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Research on the Construction and Application Mode of Digital Plans for Sudden Water Pollution Events

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Abstract: Water pollution is an important aspect of a national water treatment. Sudden water safety incidents are random and destructive, often bringing about huge losses of life and property. Due to the uncertainty of sudden water pollution, it is difficult to respond in a timely and rapid manner. Emergency personnel must deal with emergencies quickly and effectively to reduce the harm caused by these emergencies. The randomness and uncertainty of sudden water pollution events make emergency work more complicated; it is difficult for current emergency plans to play guiding roles in complex responses. The decision-making and use of traditional water safety procedures largely depend on the experiences of command personnel, as well as on the emergency plan, which often has poor applicability. This can result in ineffective implementation of emergency actions and use of resources stemming from the high subjectivity and low efficiency of emergency plans. In this paper, we summarize previous research on digital planning and platform component technology exploration in order to evaluate the use of sudden water safety emergency procedures. We first analyze the main problems in the construction and use of emergency plans (e.g., the lack of experience and adaptability). Secondly, based on the decision-making support platform, a digital emergency plan database for water pollution emergencies was established by using component technology and knowledge map technology. In doing so, the decision support platform could enable the rapid construction of digital plans that improve application efficiency in an actual response scenario. Finally, through the system example, this system model can be quickly matched from the plan database to the emergency plan that meets the current scenario. It is a recommended model used to provide rapid and effective assistance for emergency management and improve emergency efficiency.

Keywords: sudden water pollution events; digital emergency plan; emergency response; emergency plan management; knowledge visualization; decision support system

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1. Introduction

Due to natural disasters, manmade accidents, etc., sudden water pollution incidents frequently occur. These pollutants enter a water body in a short period of time, causing pollution and endangering the normal social order, economic activities, and aquatic ecosystems. The occurrences of sudden water pollution incidents are beyond the scope of normal human disposal; they are generally instantaneous occurrences, with complex performances, destructive consequences, with an urgent need of disposal, and surrounded by uncertainty. It is precisely because of these characteristics that sudden water pollution events are often beyond the scope of human disposal; they seriously endanger the normal social order, economic activities, and water ecological environment [1].

Emergency plans are pre-prepared action arrangements for possible emergencies. The specific work of each emergency phase can be quickly identified in the disposal process through the plan. An emergency plan is a principled plan for emergency response, which plays an operational guiding role in emergency response and in the full disposal of events. Although emergency plan systems have been formed, at present, in response to sudden water pollution events, their guiding roles have not been effectively utilized. Until now, even if emergency measures have (basically) been formed, their value in solving sudden water pollution events has not yet been wielded. For one thing, a lack of concrete precautionary measures, such as experience assistance, plays a pivotal role in successfully solving a real emergency. There is a lack of (specific) directions on how to respond to sudden water pollution incidents, and there are no specific expressions of incident classification, division of responsibility, disposal operations, etc., regarding the occurrence of the incident. Moreover, the application mode is not flexible enough. Most existing emergency response plans are documents in written text, which can neither achieve cross-combinations between available plans nor adapt to changes (regarding time and flexibility) in emergency processes [2]. Therefore, based on modern information technology, one important way to solve current emergencies is to make better use of precautionary measures and to support emergency solutions.

Scientists in European countries have set up corresponding departments to respond to sudden water pollution events. Robert Health proposed an emergency framework for emergencies from a macro perspective, i.e., weakening them from different sources, locations, scopes, etc., around the root causes of disasters, effectively reducing the negative impact of sudden disasters [3]. Most scholars focus on micro-technical processing, such as Deroux, who built a monitoring database for reservoir water quality based on the laws of space–time evolution of organic compounds in surface water [4]. Shafiee Mohammadmehdi analyzed the impact of sudden water pollution events on human water use and realized a real-time simulation by establishing a dynamic transport model of pollutants [5]. Chinese scholarly research on emergency management regarding sudden water pollution events mostly focus on emergency early warning and risk decision-making; i.e., Yu Zhaohui discussed techniques surrounding the early warning of sudden water pollution events [6]. Guo Yuan introduced methods to deal with sudden water pollution in reservoirs [7].

With the development of information technology, information research aimed at emergencies is increasing. The German Emergency Planning Information System (deNIS) was set up to support the jobs of victim managers [8]; the deNISII was set up to provide information services for securing emergencies, to estimate current situations, to confront problems of a disaster, to analyze securing resorts, etc. Integrated emergency management (IEM) boasts such functions as estimating the optional risks of an accident, recognizing the accident, making/evaluating precautionary measures, urgent deployment, etc. [9]. Ohio's Oil and Gas Field Emergency Response System in America provides leaders and operational staff facing emergencies with real-time contingent information; analyzing functions and information could help support the deployment of emergencies in the oil and gas field and in the formulation of solving an emergency [10]. The e-FEMA strategy from the Federal Emergency Management Agency (FEMA) includes an information hierarchical structure for emergencies [11]. Various resources in information systems could be updated, promoting information sharing among the systems, providing a decision-making process to handle emergencies with real-time urgent information and technological support.

Timperio G, from the perspective of operating precautionary measures and real-time information collection for accidents, focused on vague and dispersive information and uncertain dependent relations among urgent activities, setting up a dynamic and static information model to handle urgent activities based on certain task frameworks [12]. Marco Scaioni, considering the necessity to search for appropriate and available data information in different geographical databases during accidents, exploited an application EPM to handle and control emergencies based on GIS [13]. Mark Hoogendoorn put forward a formalized framework based on the urgent analysis and construction of a precautionary measure, applying formalized temporal trace language (TTL) to build a model and expand upon previous research projects [14]. Gheorghe Tecuci put forward an emergent application, Disciple-VPT (virtual planning team), based on the American plan of responding to an emergency, applied mainly to train and simulate maneuvers of precautionary measures [15].

Be analyzing the research, we found that domestic and overseas institutions have set up (relatively fulfilling) emergency systems. However, the ability to collect information and handle emergencies need to be explored [16–19]. Research studies on simulated maneuvers that are suitable for sudden water pollution incidents are relatively insufficient. As time progresses, technology continues to expand; however, we still do not have systematic achievements or complete theories in the current research that could solve sudden water pollution emergencies. Therefore, in an emergency that cannot be prevented, there is a need to respond quickly to the emergency; that is, when emergencies occur, managers should have ways to deal with them. Compared with previous studies, the applicability of an existing emergency plan system is very poor, because the content of the plan and the emergency do not correspond, which makes it difficult for managers to perform their work according to the plan [20–24].

In current digitalized precautionary measures, back-stage database restock and front-stage user check are mostly used, only achieving inquiries, glances, and modifications of textual precautionary measures; organic cooperation among the available multi-precautionary measures cannot be complete without links among the content, law, system, and real case; there is a lack of adaptability and low informatizing levels.

