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Investigation of the Expression Method of Theme-Typhoon Disaster Information

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Abstract: Typhoon disaster information is characterized by multiple sources, complexity and diversity, and different users of this content have different individual concerns. The expression methods of typhoon disaster information considered in previous research have been relatively simple, which cannot meet the personalized service needs of different users. In this paper, according to the diverse content needs of different users in distinct stages of a typhoon disaster, a typhoon disaster information expression method with a multi-user, multi-stage, multi-channel and multi-element combined mode is investigated. First, the audience and disaster stages are divided via demand analysis, and the demand content is summarized according to the users, stages, and release channels. Similar information is then integrated into the same theme, and it is also determined how information is expressed. Then, the analytic hierarchy process (AHP) is used to filter out the important information in each theme. The theme template is then designed according to the characteristics of particular release channels. Finally, a prototype system is developed, and Typhoon Lekima, which impacted China in 2019, is considered as a real case for analysis. The results show that the proposed method can effectively support different users to obtain disaster characteristics at distinct stages of typhoon disasters, evaluate disaster conditions, assist scientific decision-making, and enhance public awareness of risk prevention.

Keywords: typhoon disasters; theme; information expression; multi-user; AHP

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1. Introduction

The traditional definition of a disaster is composed of three components, namely the hazard-prone environment, the hazard-causing factor, and the hazard-bearing body, which are collectively referred to as the "three elements of disaster." With the advancement of science and technology and the enhancement of the ability to resist disasters, the resilience could be considered as a fourth element in the definition of 'disaster.' Disaster resilience is a comprehensive concept that includes the economic strength of a country, the execution ability of the government and rescuers, the cultural peculiarities of the public, etc., and it determines the country's ability to respond to and successfully resist to disasters [1].

Typhoons are one of the most destructive and deadly natural disasters on Earth. They occur mostly in coastal areas, and often cause serious environmental damage over a wide area [2–4]. The high winds, torrential rains, and storm surges caused by typhoons and the resulting chain of disasters have also become the focus of many researchers [5]. According to official figures, an average of seven typhoons makes landfall in China each year, causing about $5.6 billion in damage [6]. For example, in 2019, Typhoon Lekima affected 14.024 million people in China; 57 people died, 14 people went missing, 2.097 million people were urgently transferred and resettled, and the direct economic loss was $8.32 billion. There has always been an urgent need for people to take reasonable measures to improve typhoon disaster resilience and reduce the disaster risk. Due to the increasing

frequency of typhoon disasters in recent years, disaster information is also increasing, and has various forms and complex structures. The effective expression of typhoon disaster information can enable users to intuitively understand the required content, and to prevent, avoid, or make decisions related to disaster management in a timely manner.

Many scholars have made great efforts in the analysis of the information expression of typhoon disasters. For instance, Hung et al. visualized typhoons by drawing potential risk maps, and plotted the maximum effective wave height distribution maps of 18 typhoon events [7]. Yi et al. created storm surge degree maps and hazard maps of Typhoon Haiyan to improve residents' awareness of natural disaster risks [8]. Based on the Android platform, Yang et al. created a dynamic visual display of typhoon data on a map so that users could understand the strength, forecast path, wind circle coverage, and other information of a typhoon in real-time on a mobile platform [9]. GIS technology can analyze and process spatial information, and it has been widely used in various fields [10–13]. Wang et al. took the 2013 Typhoon Usagi as an example, used geographic information system (GIS) software to numerically simulate the typhoon data, and used the spatial analysis tools of GIS to obtain some thematic maps for visualization [14]. Zhang et al. combined vivid animation with a realistic 3D visualization environment to visualize hurricane storm surge and flooding [15]. Deng et al. implemented a global visualization system (GVS) based on NASA WorldWind software. The outstanding feature of GVS is its ability to produce global-based visualization, which is displayed on a globe in the form of graphics or animation to better provide the user with typhoon/storm surge information [16]. Zhou et al. carried out the real-time and dynamic assessment of storm surge based on GIS technology, and displayed the assessment results in various modes via 2D/3D visualization technology [17]. Taramelli et al. developed a GIS-based integrated approach to the Multi-Hazard model method to estimate hurricane hazards, which could ultimately be used to assist emergency management of hurricane consequences, in theory and in practice [18]. SK et al. used GIS technology to evaluate the slope, elevation, land use and rainfall of the study area, and visualized the evaluation results with thematic maps, thus realizing the assessment of cyclone vulnerability, hazard assessment and mitigation ability [19]. At the same time, there are many websites targeting typhoons. For example, Federal Emergency Management Agency (FEMA) GIS supports the emergency management community with world-class geospatial information, services, and technologies [20]. The WebGIS technology in National Weather Service (NWS) GIS Portal provides abundant meteorological data [21]. The Joint Typhoon Warning Center (JTWC) continuously monitors, analyses and forecasts the course, development and movement of tropical cyclones throughout the year to achieve its warning [22]. In most existing research, typhoon disaster information is expressed by rich thematic maps or animation methods; however, these investigations focus on a certain stage of typhoon disaster occurrence, and not all information can be expressed via thematic maps or animation.

Moreover, disaster resilience requires the improvement of the comprehensive disaster prevention ability of disaster-related personnel. However, different users have substantial differences; their interests, preferences, and cultural backgrounds are varied, and the corresponding disaster information content they require is diverse. Therefore, both audience theory and map information communication theory have emerged [23–25]. The division of the audience is the basis and premise of typhoon disaster information expression. Under the guidance of audience theory, Xu et al. divided users into four categories, namely earthquake emergency decision-makers, decision-aiding technicians, emergency rescuers, and the public, and described the representation methods used in earthquake emergency mapping for distinct audiences; on this basis, a template-matching mapping method was proposed [26]. According to the characteristics of users with individual professional knowledge backgrounds and needs, Zhang et al. divided the audience into ordinary people, disaster victims, rescue teams, and guidance experts, and proposed an adaptive construction method of a virtual debris-flow disaster environment based on multi-level, visual, task-driven techniques [27]. Gong et al. divided the users of geological disaster

emergency mapping into four categories, namely decision-makers, executors, disaster victims, and spectators, according to the classified research results of users in the geological disaster research field and the differences in task division, data demand, the degree of relevance, and the visual cognitive ability of different groups in actual emergency response work [28]. Li et al. divided the audience of debris-flow disaster emergency information into three categories, namely emergency decision-makers, rescuers, and the general public [29]. Haddow et al. divided the disaster communication audience into four categories, namely the public, elected and community officials, partners and stakeholders, and the media [30]. While these research results provide a good reference significance for the audience classification of typhoon disaster information expression, they are not highly applicable to typhoon disasters, and the existing research on typhoon disaster information expression does not distinguish between diverse types of users. Therefore, dividing users according to their needs can help them obtain the most useful content about typhoon disasters.

In the existing research, there is no distinction between user types, the typhoon disaster information needs of different users generally remain unclear and the methods of information expression are not sufficiently diversified; most methods include design templates and the standardization of thematic maps, and the term "template" is only confined to the expression of thematic maps [31–33]. Moreover, the literature only presents the visual expression of disaster information in a certain stage of a typhoon disaster, and there exists no research on a complete disaster information expression system in distinct stages [14,17]. Two problems that remain to be solved are addressed in this paper: the first is determining how to mine user needs and express the content needed by diverse types of users, and the second is determining how to adapt to the distinct stages of typhoons and express diversified information. In response to these problems, a theme-based expression method of typhoon disaster information is proposed. First, the types of users are divided, and the demand content of different users at distinct stages of typhoon disasters is sorted. Secondly, the generality of the content is analyzed according to the principles of information attributes and categories, the same type of information is integrated into the same theme, and the expression method of the information is determined. Finally, important information in varying themes is filtered out, and theme templates are designed according to the characteristics of particular release channels. The theme template realizes the adaptive expression of typhoon disaster information through a multi-user, multi-stage, multi-channel and multi-element combined mode, which embodies diversification, integrity and systematicness. The remainder of this article is arranged as follows. In Section 2, the theme-based expression method of typhoon disaster information is discussed. In Section 3, the development of the prototype system and a case study are described. In Section 4, the conclusions of this research are introduced, and future work is briefly discussed.

