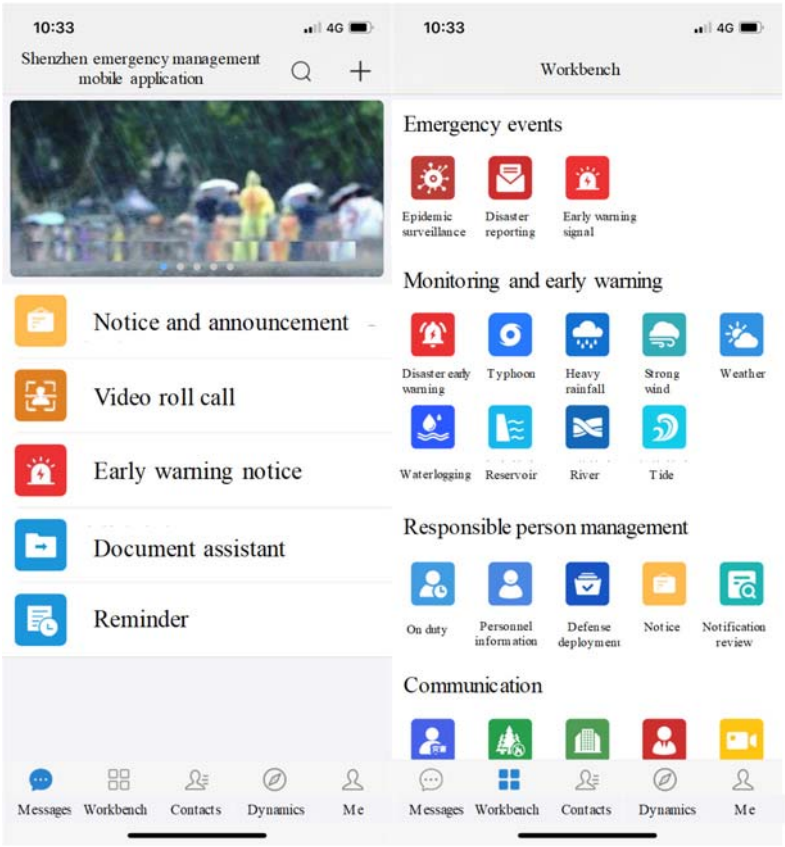

Figure 4. Shenzhen emergency management mobile application

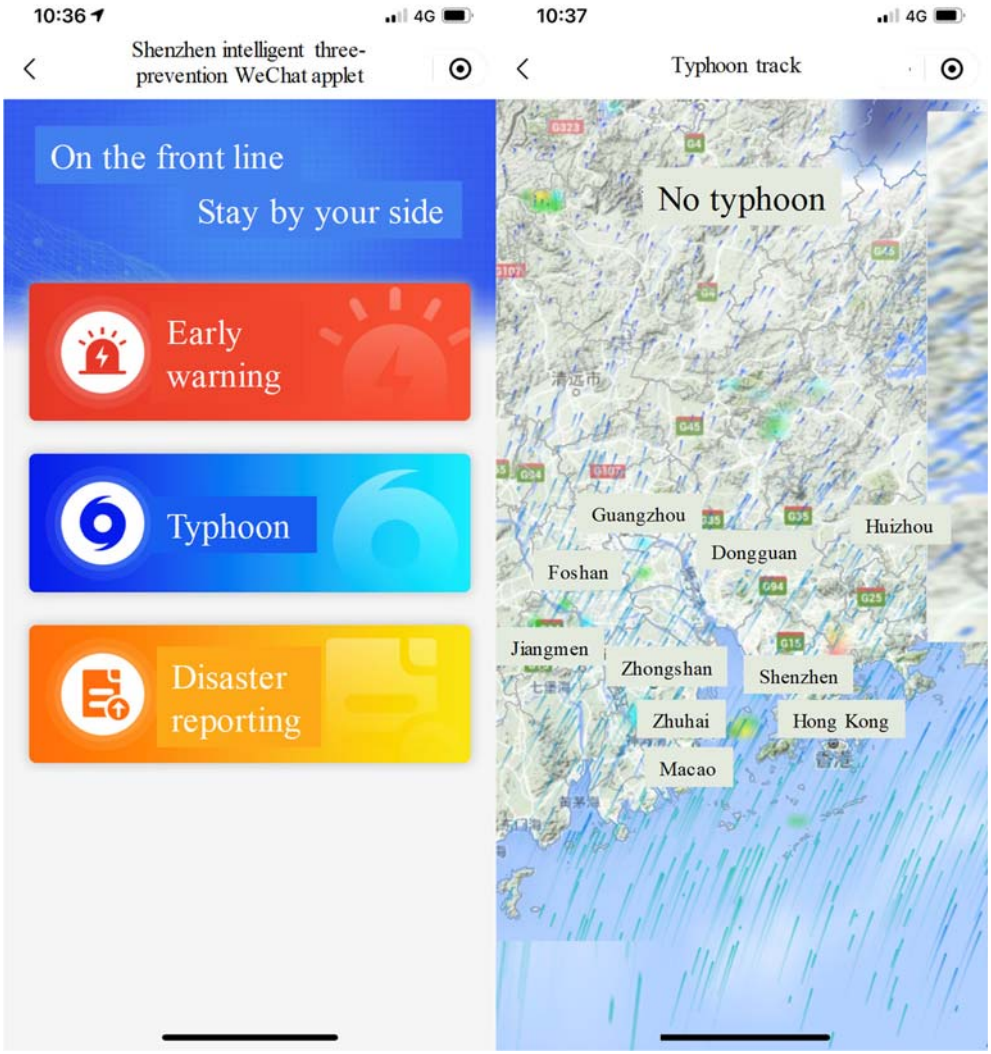

Figure 5. Shenzhen intelligent three-prevention WeChat applet

4 Some thoughts on perfecting the intelligent three-prevention system

4.1 Expanded monitoring and early warning

We will expand the monitoring and early warning of disasters caused by typhoons and rainstorms at key protection areas. It is not only necessary to comprehensively perceive information such as typhoons and rainstorms, but also to expand the monitoring and early warning of disasters derived from them by using technological means such as the internet of things and artificial intelligence. The pilot monitoring and early warning should be carried out in areas with frequent storm surges, urban waterlogging points, potential geological disasters such as landslides and debris flows, and risk areas of falling of large outdoor billboards and glass curtain walls of tall buildings, so as to improve management level of all kinds of risks and hidden dangers. We will coordinate the resources and data of various departments, connect the monitoring data and video of key protection areas such as old buildings, urban lifelines and densely populated places to the intelligent three-prevention system, and use the video intelligent analysis technology to carry out all-time and uninterrupted remote monitoring and early warning for risk points. Finally, the integration of air, sky and human monitoring of the three-prevention information will be realized, the all-directional and all-time control of the three-prevention information will be collected, so as to ensure the timeliness, accuracy and discontinuity of the early warning information transmission of flood, waterlogging, typhoon and other disasters.

4.2 Strengthen decision support

We aim to establish a perfect disaster situation analysis system and strengthen the auxiliary decision-making function. The demand of the three-prevention headquarters to control the emergency response and rescue situation is increasingly strong, but the traditional disaster analysis, target research and judgment work are not perfect, the form of information display is relatively single. Through the establishment of disaster information database, using OLAP analysis, data mining and other related technology, with accurate and reliable flood, storm surge, wind field model for risk assessment, using visual

chart, platter, dynamic heat map and other forms to display data index and situation, so we can achieve the effective integration and carding of all factor information，and assist in comprehensively analyzing disaster characteristics, scientifically adjusting the deployment of rescue forces, implementing directional and precise deployment, so as to achieve the ultimate goal of intelligent assisted decision-making.

4.3 Improve command and dispatch