In order to reduce the influence from sudden disasters, to a large extent, digitalized precautionary measures should be built, aimed at handling cases in suitable ways, such as setting a 'case base' to provide complete assistance, analyzing current precautionary measures and case characteristics to build a precautionary mode (to handle water pollution), realizing the digitalized management and flexible applications by dividing and combining each opinion about a precautionary measure, and using visible forms to deploy logical arrangements, according to data, information, the model, and the method organized by the procedure.

In view of the above problems in the response to sudden water pollution incidents, the purpose of this paper was to create a system that could quickly push out emergency plans for sudden water pollution events. In order to achieve the purpose of rapid response and rapid matching, it must be done with the help of information technology. SOA and Java EE architecture were used to build a visualization platform; the logical relationship between businesses is expressed by knowledge map technology, and the business function is realized by component technology. This information mode can enable managers to quickly form effective response plans for different kinds of emergencies. Finally, regarding the system, we provide an example of how to quickly match the plan and apply it. We believe this approach can draw on many areas of emergency response to help emergency managers.

2. Materials and Methods

2.1. Data Collection

Data from the emergency plan were downloaded from the official websites of city governments (Bureau of Emergency Management of Tianjin, Available online: http://yjgl.tj.gov.cn/, accessed on 2 December 2013) and counties directly under the central government (Ministry of Emergency Management of the People's Republic of China, Available online: https://www.mem.gov.cn/, accessed on 1 November 2018). The various levels of water pollution event profiles are stored in a local database so that they can be invoked later in component-based development.

2.2. Support Platform

SOA is a software architecture designed with service orientation at its core, enabling the separation of business and technology, which communicates through interfaces between different services without involving the underlying programming interface and communication patterns by building a service architecture that is coarse-grained, loosely coupled, with location and a transparent transmission protocol. By combining the different services of the application with good interfaces and standards, the service components scattered in the distributed environment are integrated into a new whole process, and the user is provided with services in the form of components to solve the heterogeneous problems faced in the distributed application system based on the components. Using SOA and Java EE architectures, a comprehensive integrated support platform for knowledge visualization has been developed [25]. Users can build a variety of theme application services on the platform. The platform is the carrier, and the knowledge map is the tool to describe the logical relationship. Business process relationships can be expressed by drawing knowledge maps, and components can be customized to enable business functions. The platform provides a business environment, which provides a strong support and guarantee for the business environment regarding emergency management of sudden water pollution events [26].

2.3. The Assembly of Precautionary Measures Base

In the process of solving an emergency, besides precautionary measures being used in decision assistance, we usually depend on the solving experiences of decision makers themselves. Therefore, analyzing real cases that took place before is an effective way for a decision maker to improve his/her experience in solving a similar case. The combination of precautionary measures and real cases could improve the operating efficiencies in solving emergencies using these precautionary measures and reduce unreasonable behaviors that lack overall viewpoints in solving emergencies.

A precautionary measure 'base' for an emergency should be built. Files on precautionary measures, laws, regulations, and regulating systems to solve water pollution are massive, because state-owned and local enterprises all have corresponding precautionary measures for emergencies. According to different characteristics designed on the bases of level and district divides, precautionary measures are classified and managed, providing application with foundation. The classification tables of emergency response plans at different levels are shown in Table 1.

Table 1. Part of the pre-plan hierarchical management table.

Code	Grade	Administrative Divisions	Type	Plan
1	National	National	emergency plan	National emergency plan for water pollution emergencies
2	Municipal	City	emergency plan	Emergency Plan for Sudden Water Pollution Incidents in Beijing
3	Municipal	City	emergency plan	Emergency Plan for Water Pollution Incidents in Tianjin
4	District and County	District	emergency plan	Emergency Plan for Sudden Water Pollution Incident in Changping District
5	Company	/	emergency plan	Emergency Plan for Water Pollution Incidents of Water Supply Company
6	Company	/	Regulations	Guiyang Railway Investment Corporation's emergency handling system

A real case base should be built. Normal cases could be handled by following stages. Firstly, when an accident occurs, an abnormal 'inspecting' alarm or public report will be received. Previous management will be 'applied', according to the relative situation. The professional team will have discussions while the operational staff and supplies are sent to the emergency spot. The discussed managing project will be sent to the spot. After the emergency is under control, remedial work will proceed, and the leadership and professionals will have to make conclusions and estimations of the process of handling the emergency. Analyzing previous water disaster cases and simulated maneuver cases, referring to the process–managing mode, sequenced according to time, the normal procedure of a case is usually divided into three stages—preparation before the case, management during the case, and management after the case. Extracting the key points from each stage, we can divide the main work of each stage in detail. According to the divided models, information of a case is written into a standard precautionary model, and the case will be a precautionary measure, from which we can search details to solve an emergency and provide experience for a decision, as shown in Figure 1.