2. Methodology

2.1. Overall Framework

In view of the complexity and expression diversity of typhoon disaster information in distinct stages, the dimensions of the audience, disaster stages and release channels are first analyzed; the audience and disaster stages are divided, and the characteristics of the release channels used by various users are summarized. Then user demand content for typhoon disasters through the questionnaire surveys, field surveys, network and other ways is sorted, and the demand information of different users at distinct stages of disaster occurrence is obtained. In addition, disaster information is classified by theme to obtain a theme library. Then, the expression method of each type of information though four expression principles is determined, and the five expression elements of a thematic map, statistical graph, statistical table, text, and video are selected. Secondly, important information in varying themes is screened out via the analytical hierarchy process (AHP), and the theme template is designed according to the characteristics of particular release channels. Finally, the elements are combined to generate themes, which are released to different channels. The overall framework of the proposed method is presented in Figure 1.

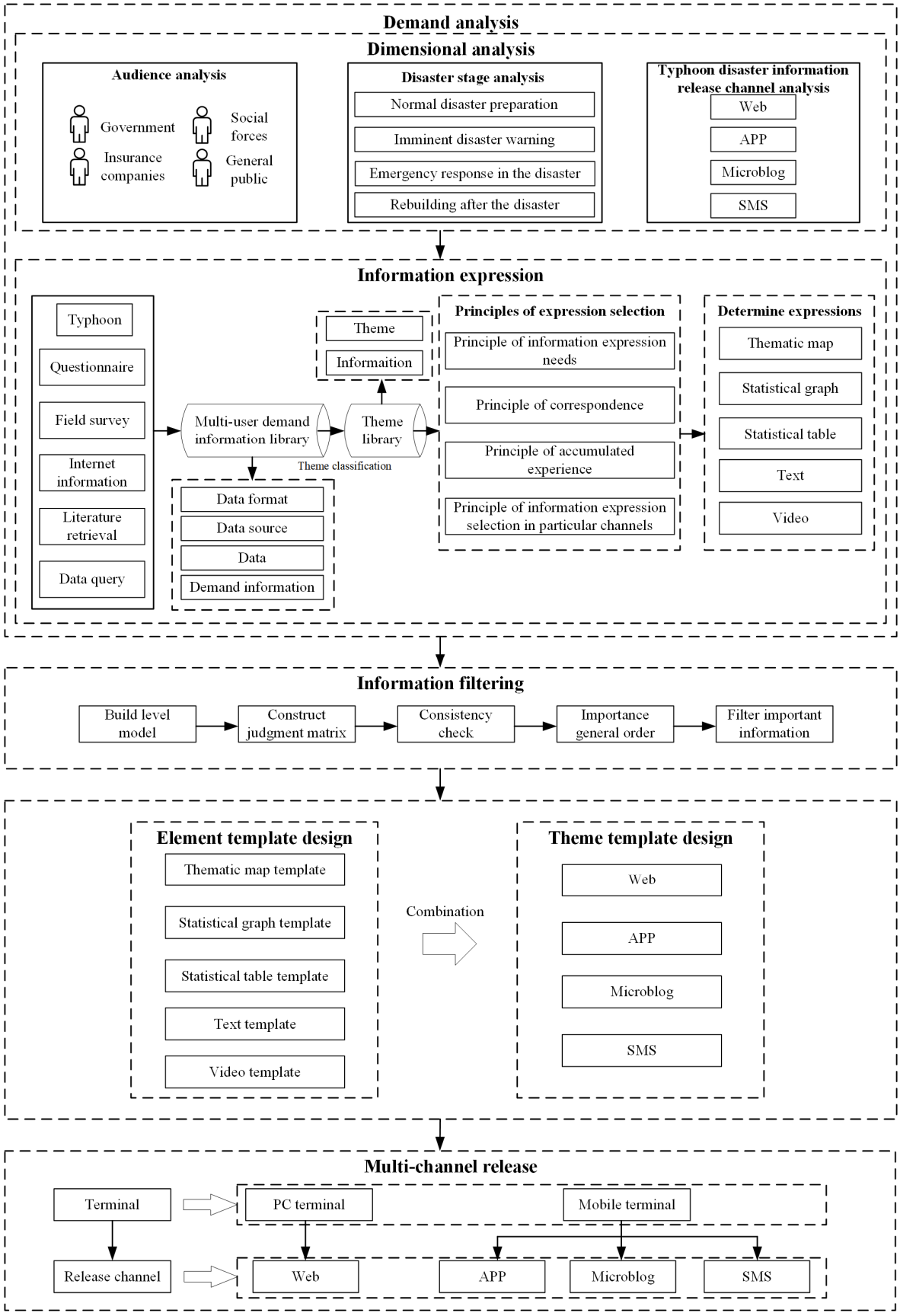


Figure 1. Overall framework for Investigation of the expression method of the theme-based typhoon disaster information.

2.2. Demand Analysis

2.2.1. Dimensional Analysis

Audience Analysis

The coastal areas of China are seriously affected by typhoon disasters, and the audience of the paper mainly come from these areas. According to the "National Meteorological Disaster Prevention Plan (2009-2020) [34]," the "Meteorological Law of the People's Republic of China [35]," "Meteorological Disaster Prevention Regulations [36]," and other relevant laws and regulations, it is necessary to "strengthen the organization and leadership of meteorological disaster prevention" and "improve the ability to deal with emergency meteorological disaster" rules. Moreover, a management system and operational mechanism for close coordination among relevant departments in handling meteorological disasters must be established and improved, and the capacity for meteorological disaster prevention and emergency rescue must be enhanced. As per these plans and regulations, units and individuals should be encouraged "to purchase insurance, establish a disaster risk insurance system supported by state finance, and give full play to the role of the financial and insurance industry in meteorological disaster relief, recovery and reconstruction," and should be prompted to "strengthen the construction of disaster prevention and emergency response teams, actively mobilize social organizations, volunteers and other social forces to participate in the emergency rescue work." Therefore, in this study, the audience of typhoon disaster information is divided into four categories, namely the government, insurance companies, social forces, and the general public.

Government: The command and decision-makers are the core of the entire typhoon disaster emergency response system; these people usually perform work in headquarters, which are subordinate to government departments. They manage disaster relief resources and are responsible for the scheduling and command of humans and resources. In the decision-making process of commands, reasonable information expression methods are required for support. According to the relevant rules of emergency response outlined in the "National Meteorological Disaster Prevention Plan (2009–2020)," emergency rescuers are usually included in the relevant government departments and perform disaster relief tasks, and appropriate information expression methods are also required in the disaster relief process. Therefore, government departments are composed of the command and decision-makers, and emergency rescuers. These users have certain professional knowledge, make scientific decisions, control the disaster situation from the macro-level, and focus on the monitoring and early warning of typhoon disasters, emergency plans, site situations, disaster impact, etc.

Insurance companies: Insurance company workers are mainly responsible for managing disaster-related insurance services for people in the affected areas to mitigate disaster risks, and play a major role in disaster relief, recovery, and reconstruction. They focus on the overall disaster situation to carry out damage assessment, post-disaster supplement and claims, and other related work.

Social forces: This audience includes non-governmental organizations (NGOs), which are a portion of the emergency rescuers and assist with disaster relief. Social forces are usually rescue groups such as the Blue Sky Rescue and Red Cross, for which various charities, volunteers, etc., serve as the backbone. They focus on the basic information of disasters, material scheduling, rescue status, etc., facilitate timely rescue work, and help victims to rationally allocate resources.

General public: The general public includes disaster preparedness workers and disaster victims who focus on the immediate disaster, disaster forecasting, disaster recovery, and other work. Appropriate disaster information expression can achieve instant refuge and reduce disaster loss for these people.

Disaster Stage Analysis

Numerous scholars have conducted related research on the division of disaster stages. For instance, Huang et al. divided disasters into four stages, namely preparedness, emer-

gency response, impact, recovery [37]. Neal et al. identified four stages of emergency management, namely mitigation, preparedness, response, and recovery [38]. The whole life cycle of a typhoon disaster consists of an incubation stage, development enhancement stage, maturity stage, and extinction stage [39]. According to the life cycle of typhoons and the existing disaster stage classification standards, typhoon disasters are divided into four stages in the present study, namely normal disaster preparation, imminent disaster warning, emergency response in the disaster, and rebuilding after the disaster.

Normal disaster preparation: At this stage, a typhoon disaster has not been gestated, and preparation refers to daily preparation, material storage, etc.

Imminent disaster warning: At this stage, the typhoon disaster is in the gestational stage, and strong cumulonimbus clouds form a tropical cyclone, which eventually creates a tropical depression after a series of changes. Therefore, this stage refers to the stage before a typhoon when a disaster is predicted to occur, and there are different warning stages for different regions.

Emergency response in the disaster: At this stage, a typhoon disaster is in the stage of strengthening development and maturity. During the process of development to the mature stage, the typhoon has the ability to cause disasters and huge losses to society. Therefore, this stage focuses on rescue work.