The construction of visual command and dispatch will be strengthened to improve the efficiency of emergency response. On the basis of real-time monitoring video resources and GIS information of relief supplies, shelters, rescue forces of various facilities, with the help of virtual reality, augmented reality technology to bring immersive visualization, we will improve all kinds of information display intuitive and operability, flexibly realize the information sharing and collaborative work, provide accurate, real-time and comprehensive decision-making basis. Visualized command and dispatch need to realize disaster situation display, rescue force matching and other functions. Large screen displays statistical data, images, videos and other materials at the scene of disaster accidents, so as to facilitate the headquarters to grasp the situation and guide the rescue on the scene. The location of all kinds of materials and defense facilities are displayed in the way of map distribution, and the information of surrounding materials, rescue forces, refuge places and the person responsible for three-prevention is automatically associated with the disaster site, so as to quickly and accurately send all kinds of combat instructions and data information.

4.4 Enhancing Public Services

It is important to stick to the idea of “putting people first and putting life first”, improve the prevention of natural disasters, and promote the development of mobile internet technology and integration of Shenzhen Emergency Management mobile application, the intelligent three-prevention WeChat applet, community terminal and other channels. In this way, the intelligent three-prevention system can reach out to citizens and the public service can be improved comprehensively. We will continue to strengthen publicity and education to enhance the people's awareness of disaster prevention and reduction, self-help skills and emergency response capabilities. Based on location information and personnel thermodynamic data of flood risk targeted publishing platform, in case of danger, the system will issue evacuation instructions to the target population precise position, and provide timely provide key information such as the location of emergency shelters, the way to go and the latest evacuation time, to ensure the safety of people’s life and property as well as social stability.

5 Conclusion

Shenzhen is a city of science and technology and a city of innovation. To perform well in disaster prevention and mitigation, it is especially necessary to promote science and technology and utilize modern information technology to serve the city's emergency management. The application of big data, internet of things, cloud computing, artificial intelligence technology, the Shenzhen three-prevention system has realized the interaction of people, technology and materials. And it further developed and extensively used information resources such as water affairs, meteorology, oceans, and buildings, and improved the ability of disaster monitoring and early warning efficiency, risk analysis, emergency rescue and decision making when the city is faced with typhoons, rainstorms and other derivative disasters. The defense deployment command platform, which integrates "monitoring and early warning, auxiliary decision-making, command and dispatch, on-duty management, and one-map display" and other functions, is a sharp tool to win the three-prevention battle. Shenzhen always adheres to the people-centered idea and the protection of the safety of people's lives and property. The intelligent three-prevention system developed with disaster early warning, decision-making command, assessment and analysis in the whole disaster process, will certainly promote the safety of urban construction and resilient development.

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