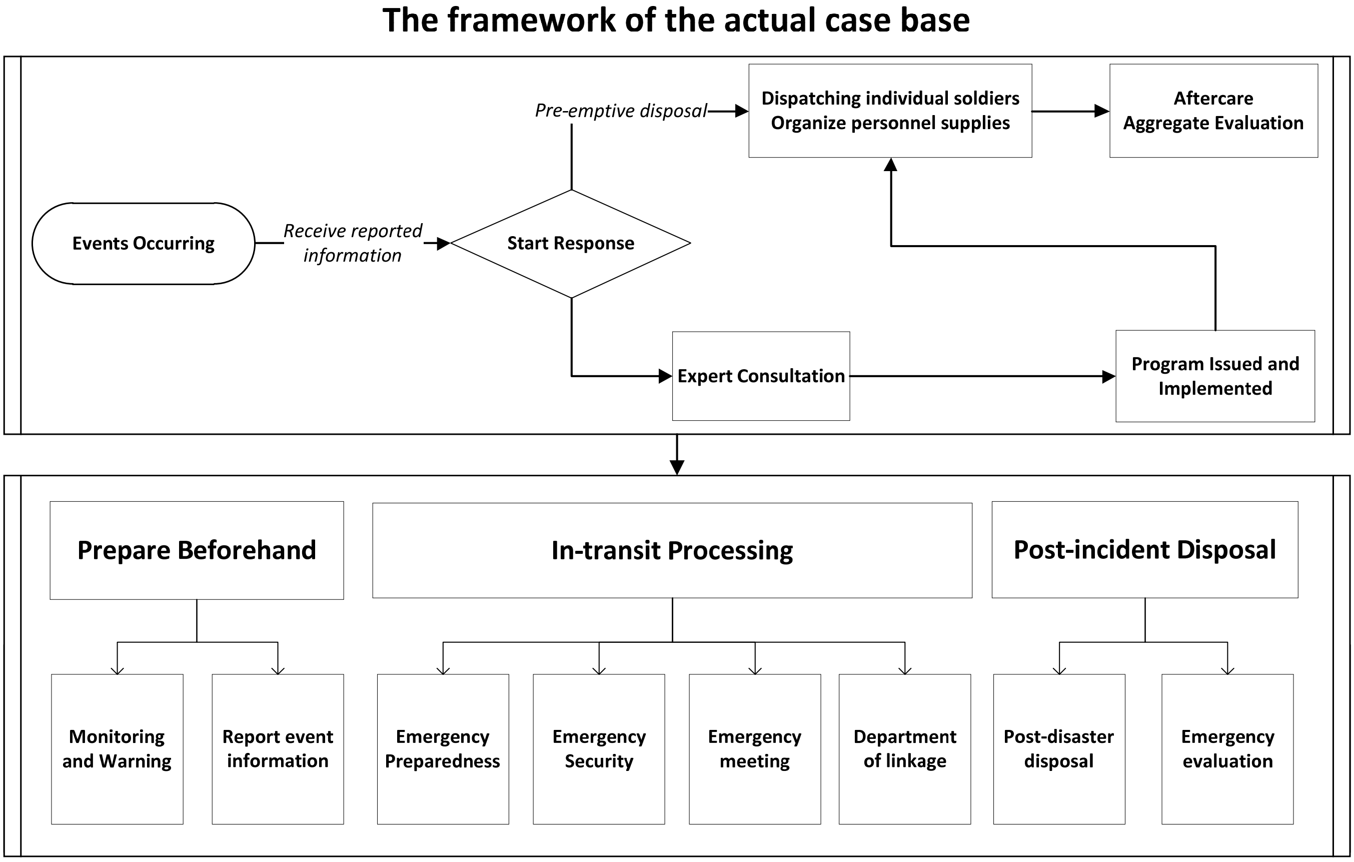


Figure 1. The framework of the actual case base.

2.4. Construction Method

Regarding the construction of traditional precautionary cases—there is more of an emphasis on showing the content, but not on the connection between precautionary measures and real cases. In the precautionary measures, there is no targeted or specific case/detailed solving method. Through contractually dismantling precautionary measures, the working content of an emergency is extracted and filed in a precautionary database by building a knowledge graph. In the application, suitable entries are inquired about and extracted constantly according to real situations, and digital precautional measures are built quickly to adapt to current emergencies on the basis of describing the procedure of precautionary measures, as shown in Figure 2.

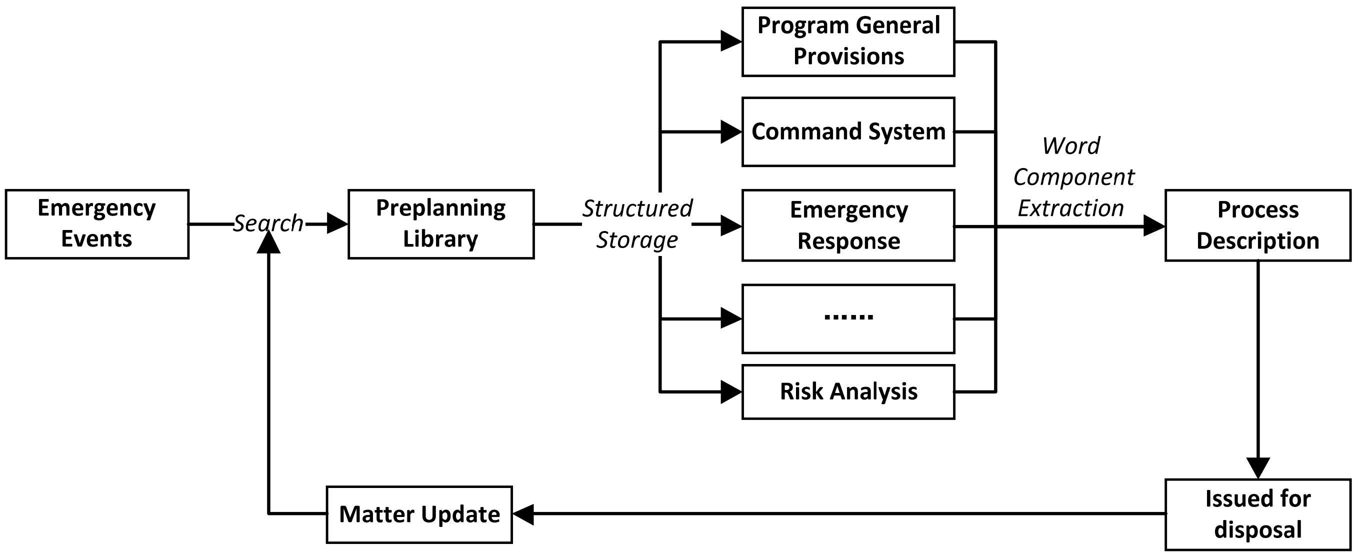


Figure 2. Digital plan construction technical frame diagram.

(1) Structural dismantle. Horizontal dismantle means that, based on the chapter and concrete content of precautionary measures, precautionary measures are dismantled structurally according to different level. Working contents to handle an emergency, after being analyzed and extracted stage-by-stage, are packaged and stored separately, as shown in Figure 3.

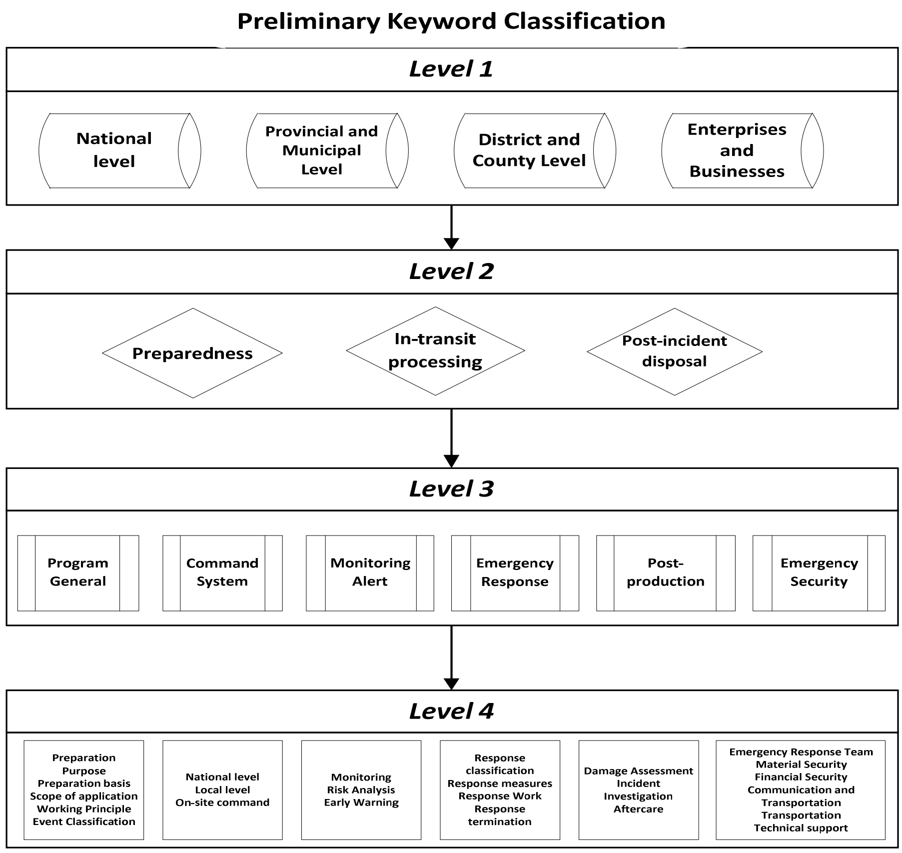


Figure 3. Pre-plan structure classification table.