Rebuilding after the disaster: At this stage, the typhoon disaster is in the extinction stage, and various trades need to carry out related recovery work.

Typhoon Disaster Information Release Channel Analysis

At present, the general disaster information release channels are microblogs, the Web, mobile applications (APPs), and short message service (SMS). Among them, microblogs include Sina Weibo, the most popular microblog in China, which is similar to Twitter abroad. Microblogs are social media platforms for the transmission of short and real-time information, which can realize timely information sharing, communication, and interaction. The Web contains a plethora of information, and is characterized by strong operational complexity, pushability, interactivity, and uploadability. Moreover, the PC terminal is characterized by good software and hardware conditions, a large screen size, and either horizontal or vertical scrolling. Moreover, number of views of webpages is large and complex. The window can store text, thematic maps, statistical graphs, statistical tables, and videos. APPs also contain a substantial amount of information and have strong operational complexity, and the information is pushable, interactive, and uploadable. The software conditions are good, the screen sizes of mobile devices are small, and users are accustomed to vertical scrolling. As with the Web, the number of views of APPs is large and complex, and the window can store text, thematic maps, statistical graphs, statistical tables, and videos. Microblogs and SMS contain less information and are characterized by simple operation, and the windows can only store text, images, videos, and links. Therefore, the release channels chosen for consideration in this study include the Web for access on personal computers (PCs), and APPs, microblogs, and SMS for access on mobile platforms.

The use channel is judged based on user habits and mobility requirements. Because PCs are characterized by poor mobility, APPs and SMS are more flexible platforms for information dissemination to mobile users. Emergency rescuers of the government are usually on-site, and APPs and SMS are selected for them. The command and decision-makers of the government are usually not on-site, and the PC terminal is more suitable. Moreover, the produced theme can be easily printed. Therefore, APPs, SMS, and the Web are selected as the information release channels for government users. Insurance company employees are usually not on-site, so the Web is selected as their use channel. Social forces are usually on-site, and considering the requirements of mobility, APPs and SMS are more suitable channels. Finally, the general public is generally used to using mobile phones, and the majority of microblog users are the general public. Therefore, three channels are selected for the public: microblogs, APPs, and SMS.

2.2.2. Information Expression

Different users require diverse information in distinct disaster stages. Data on the information required by different users were collected via questionnaire surveys, field surveys of relevant units, network, literature retrieval, basic data inquiry and sorting, etc. According to the principles of information attributes, categories, etc., the generality of information is analyzed, and the same kind of information is integrated into the same theme to obtain a theme library. Some of these themes can well reflect and ultimately enhance disaster resilience. For example, for the government, the themes of disaster preparation precaution and rescue guarantee reflect the executive and rescue powers of the government, while the theme of social economy well reflects economic strength. Additionally, rainfall monitoring information, which falls into the theme of typhoon monitoring, is usually monitored by meteorological stations, which reflects the power of science and technology. Next, the expression method of each type of information was researched individually. According to the basic expression form of typhoon disaster information and visual differences, element templates are divided into five categories, namely the thematic map template, statistical graph template, statistical table template, text template, and video template. Thematic maps are divided into four categories, namely vector point, vector line, vector polygon, and grid. Statistical graphs include line charts, bar charts, pie charts, scatter charts, tree charts, etc. The principles for determining the information expression method are as follows:

(1) Principle of information expression needs

It is more intuitive to choose statistical tables for the expression of typhoon disaster information with more numbers, yet choosing thematic maps will increase the difficulty of reading. For information that changes temporally, it is more appropriate to choose a histogram (a statistical graph). Histograms can intuitively present the trends of changes over time. For typhoon disasters, the expression of some information must reflect dynamic and interactive characteristics. Therefore, thematic maps can express this kind of disaster information more intuitively and effectively. For example, the probability forecast information of typhoon path can be better expressed by a dynamic line shape; thus, in this case, it is more reasonable to choose a vector line (thematic map).

(2) Principle of correspondence

There are one-to-one and one-to-many relationships between graphs and information. For example, the theme of disaster preparation precaution in the government's imminent disaster warning stage includes information on disaster preparedness warehouses, resettlement points, rescue agencies, insurance companies, hospitals, government departments, escape routes, and other information that can be expressed on a map with different colors and symbols [40,41].

(3) Principle of accumulated experience

According to a literature review and information from existing websites, WeChat public numbers, APPs, and other channels, some common expression methods of information were sorted and summarized. For example, via the collation and summary of the existing literature, it was found that the risk assessment information of typhoon disasters is usually expressed by thematic maps [42,43].

(4) Principle of information expression selection in particular channels

According to the characteristics of the various information release channels, the most appropriate method of expression in different channels was chosen. If the channel is the Web or APPs, the transmission rate, network speed, etc., will not be restricted. When a thematic map coexists with several other elements, the thematic map is selected. If the channel is a microblog, only text and images can be selected for expression. If the channel is SMS, only text can be selected for expression.

The specific expressions method of different types of information are listed in Table A1 in Appendix A. For example, path probability prediction information is expressed in the

form of a thematic map (vector line) and text according to the expression needs. According to the principle of information expression selection in particular channels, if the release channel is the Web or an APP, a thematic map (vector line) is selected. If the release channel is a microblog, the image form is selected, and the image will be generated by the APP webpage. If the release channel is SMS, text is selected as the information expression method.

2.3. Theme Information Screening Method Based on AHP

Each of the themes shown in Table A1 in Appendix A often contains a lot of information; if all this information is expressed, not only will there be no distinction between primary and secondary information, but the efficiency of expression will also be affected. AHP is widely used in the risk assessment of natural disasters and the geological environment [44–48]. In this work, AHP was chosen to generate the weights of typhoon disaster information, and to filter out less-important information. AHP is a decision-making method that decomposes decision-related elements into a target layer, criterion layer, and scheme layer, based on which qualitative and quantitative analyses are carried out. The steps for assessing the importance of disaster information in the same theme based on AHP are as follows:

(1) Establish a hierarchical structure model, which is divided into a target layer, criterion layer, and scheme layer;
(2) Use expert experience to compare the importance of each index in the same level based on a certain criterion, and construct the judgment matrix of pairwise comparison;
(3) Calculate the weight value of each index based on the judgment matrix, and check the consistency of the judgment matrix. The consistency index is defined as

$$CI = \frac{\lambda - n}{n - 1} \tag{1}$$

where CI is the consistency index, λ is the maximum eigenroot of the judgment matrix, n is the order of the matrix, and the random consistency index RI is introduced to measure the size of CI. The average RI values for $n = 1, \ldots, 11$ are presented in Table 1. The test coefficient CR was obtained by comparing CI with RI, which is defined as follows:

$$CR = \frac{CI}{RI} \tag{2}$$

If CR is less than 0.1, the judgment matrix is considered to be satisfactorily consistent; if not, it needs to be adjusted or abandoned;
(4) Calculate the total ranking weight of each level in the system, and calculate the weight values of all indicators to obtain the ranking of the importance evaluation values of typhoon disaster information in the same theme;
(5) Calculate the average value of information weight as follows:

$$p = \frac{1}{k} \tag{3}$$

where p is the average value and k is the quantity of information in the theme. If the weight of a certain piece of information is greater than or equal to p, it is of great concern, and this information is expressed.

Table 1. Average random consistency index values.

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

2.4. Theme Template Design

In the present study, the theme template is utilized to express multiple pieces of information, and is obtained by combining the element templates. The theme template of the Web on the PC terminal is presented in Figure 2, and includes the theme title, creation time, font selection, printing page, and the purpose and introduction of the generated content. Information is ranked in order of importance from top to bottom, each information should be expressed by selecting one of the five elements. Due to limited space, the selection process is only shown in information 1. The name of the thematic map template is located in the top-middle area, and the main map area is located in the middle, which is used to place the background base map of basic geographic information, disaster information, and other thematic vector layers, as well as symbols, specifications, colors, projections, etc. The name of the statistical graph template is in the upper-left corner, the legend is located to the right of the graph name, and the middle part is the histogram, line chart, pie chart, etc. The table name of the statistical table template is in the top-middle area of the table, the text name of the text template is in the upper-left corner, and the video name of the video template is in the middle. Figure 3 presents the theme template design of an APP; due to the small size of the mobile terminal, each element occupies a separate line, as does the text explanation of each element. Figure 4 exhibits the theme template of a microblog; due to the limitations of the microblog itself, the top area presents a brief description of the information contained in this theme, which is followed by the theme diagram. The theme template of the SMS channel is presented in Figure 5; due to the limitations of SMS itself, the text contains a brief description of the information in the theme, which is followed by a link to the specific information.