Vertical dismantle means utilizing special keywords to separate these cases according to the causes or handling methods. Moreover, those cases are packaged and stored according to the causes and handling methods. The specific classification is shown in Table 2.

Table 2. Keywords of emergency water events.

Classification Basis	Factor 1	Factor 2	Factor 3
Cause of Accident	Pollution caused by traffic accidents	Oil pollution	Petroleum substances
	Pollution caused by production accidents	Heavy metal pollution	zinc, etc.
	Pollution caused by natural changes	Aquatic Biological Pollution	Algae
	Pollution caused by wastewater discharge	Chemical pollution	Mercury, etc.
	Pollution caused by natural disasters	Construction waste pollution	stone
	Pollution caused by manmade damage		
Disposal Methods	Engineering measures	Emergency Dispatch	
	Non-engineering measures	Adsorption interception	
		Catalytic oxidation	
		Biodegradation	

All precautionary measures or cases, matched according to specific keywords inquired through a fuzzy query function, were filtrated. Moreover, part modules of those precautionary entries or handling methods suitable to the current real situation were extracted, so that quick construction responding to previous precautionary measures and the project to adapt change in the duration were achieved.

(2) Construction of precautionary measure modules. With the help of technologies, such as module technology and Web Service, constructions, such as J2EE and SOA, and procedures, such as business extraction and classification, module dismantling, exploitation, registration and publishment, working content, case information, and handling methods dismantled in precautionary measures, cases are exploited and filed into imputing and outputting standard modules [27]. Building a business application module base could support the management and the adaptable application of digital precautionary measures. The planned component development process is as follows:

Step 1: build a new project on the file menu and name it. Compile new Java code that a program needs in the "*scr*" file package in the project file.

Step 2: edit the interface accustomed by a user and the Jelly file corresponding to the main Java program.

Step 3: according to the edited Jelly file, make sure the "*LOVResponse*" receptor will be used in the Jelly file, including the methods of "*getLOV*()" and "*getLOVSchema*()".

Step 4: make sure the "*ActionCode*()" corresponds to each main program in "*ActionResponse*" and complete the registration in the "*ActionRegistray*()" method.

Step 5: in the "*ActionHelper*()" method of "*ActionResponse*", return to step 2 to make the Jelly file.

Step 6: compile input "*SCHEMA*" and return the "*ActionInputSchema*()" method in "*ActionResponse*".

Step 7: compile the "*execute*()" method in "*ActionResponse*", achieve the case detecting and searching function and return with the "*XML*" form.

Step 8: output the result with the "*SCHEMA*" form.

Step 9: return the module name through the "*ActionName*()" method in "*ActionResponse*". The flowchart is shown in Figure 4.

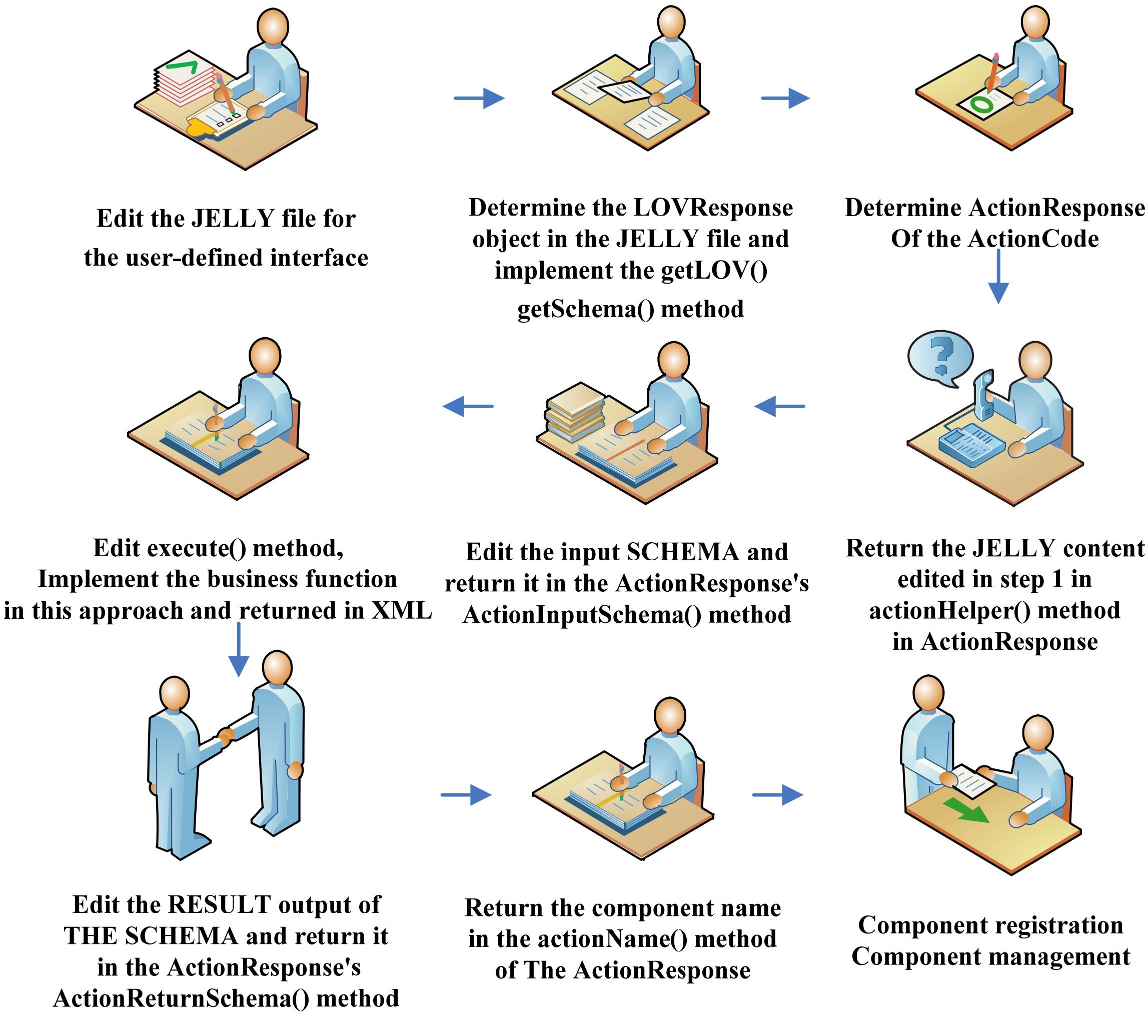


Figure 4. Development process diagram.