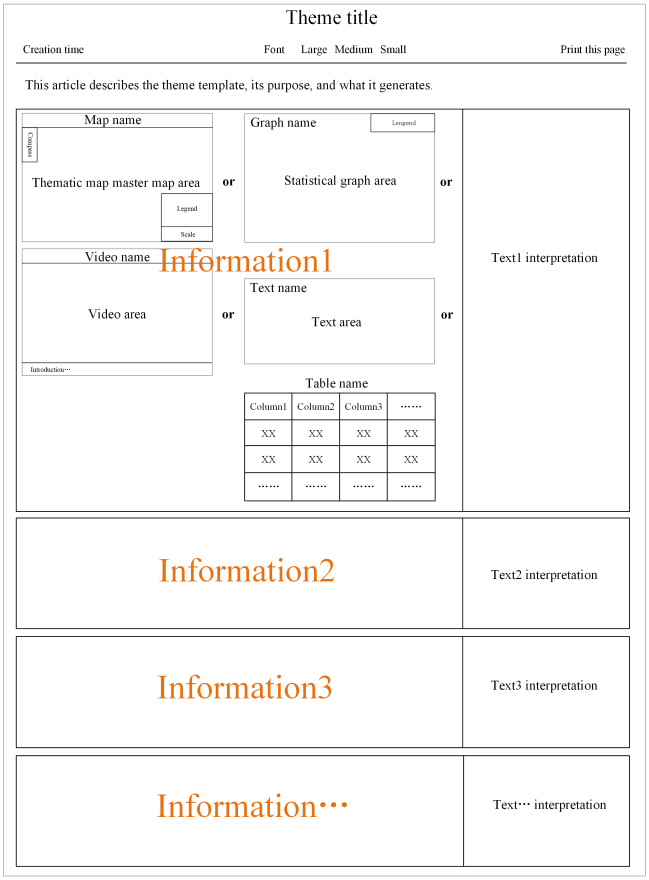


Figure 2. Web design diagram.

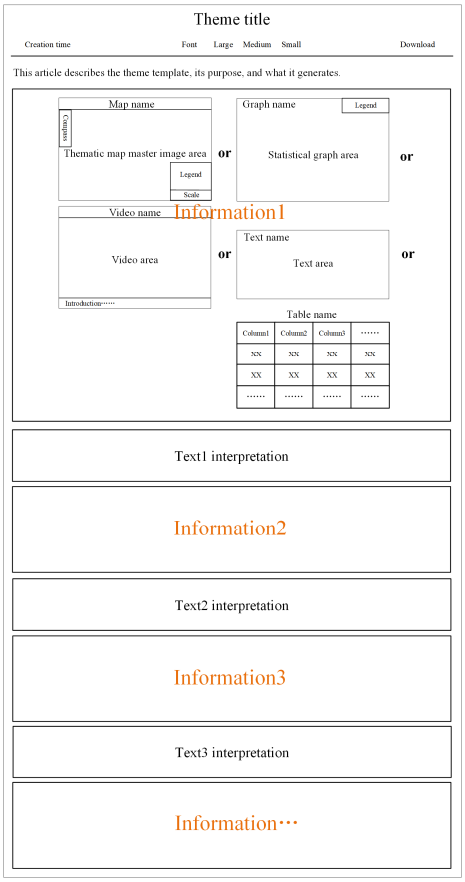


Figure 3. APP design diagram.

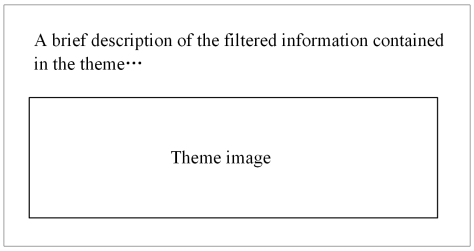


Figure 4. Microblog design diagram.

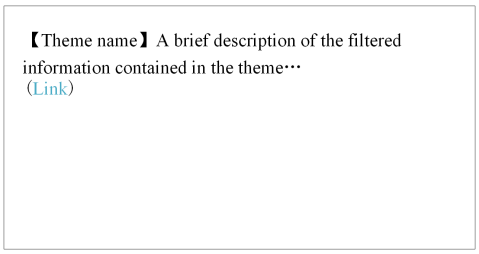


Figure 5. SMS design diagram.

2.5. Multi-Channel Release System Design

The overall architecture of the system is divided into four layers from bottom to top, namely a data access layer, business logic layer, user interface layer, and user layer. The data access layer is the main control system of the database and the foundation of the entire system, which is used to obtain the data needed for information from various channels. Data sources include The China Meteorological Data Service Center (CMDC),

government departments, field trips, social media, etc. Data include meteorological data, model simulation data, government data, field survey data, crawler data, etc. Data formats include text, numeric, vector point, vector line, vector polygon, and grid. The business logic layer is the operation of the data layer; the user first selects the theme, and the system obtains data of the corresponding theme from the database. According to the principles of expression, elements of information expression are selected, and the theme is finally generated via element combination. The user interface layer is the interface that interacts with the four types of users, and is used to display the generated theme on the four release channels. The user layer refers to the four types of users, the release channels of which are shown in Figure 6.

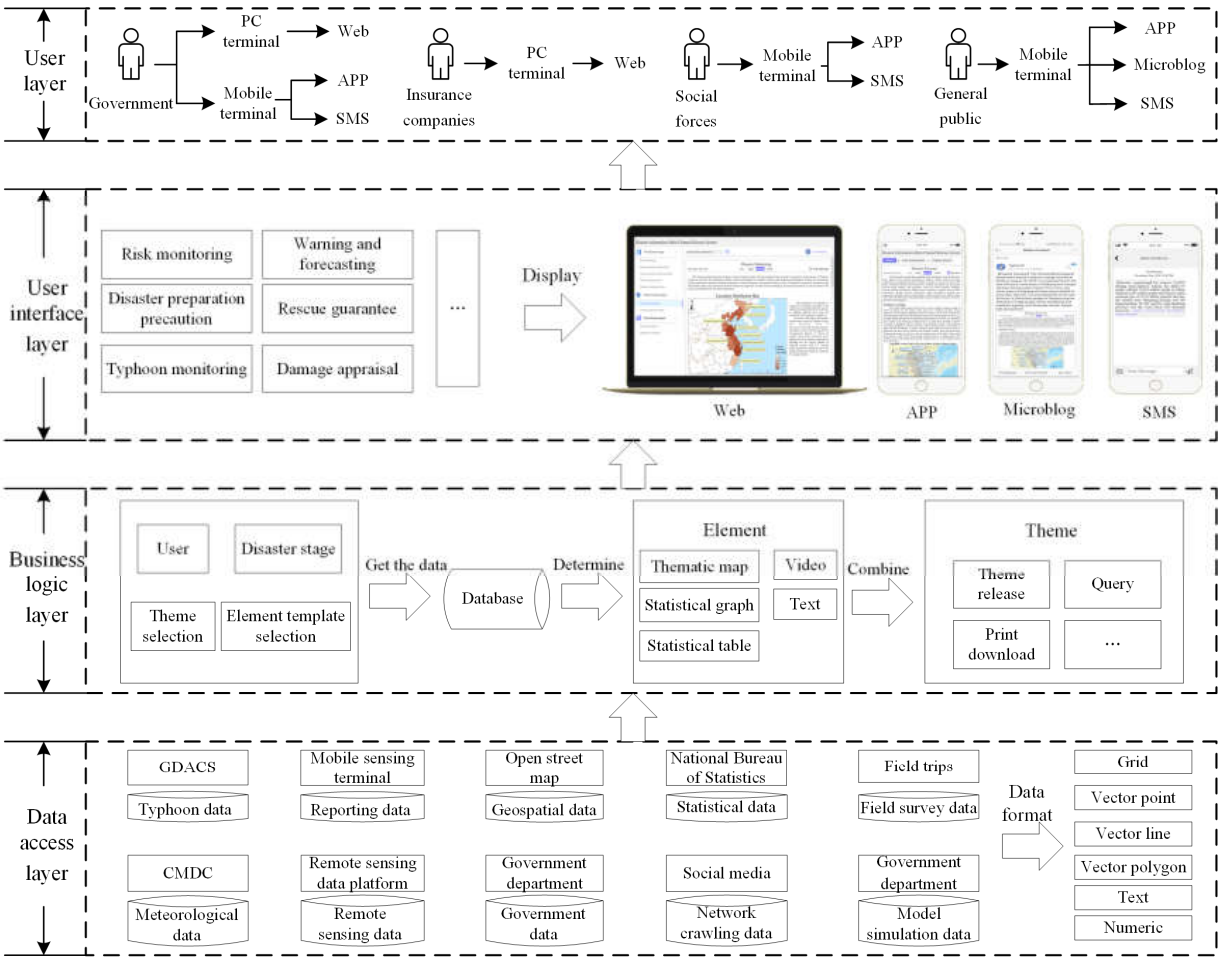


Figure 6. System architecture diagram.