After the component is developed, the encapsulation process is as follows.

After the module is exploited, Web Service technology will be needed to package the module into standard form in accordance with Web Service. Then, the module should be registered in UDDI and deployed to the server that is needed.

Step 1: set up the exploiting environment. Choose the Tomcat applicating server and configurate corresponding environment variants. Set up Axis (based on Java language and published in the web application form.)

Step 2: package module. With help from the exploiting application, package the module and build a new file with ".aar" as the name suffix.

Step 3: upload the module. Uploading of the module is relatively easy. If the Tomcat servicer is built in a local computer, open the starup.bat in the Tomcat file and enter http://localhost:8080/axis2-1.1.1. Then, upload the packaged file after user log in.

Step 4: publish the server. The website address is http://localhost:8080/uddibrowser. After one enters, logs in, and registers, fill in the entrance URL that a service needs, and then publish it on the internet. All services could be inquired in uddibrowser. Part of the code for the development process is shown in Figure 5.

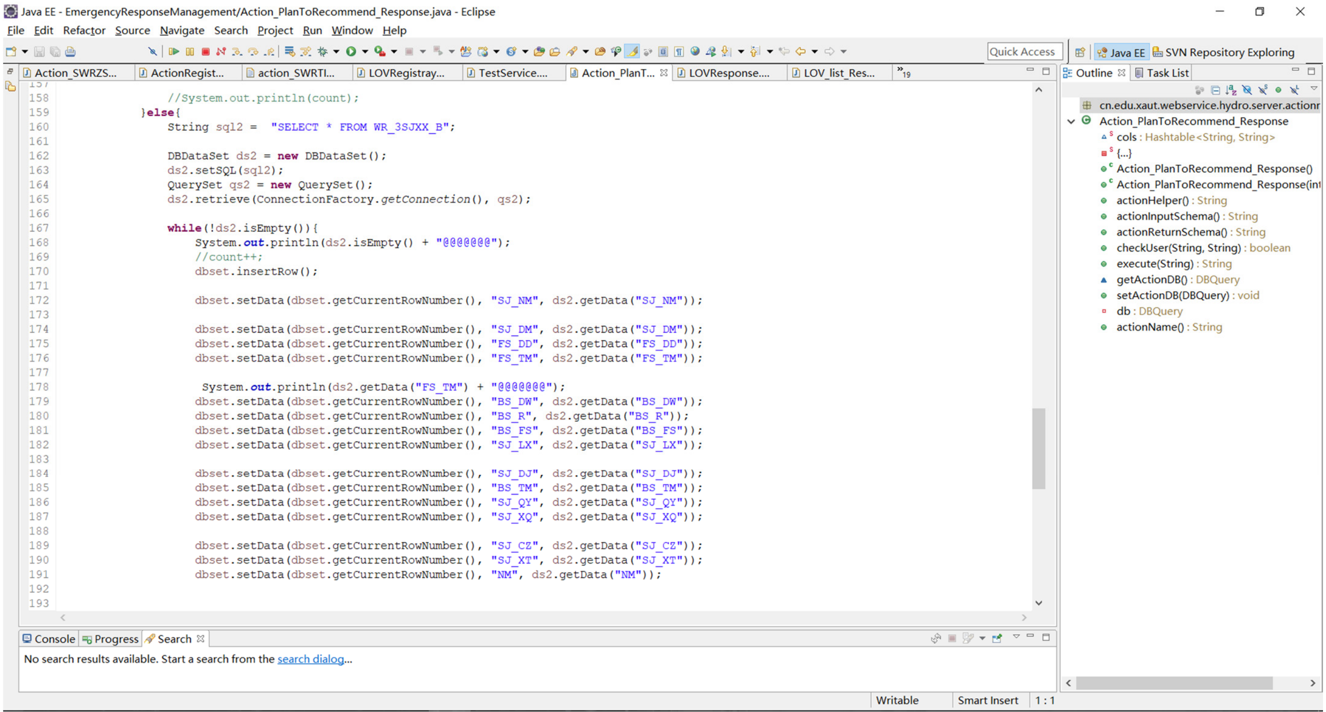


Figure 5. Part of the code for the development process.

2.5. Streamlined Description

The streamlined description combined with graphs can simulate people's minds, changing random and illogical information into highly organized graphs and expressing them. That is what is called a streamlined description. Based on the thinking of service combination, the assembling technology is applied to package modules and compile business procedures. Based on the visible platform in a graphical way, the business procedure is shown to improve the flexibility of business procedure. Moreover, the visible effect, based on the research and achievement of knowledge graphs, can help us understand the streamline deduction toward an emergency. The handling procedure of an emergency could be recorded in the figure.

Regarding the framework and chapter content of such precautionary measures of water pollution, in combination with the overall framework of the emergency handling platform made by the nation to solve an emergency, the standard handling procedure of an emergency should be built, including pre-emergency inspection guarantees, emergency discussions and cooperation, post-emergency management estimations, and other procedural modules. The procedure framework is shown in Figure 6.

Regarding precautionary measures, a precautionary measure module that is exploited should be filled with relative concrete content (of precautionary measures) with the help from module technology, to achieve the digital precautionary measures, to handling procedures and business logic, as well as the exhibition of related information, models, and methods. Based on the precautionary measures, business applications and the deduction of modularized precautionary measure procedures of each stage, direct visibility of precautionary measures could be completed.

Data transfer and change between knowledge pictures are usually stored in XML form. When used, the reflection relation between the information of the conception, link, and source in a knowledge picture and the XML file should be built in advance; the data flowing direction and module information should be described and the relationship between the file information and knowledge picture should be analyzed, so that the user can achieve flexible customization of system construction, modification, and business applications by using the working procedure in the application system according to XML, modifying the module of the knowledge picture. The business module in a knowledge picture features visible characteristics, which provides user with various business activity situations and the data flowing exhibition project, achieving knowledge visibility and showing users direct decision-making processes and outcome exhibitions. The knowledge picture could effectively describe overt knowledge in normalized and systemized ways, as well as show the description of covert knowledge and the procedure of transferring overt knowledge into covert knowledge.

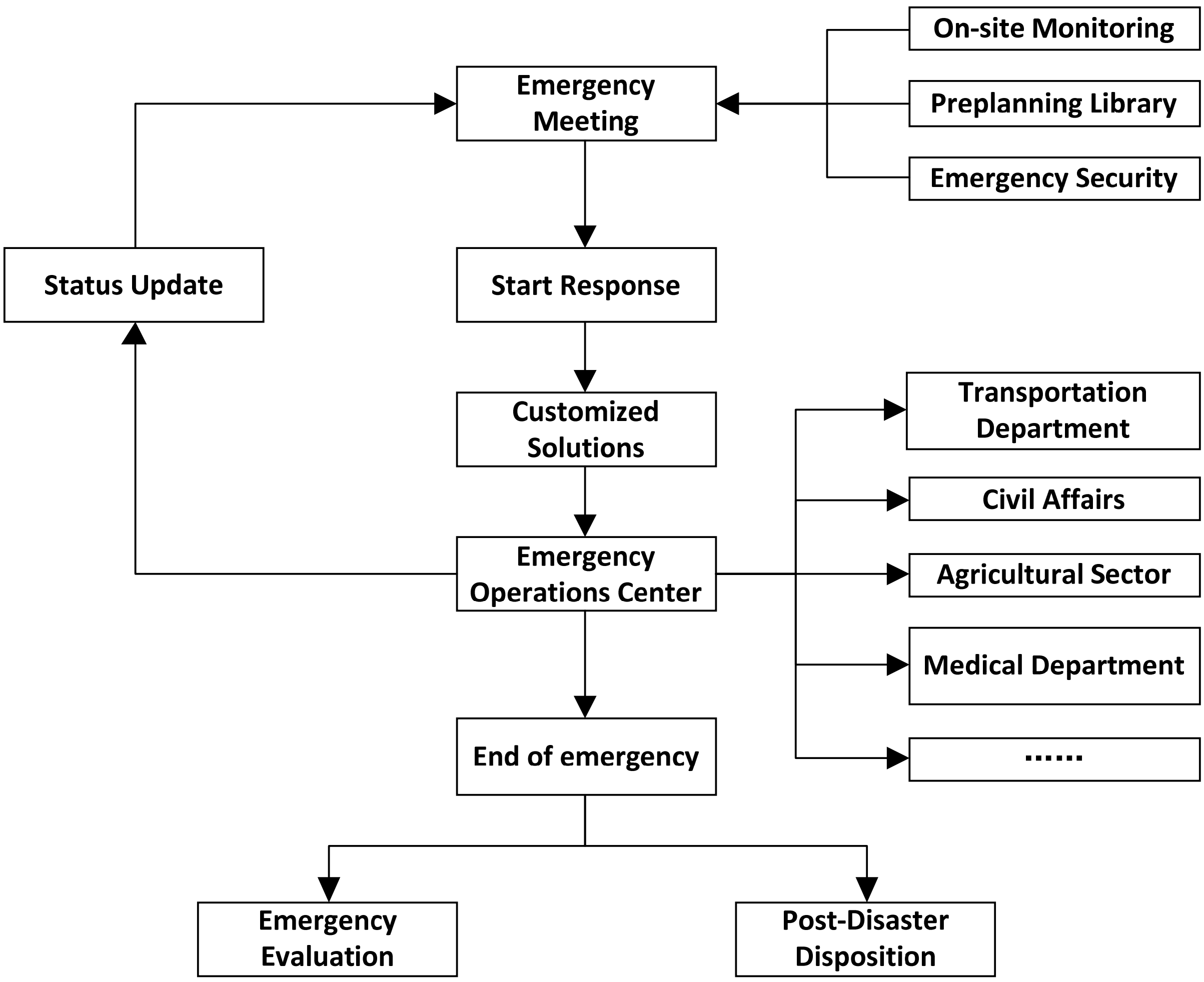


Figure 6. Modular standard disposal process.

3. Adaptive Application Models

Application is the criterion used for judging the value of a precautionary measure, and dynamic adaptation and operability are important manifestations of the application value of digital precautionary measure. Relying on the form of the process knowledge diagram to show the overall process of disposal, and using node components, the usability of the precautionary measure is realized; in response, by adding and deleting components to the corresponding nodes on the framework diagram of the precautionary measure, the rapid precautionary measure is realized. In the response, the precautionary measure can be built quickly and adapted to the development of the situation by adding and deleting components to the corresponding nodes on the precautionary measure framework. The textual emergency precautionary measure is transformed into a practical emergency response plan that meets the current situation and guides the response and emergency management of water pollution incidents. The framework is shown in Figure 7.

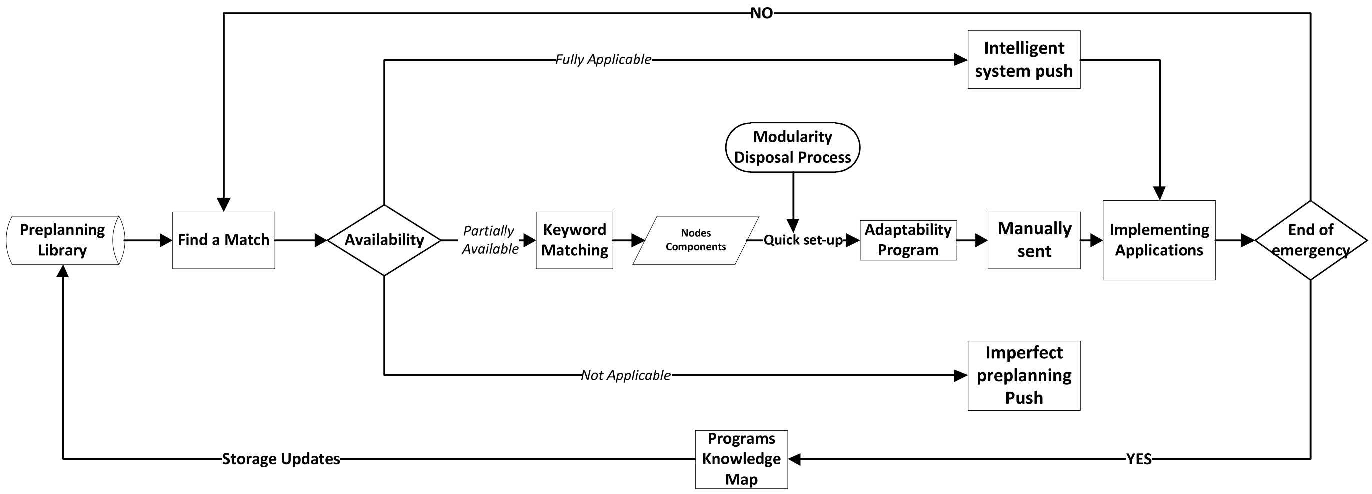


Figure 7. Modular standard disposal process.

3.1. Three Application Modes

(1) The system intelligently pushes; that is, the digital precautionary measure management platform can intelligently generate precautionary measures to push to users according to the current information, to realize the rapid application of the precautionary measure. According to the current input information, the system matches the extracted keywords with the phrases in the precautionary measure library and pushes the application after a small-scale adaptation of the same instances that have occurred before.

The system intelligent push of precautionary measures mainly responds to events that already have perfect disposal experiences. If an emergency event that has already occurred recurs, the system pushes out existing emergency response experience. For this type of emergency, the precautionary measure itself has the highest degree of "adaptability" because the precautionary measure library contains the previous application of the precautionary measure and disposal cases of the event.