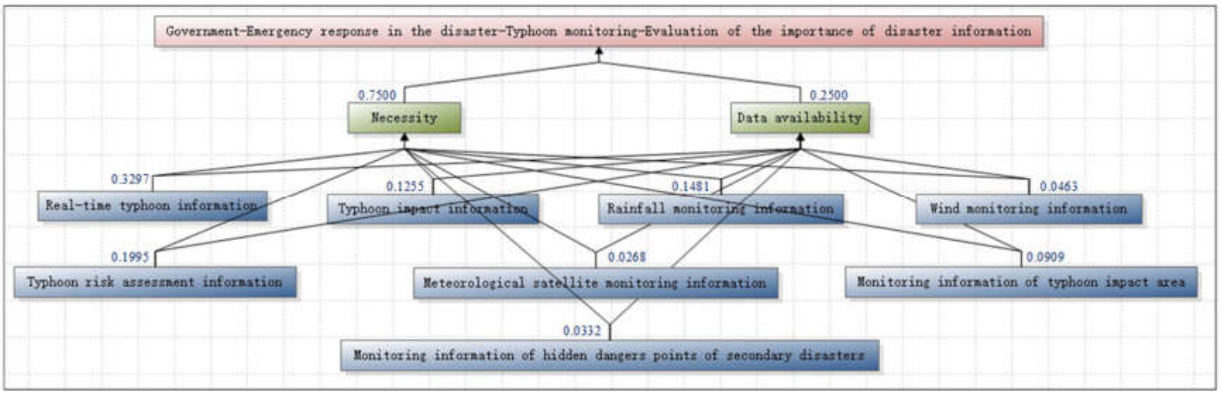
3. System Application Case

Visual Studio 2019 (Microsoft, Redmond, Washington, USA) and HBuilder software (DCloud, Beijing, China) were used to develop a multi-channel release system. A front-end and back-end separation architecture was adopted for the system, and Vue.js was adopted for the client. Moreover, WebGIS technology was used to achieve the front-end visual display. The C# language and the ASP.NET Core framework were used for the server. The information under the theme of typhoon monitoring can provide the real-time changing situation of typhoon, which is convenient for government to make scientific decisions. The information under the theme of disaster forecasting can provide typhoon path probability forecast, rainfall forecast and other information, which is conducive to the general public to prevent and mitigate disasters. Therefore, Typhoon Lekima, which impacted China in 2019, was taken as an example to create and realize the theme of typhoon

monitoring under the government's emergency response in the disaster stage, and the theme of disaster forecasting under the general public's imminent disaster warning stage.

3.1. Information Filtering

AHP was used to filter the importance of the information for the two themes shown in Table A1 in Appendix A. First, hierarchical models based on the government and the general public were constructed, and the target layer is the importance evaluation of disaster information, and the criterion layer included necessity and data availability. The necessity of information corresponds to the degree of disaster resilience. If the information can improve disaster resilience to a certain extent, then the information is deemed necessary. Additionally, if data of the information are not available, the expression of the information will be affected. Therefore, these two factors were selected as the criterion layer. The scheme layer included all types of demand information. Expert scores were determined according to the prior knowledge accumulated by the experts from the emergency management department of a disaster reduction center. The final weight distributions are presented in Figure 7. Among them, the target layer corresponds to the red box in the figure, and the criterion layer corresponds to the green box in the figure, and the scheme layer corresponds to the blue box in the figure.



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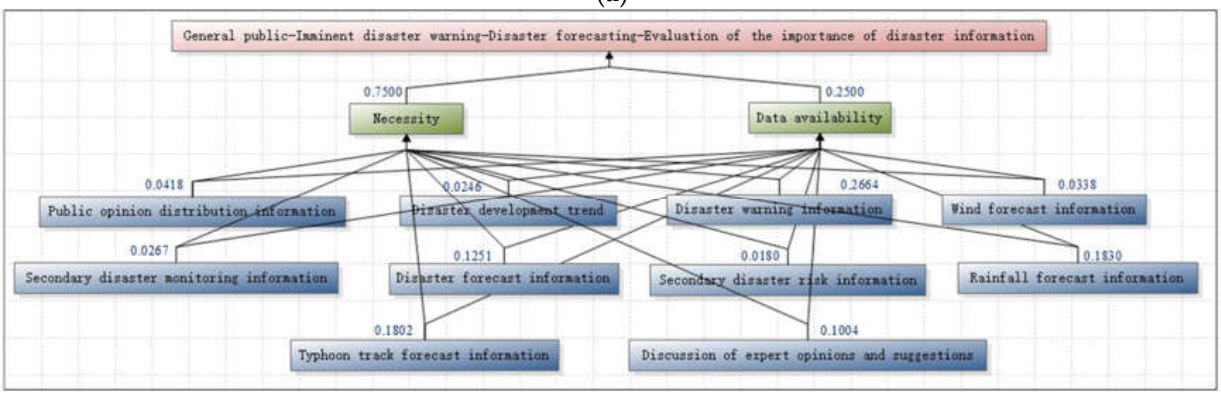


(**b**)

Figure 7. (**a**) The typhoon monitoring information weight distribution map of the emergency response in the disaster of the government. (**b**) The disaster forecasting information weight distribution map of the immediate disaster warning of the general public.

The information was sorted according to the weight value from greatest to least. The government's theme of typhoon monitoring contained eight pieces of information with an average value of 0.125. The information with importances greater than this value was ranked, and included, from greatest to least importance, real-time typhoon information, typhoon risk assessment information, rainfall monitoring information, and typhoon impact

information. The public's disaster forecasting theme contained 10 pieces of information with an average value of 0.1. The information with importances greater than this value was ranked, and included, from greatest to least importance, disaster warning information, rainfall forecast information, typhoon track forecast information, disaster forecast information, and discussion of expert opinions and suggestions.

3.2. Theme Display

According to results presented in Table A1 in Appendix A, for the Web and APP platforms used by the government, a thematic map (vector line) was selected for real-time typhoon information, a thematic map (vector polygon) was selected for typhoon risk assessment information, a thematic map (vector polygon) was selected for rainfall monitoring information, and a statistical graph was selected for typhoon impact information. For the microblog platform, a brief text expression of the four pieces of information was adopted, and the image was converted from the APP webpage. For the SMS platform, a brief text expression of the four pieces of information was selected, and the link was the address of the APP webpage. In the meantime, for the Web and APP platforms used by the public, a thematic map (vector line/vector polygon) combined with text was selected for disaster warning information, a thematic map (vector polygon) was selected for rainfall forecast information, a thematic map (vector line) was selected for typhoon track forecast information, and text was selected for both disaster forecast information and discussion of expert opinions and suggestions. For the microblog platform, brief text expressions of the five pieces of information were adopted, and the image was converted from the APP webpage. For the SMS platform, brief text expressions were adopted for the five pieces of information, and the link was the address of the APP webpage.

Elements of the two themes of typhoon monitoring and disaster forecasting were combined and released on different channels. The government's release channels included the Web, APP, and SMS, while the public's release channels included the APP, SMS, and microblog. The complete content of the government PC terminal is shown in Figure 8. While the content of the mobile terminal was the same as that of the PC terminal, the layouts of the two terminals were different, and the text explanation of each element occupied a separate line. Due to limited space, only the government's PC terminal content map is displayed. The information shown in Figure 8 is real-time typhoon information, typhoon risk assessment information, rainfall monitoring information, and typhoon impact information of Typhoon Lekima. Figure 9 presents the complete content of the mobile terminal for the public. The information shown in Figure 9 is disaster warning information, rainfall forecast information, typhoon track forecast information, disaster forecast information, and discussion of expert opinions and suggestions. Based on the current monitoring situation of Typhoon Lekima, the path and rainfall of it in the future period are forecasted. The forecast situation for August 10, 2019 is shown here. The disaster warning information is composed of path forecast and rainfall forecast. Most of the predicted content is obtained through web crawling.