(2) Human involvement in pushing. Due to the complexity of emergency response, in most cases, the precautionary measure cannot directly fit the process of handling the situation. In order to deal with the poor "adaptability" of this kind of precautionary measure, human participation is needed to modify the precautionary measure and push it to the application. First, according to the keywords entered by the front-end, the system precautionary measure library is matched. Then, according to the development and changes of the situation, the corresponding node components are modified in the matched precautionary measure modular disposition process to realize the rapid formation of the response plan. Then, according to the feedback information after the plan is issued and executed, real-time modification is carried out, and the response plan is provided continuously until the end of the emergency.

(3) Imperfect intelligence precautionary measure push. There is a situation in the emergency response; that is, "a new event that has not happened at all, without any similar and available precautionary measure". For this type of emergency, since it is impossible to match the available precautionary measure, the system can push out the modular disposal process framework of the digital precautionary measure, and according to the specific situations of real events, use the components in the framework to quickly build and issue the plan for execution. Since the system pushes out the precautionary measure process framework, the content of the plan needs to be prepared by the decision maker according to the actual situation, so this application mode is an imperfect intelligence 'pushing' precautionary measure.

3.2. Precautionary Measure Matching Acquisition

The precautionary measure is obtained using case-based reasoning techniques. Case-based reasoning (CBR) is a newly emerged method for problem solving and knowledge inference in artificial intelligence. The basic process: when a new problem arises, the system searches and retrieves the original instance database according to its relevant features to find the candidate instance with the most similar features to the new problem, and then reuses this candidate instance. If the solution of the candidate problem is not satisfactory, it can be modified to fit the problem to be solved, and finally the modified example is stored in the example base as a new example to be used as a new reference to solve the problem when a similar problem is encountered in the future. The reasoning process of CBR is as follows: (1) it retrieves the relevant examples similar to the new problem from the example base according to the characteristics of the new problem; (2) it retrieves the relevant examples from the retrieved, selecting the most similar examples or cases from the retrieved examples or by combining multiple examples to form a solution to the new problem; (3) it makes a revised solution to the new problem, verifying the obtained solution; (4) it stores the solved new problem as a case in the example base for future use. By extracting the characteristic keywords of the sudden water pollution event, the relevant process-oriented precautionary measure can be retrieved from the precautionary measure library, and after similarity selection, the precautionary measure with the highest applicability to the current sudden event is obtained as the emergency management solution [28]. The flow chart is shown in Figure 8.

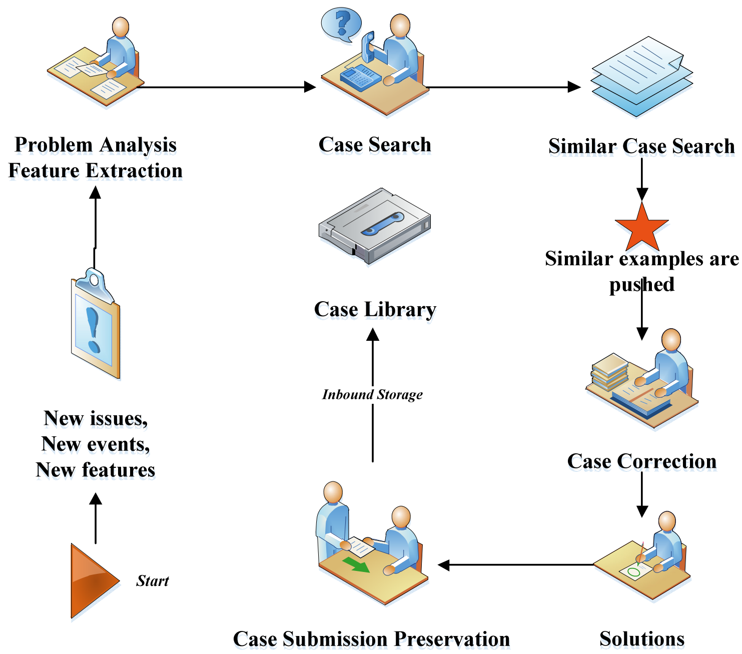


Figure 8. CBR workflow.

3.3. Adaptive Modifications of Precautionary Measure

The precautionary measures acquired through matching are more or less modified and newly created to achieve interconnection with emergencies due to differences in the degree of adaptation. Modifying the emergency precaution measure to adapt to the current emergency management requirements is valuable when implementing emergency solutions.

By adding and changing node components on the knowledge graph of the process-oriented precautionary measure, adaptive changes of the precautionary measure with the development of events are realized. Based on matching the precautionary measure, new components are created or applicable components are searched for, quick responses, according to specific events; applications are continuously issued, and then changes continue to be made according to the feedback information of implementation, which is continuously applied, accumulated, and improved.

Each disposal over the event processes precautionary measures stored in the database. With the continuous responses, the program knowledge map and components are constantly enriched to expand the existing emergency solution database. When a similar event occurs, the knowledge map of the scenario is acquired, modified, adapted to the real situation, and stored while being used, so that it is continuously accumulated, adapted, and developed. The open and growable precautionary measure and scheme involve the process of knowledge inheritance, accumulation, and expansion, in which the combination of multiple topics and the growth of the knowledge system, from a simple description and seminar process, gradually approach the complexity of the problem, realizing the human–machine combination and scientific decision-making.

The visual description is divided into three steps: first, the subject of the visual description as well as the information to be described under the subject are made clear; second, the appropriate description method according to the actual situation on the basis of the subject and information are chosen; finally, the visual description knowledge diagram is drawn on the comprehensive integration platform. The visual description process is shown in Figure 9.