Additionally, the system interfaces of the government users for the three channels of the Web, APP, and SMS are exhibited in Figure 10, and the system interfaces of the public users for the three channels of the APP, SMS, and microblog are shown in Figure 11. In the webpage of Web terminal, the theme bar under various disaster stages of the government is shown on the left, and the detailed page of the theme is displayed on the right, and the entire content can be scrolled for review, and theme queries can be made by searching for keywords. In the webpages of APP terminal, users enter from the homepage, select the theme, and then see this detailed page.

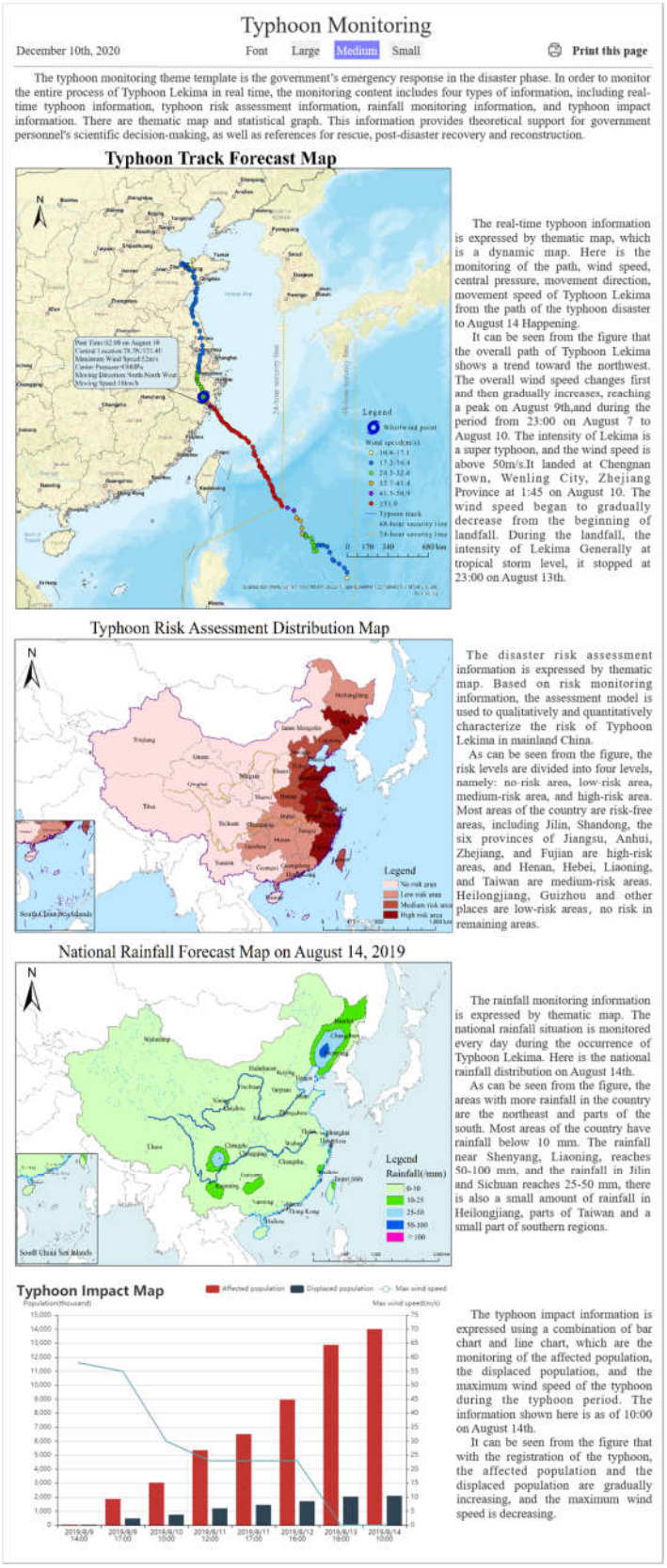


Figure 8. Government PC terminal content display map.

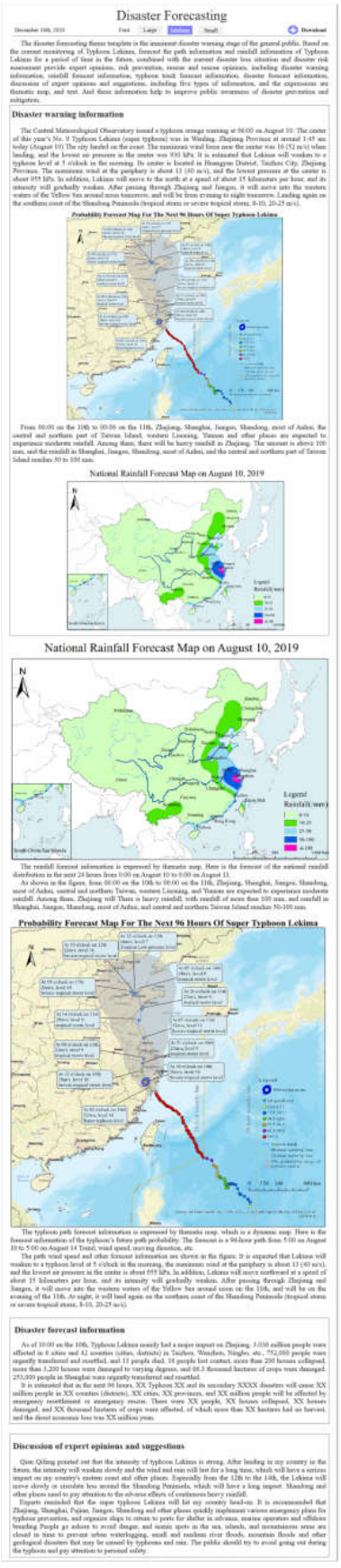
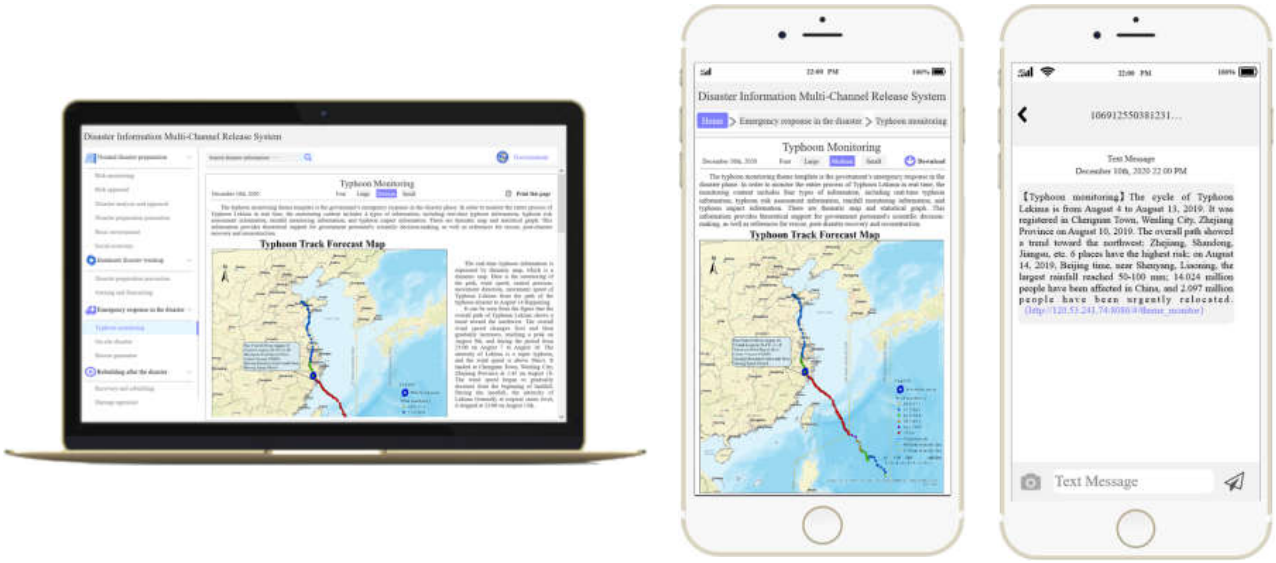
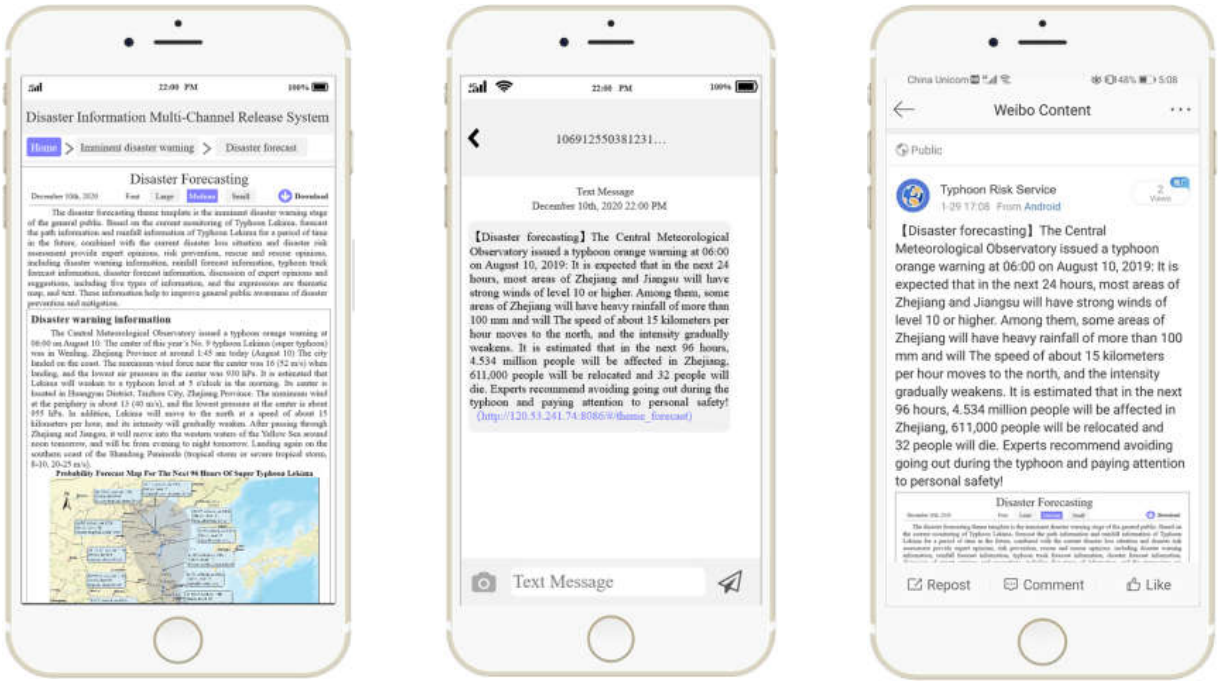


Figure 9. Public mobile terminal content display map.



(**a**) (**b**) (**c**)

Figure 10. Government interface map. (**a**) Web; (**b**) APP; (**c**) SMS.



(**a**) (**b**) (**c**)

Figure 11. General public interface map. (**a**) APP; (**b**) SMS; (**c**) Microblog.

3.3. Discussion

In the present study, the audience of typhoon disaster information expression is divided into four categories, namely the government, insurance companies, social forces, and the general public. Meanwhile, the disaster stages are divided into four categories, namely normal disaster preparation, imminent disaster warning, emergency response in the disaster, and rebuilding after the disaster. In addition, the demand content of different users at distinct stages of typhoon disasters is sorted. This answers the two questions, namely who is the audience of typhoon disaster information expression and what content

do they need in distinct disaster stages, which lays the foundation for the production of the theme map.

The theme template is distinguished from previous thematic mapping template. Previous thematic mapping templates were confined to thematic map elements and could only display limited content. In [31], Sun et al. made a thematic map template of the earthquake impact field based on the map world, and finally showed the relevant content of the impact field. In [32], Xu et al. introduced earthquake emergency mapping, and studied the realization method of earthquake emergency mapping based on template-matching, and presented the earthquake emergency information. In [33], Tan et al. made the thematic map of earthquake emergency through a new rapid production method of the thematic map, which showed the location information of the earthquake epicenter. The theme templates proposed in this paper contain five types of template elements, namely thematic maps, statistical graphs, statistical tables, text, and videos. The combination mode of various elements supersedes the single expression of thematic map. For example, in Figure 8 of the case, the typhoon monitoring theme map based on Typhoon Lekima is made, and real-time typhoon information, typhoon risk assessment information, rainfall monitoring information, and typhoon impact information are presented to the government. According to characteristics of release channels, the appropriate information expression elements can be selected adaptively so as to display similar information required by users at the same time, which meets the personalized service needs of different users. In addition, the theme template is also designed according to the importance, and it can be displayed according to the user's attention when it is finally released, which finally realizes the adaptability and diversification of information expression.

AHP is used to rank the importance for typhoon disaster information in this study, and the unimportant information is screened out according to the evaluation criteria to solve the redundancy of information, which provides a reference significance for the screening of disaster information.

4. Conclusions and Future Work

Previous research on typhoon disaster information expression has mainly focused on problems including only a single user, single occurrence stage, single expression, and single channel. Most methods cannot meet the information acquisition requirements of multiple types of users in distinct disaster stages. Aiming at these problems, a theme-based expression method of typhoon disaster information was proposed in the present study. First, four distinct audiences were divided via demand analysis, and the division of audiences for typhoon disaster information expression can provide personalized services for different users. The AHP method was then used to complete the importance evaluation of diverse types of typhoon disaster information, which can be displayed according to users' information needs when it is finally released. The themes proposed in this paper present complete disaster information and comprehensive expression methods at each stage of a typhoon disaster. After AHP screening, for example, the theme of rescue guarantee can provide the government with disaster preparedness warehouses, resettlement sites, typhoon escape routes, rescue personnel distribution information, etc., and the theme of on-site disaster can provide the government with disaster information, casualty distribution information and economic loss distribution information, etc. Moreover, the template proposed in this paper can adapt to the needs of the expression of various types of information, provide appropriate typhoon disaster information for all types of users, and enhance the comprehensive disaster prevention ability of relevant personnel. The proposed method can also reasonably and aesthetically display typhoon disaster information on particular release channels. The case results demonstrate that the proposed theme-based typhoon disaster information expression method lays a foundation for diverse types of users to intuitively understand disaster information. The theme template is a novel idea that supersedes the previous single-expression research of the thematic mapping template, and utilizes a multi-user, multi-stage, multi-channel, multi-element combined expression mode to express typhoon

disaster information, thereby forming a relatively complete system. This method is not only suitable for the expression of typhoon disaster information, but also has important research value for the expression of other types of disaster information.

In future work, mining technology for social media information should be considered as data support to further study multi-disaster information expression methods and classify the types of audiences to better meet users' needs for the expression of information on various disasters.

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Abbreviations

The following abbreviations are used in this manuscript:

AHP	Analytic Hierarchy Process
GIS	Geographic Information System
GVS	Global Visualization System
NGOs	Non-Governmental Organizations
SMS	Short Message Service
PCs	Personal Computers
GDACS	Global Disaster Alerting Coordination System
CMDC	The China Meteorological Data Service Center
FEMA	Federal Emergency Management Agency
NWS	National Weather Service
JTWC	Joint Typhoon Warning Center

Appendix A

Table A1. Demand analysis results table.

User	Channel	Disaster stage	Theme	Information	Expression method
Government	Web, APP, SMS	Normal disaster preparation	Risk monitoring	Typical area monitoring information, high-risk area monitoring information	Thematic map (grid)
				Major project/activity monitoring information	Thematic map (grid)
				Basic risk information	Statistical table
			Risk appraisal	Comprehensive disaster risk information in different periods	Statistical graph
				Historical information of similar typhoons in high-risk areas	Thematic map (vector line), statistical table
				Comprehensive typhoon risk assessment information in high-risk areas	Thematic map (grid)
				Comprehensive typhoon loss assessment information in high-risk areas	Thematic map (grid), statistical graph
				International disaster risk information	Thematic map (grid)

Table A1. *Cont.*

User	Channel	Disaster stage	Theme	Information	Expression method
Government	Web, APP, SMS	Normal disaster preparation	Disaster analysis and appraisal	Major typhoon disaster information	Thematic map (vector point, vector line, vector polygon), text
				Disaster analysis in different periods	Statistical table
				Major typhoon damage assessment information	Thematic map (grid)
				Historical information of similar typhoons	Thematic map (vector line), statistical table
				Historical typhoon statistics in high-risk areas	Statistical table
				Capacity assessment information of disaster relief needs	Text
				International major disaster assessment information	Thematic map (grid)
				Natural disaster assessment information	Text
			Disaster preparation precaution	Disaster preparedness warehouses, resettlement sites, relief agencies, hospitals, governments, insurance companies, and other information	Thematic map (vector point)
			Basic environment	Important infrastructure information	Thematic map (vector point)
				Building distribution information	Thematic map (vector point)
				Administrative division information	Thematic map (vector polygon)
				Topographic information	Thematic map (grid), text
				Water system information, traffic network information	Thematic map (vector line)
				Land-use information, vegetation cover information	Thematic map (grid)
				Real-time weather information	Thematic map (grid)
			Social economy	Information on the population in disaster areas, GDP information	Thematic map (grid), statistical graph
				Industrial structure information, urbanization level information, industrial and mining enterprises	Statistical graph
		Imminent disaster warning	Disaster preparation precaution	Disaster preparedness warehouses, resettlement sites, relief agencies, hospitals, governments, insurance companies, and other information	Thematic map (vector point)
				Escape route information	Thematic map (vector line)
			Warning and forecasting	Information of the popular discussion of disasters	Text
				Public opinion monitoring information	Thematic map (vector polygon), statistical graph, text
				Warning information	Thematic map (vector line, grid), text
				Path probability forecast information	Thematic map (vector line), text
				Wind forecast information, rainfall forecast information	Thematic map (vector polygon), text
				Disaster trend prediction and judgment information	Thematic map (vector line), text
				Discussion of expert opinions and suggestions	Text

Table A1. *Cont.*

User	Channel	Disaster stage	Theme	Information	Expression method
Government	Web, APP, SMS	Emergency response in the disaster	Typhoon monitoring	Real-time typhoon information	Thematic map (vector line), statistical table, text
				Rainfall monitoring information, wind monitoring information, typhoon risk assessment information	Thematic map (vector polygon), text
				Typhoon impact information	Statistical graph, text
				Meteorological satellite monitoring information	Thematic map (grid)
				Monitoring information of hidden dangers of secondary disasters	Thematic map (vector point)
				Typhoon impact area monitoring information	Thematic map (grid)
			On-site disaster	Disaster information	Statistical graph, statistical table, text
				Casualty distribution information	Thematic map (vector point, vector polygon)
				Forecast information on the disaster-affected personnel distribution	Thematic map (grid)
				Economic loss distribution information, crop damage distribution information, building damage distribution information, infrastructure damage distribution information	Thematic map (vector point, vector polygon)
				Lifeline loss distribution information	Thematic map (vector point, vector line)
				Traffic damage information	Thematic map (vector line)
			Rescue guarantee	Disaster preparedness warehouses, resettlement sites, relief agencies, hospitals, typhoon escape routes, airports, docks, stations	Thematic map (vector point)
				Rescue personnel distribution information, medical personnel distribution information	Thematic map (vector point)
				Public security information	Thematic map (vector point), text
				Material dispatch information, live rescue information	Thematic map (vector line)
				Traffic control advice information	Thematic map (vector line), text
		Rebuilding after the disaster	Recovery and rebuilding	Social development and reconstruction, educational reconstruction, economic and industrial reconstruction, ecological and environmental restoration, emergency capacity building, fundraising, etc.	Text
				Infrastructure reconstruction information	Thematic map (vector point)
				Transportation reconstruction information	Thematic map (vector line)
			Damage appraisal	Economic loss assessment, housing damage assessment, crop damage assessment, lifeline damage assessment, infrastructure damage assessment, etc.	Thematic map (vector polygon), statistical graph

Table A1. *Cont.*

User	Channel	Disaster stage	Theme	Information	Expression method
Insurance companies	Web	Normal disaster preparation	Insurance statistics	Insurance product information	Text
				Insured information statistics	Statistical graph, statistical table
				Loss risk information of the insured body	Thematic map (grid)
				Spatial distribution information of the disaster-bearing body	Thematic map (vector point, vector polygon)
				Analysis information of insurance loss in key areas	Thematic map (vector polygon), text
		Emergency response in the disaster	On-site disaster	Disaster information	Statistical graph, statistical table, text
				Casualty distribution information	Thematic map (vector point, vector polygon)
				Economic loss distribution information, crop damage distribution information, building damage distribution information, infrastructure damage distribution information	Thematic map (vector point, vector polygon)
				Lifeline loss distribution information	Thematic map (vector point, vector line)
		Rebuilding after the disaster	Synthesis appraisal	Insured loss information of the disaster-bearing body	Statistical table, text
				Estimated data of insurance claims	Statistical table, text
				Claim publicity	Text
				Disaster analysis	Thematic map (vector polygon), text
				Disaster loss statistics	Statistical graph, statistical table, text
				Damage assessment information	Thematic map (vector polygon)
Social forces	APP, SMS	Normal disaster preparation	Risk monitoring	Monitoring information of hidden danger points in high-risk areas	Thematic map (grid)
				Monitoring information of disaster-bearing bodies in typical areas	Thematic map (grid)
				Spatial monitoring information of disaster-bearing bodies in major projects	Thematic map (grid)
			Disaster preparation precaution	Disaster preparedness warehouses, resettlement sites, relief agencies, governments, hospitals	Thematic map (vector point)
				Disaster prevention popular science information	Text, video
			Basic environment	Administrative division information	Thematic map (vector polygon)
				Topographic information	Thematic map (grid), text
				Water system information, traffic network information	Thematic map (vector line)
				Digital elevation information, real-time weather monitoring information	Thematic map (grid)
				Land-use information, vegetation cover information	Thematic map (grid)
			Social economy	Information on the population in disaster areas, GDP information	Thematic map (grid), statistical graph
				Industrial structure information, urbanization level information, industrial and mining enterprises	Statistical graph

Table A1. *Cont.*

User	Channel	Disaster stage	Theme	Information	Expression method
Social forces	APP, SMS	Emergency response in the disaster	Typhoon monitoring	Real-time typhoon information	Thematic map (vector line), statistical graph, text
				Rainfall monitoring information, wind monitoring information	Thematic map (vector polygon), text
				Typhoon impact information	Statistical graph, text
				Meteorological satellite monitoring information	Thematic map (grid)
				Typhoon impact area monitoring information	Thematic map (grid)
			On-site disaster	Disaster information	Statistical graph, statistical table, text
				Casualty distribution information	Thematic map (vector point, vector polygon)
				Forecast information on the disaster-affected personnel distribution	Thematic map (grid)
				Crop damage distribution information, building damage distribution information, infrastructure damage distribution information	Thematic map (vector point, vector polygon)
				Lifeline loss distribution information	Thematic map (vector point, vector line)
				Traffic damage information	Thematic map (vector line)
			Rescue guarantee	Disaster preparedness warehouses, resettlement sites, relief agencies, hospitals, typhoon escape routes, etc.	Thematic map (vector point)
				Disaster relief popular science information	Text, video
				Disaster relief progress information	Thematic map (vector line, vector polygon)
				Information on distribution of relief supplies	Thematic map (vector line)
		Rebuilding after the disaster	Recovery and rebuilding	Infrastructure reconstruction information	Thematic map (vector point)
				Transportation reconstruction information	Thematic map (vector line)
				Fundraising information	Text
General public	Microblog, APP, SMS	Normal disaster preparation	Risk monitoring	Monitoring information of hidden danger points in high-risk areas	Thematic map (grid)
				Information on hidden dangers of disaster risk, historical information on similar typhoons	Thematic map (grid)
			Disaster preparation precaution	Resettlement sites, relief agencies, hospitals, governments	Thematic map (vector point)
				Disaster popular science information, rescue guidance information, insurance product information	Text, video
		Imminent disaster warning	Disaster forecasting	Disaster forecast information, discussion of expert opinions and suggestions	Text
				Disaster warning information	Thematic map (vector line, vector polygon), text
				Rainfall forecast information	Thematic map (vector polygon), text
				Typhoon track forecast information	Thematic map (vector line), text

Table A1. *Cont.*

User	Channel	Disaster stage	Theme	Information	Expression method
General public	Microblog, APP, SMS	Imminent disaster warning	Disaster forecasting	Public opinion distribution information	Thematic map (vector polygon), statistical graph, text
				Wind forecast information	Thematic map (vector polygon), text
				Secondary disaster risk information, secondary disaster monitoring information	Thematic map (vector polygon)
				Disaster development trend	Thematic map (vector line), text
			Disaster preparation precaution	Rescue guidance, resettlement sites, relief agencies, hospitals	Thematic map (vector point)
				Typhoon escape routes	Thematic map (vector line)
				Disaster popular science information	Text, video
		Emergency response in the disaster	Rescue guarantee	Resettlement sites, relief agencies, hospitals, airports, docks, stations	Thematic map (vector point)
				Typhoon escape route information	Thematic map (vector line)
				Rescue guidance information	Text, video
				Rescue personnel distribution information	Thematic map (vector point)
				Traffic damage information	Thematic map (vector line)
		Rebuilding after the disaster	Recovery and rebuilding	Infrastructure reconstruction information	Thematic map (vector point)
				Psychological counseling information	Text, video

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