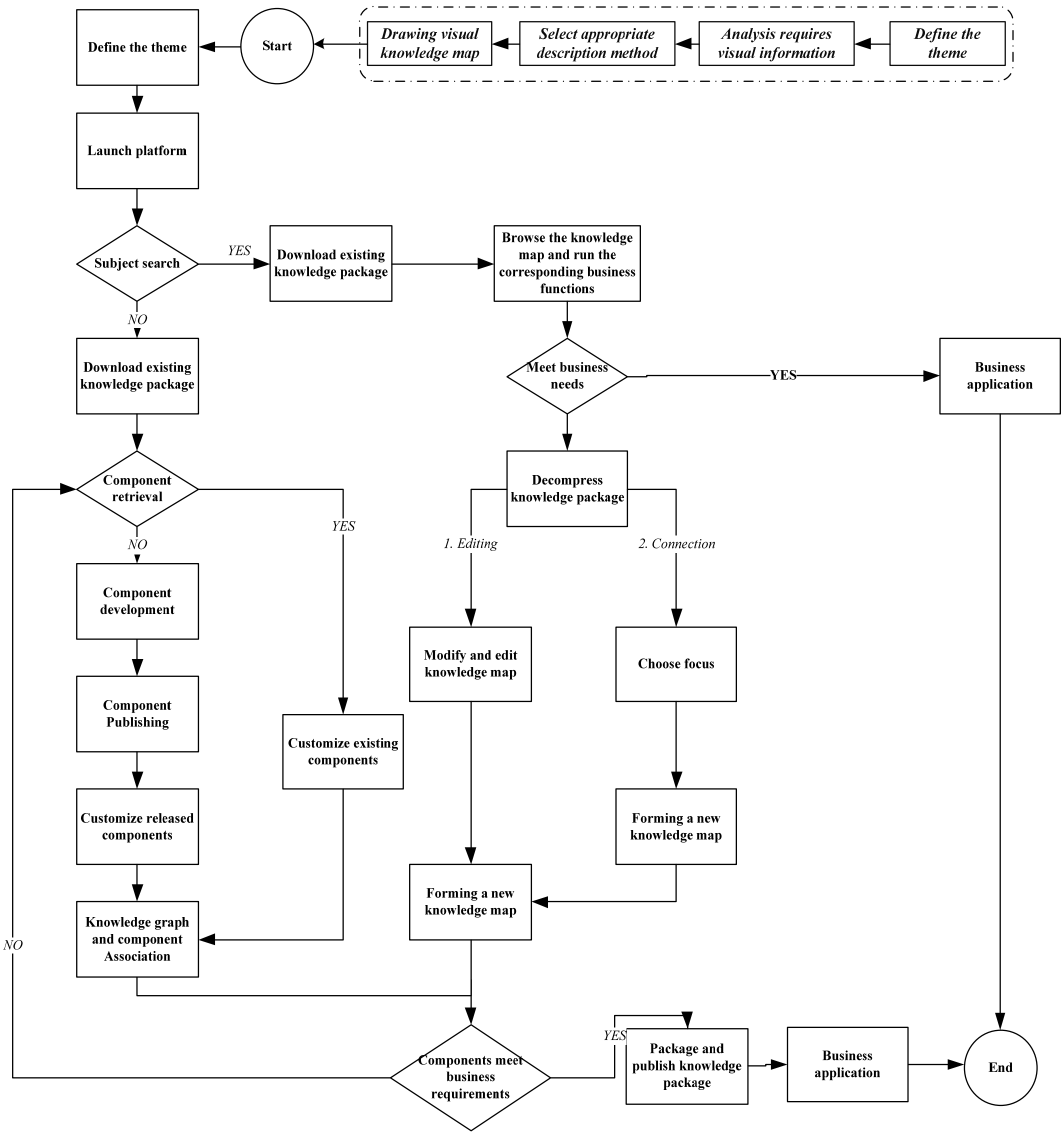


Figure 9. Visual description process.

Through visual expression, we built a digital pre-planning system of the platform. The visual part of the main interface is the processing process for emergency management, and the function is implemented through custom components under each node. The main system interface is shown in Figure 10.

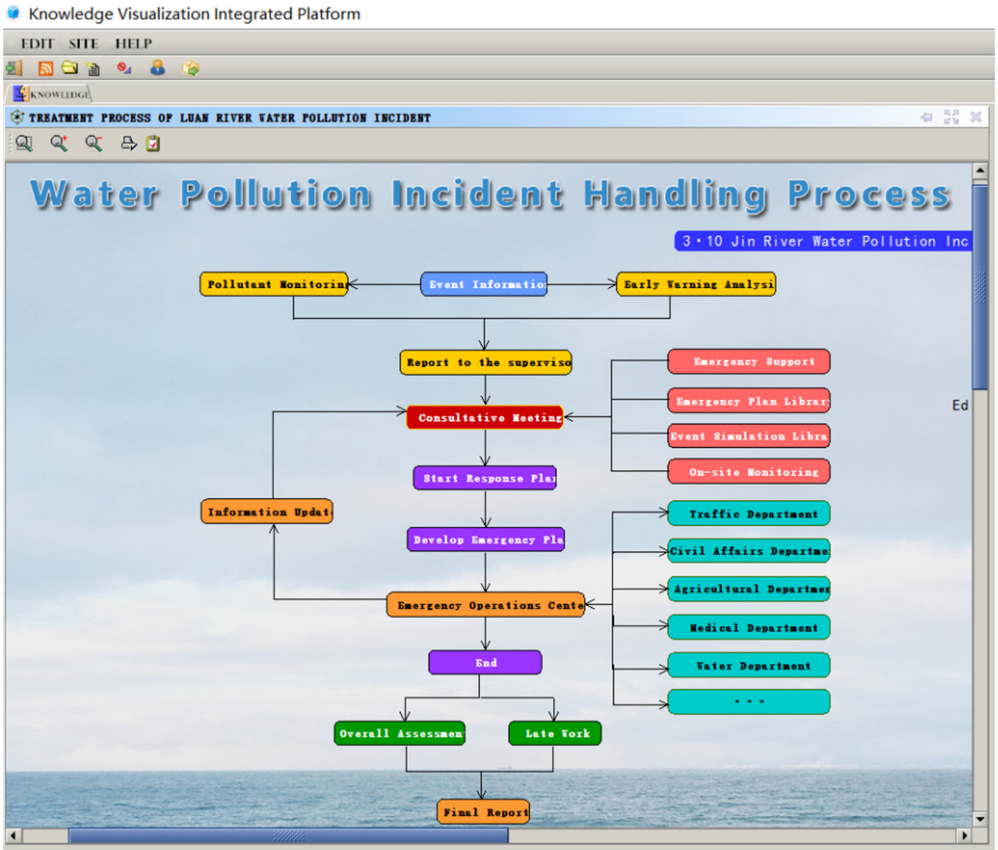


Figure 10. The main interface of the system.

4. System Application

The digital precautionary measure is based on a water pollution event in the Luanjiang–Tianjin river. The Luanjiang–Tianjin project is an urban water supply project that brings the Luan River from Hebei province to Tianjin, across the river basin. With the Panjiakou Reservoir as the water source, the project alleviated the water supply difficulties in Tianjin, improved water quality, reduced the intensity of groundwater extraction, and stabilized the ground subsidence in Tianjin city. The project starts from Panjiakou Reservoir and Daheiting Reservoir, and enters the Yuqiao Reservoir in Jixian County, Tianjin, through the main water transmission canal through Qianxi and Zunhua, with a total length of 234 km. Due to the wide range of the scope involved, the pollution situation is often complex and changeable, including reservoir aquaculture pollution, mineral sand pollution, domestic pollution, agricultural pollution, etc.

The water quality of the main water source in the bridge reservoir is the national surface water class IV; the total nitrogen seriously exceeds the standard. The total nitrogen value of the bridge reservoir in 2013 was 5.01 to 4.44 mg/L, which was higher than the national surface water class III; 1.0 mg/L standard. The total nitrogen and iron of the water entering the reservoir exceed the standard and cannot meet the three standards of surface water and drinking water requirements. Through the integration of data and historical experience, the digital plan has established a response mechanism model of timely response and flexible adaptation, and improved the supervision and emergency response capabilities of water environmental protection management, from the aspects of organizational coordination and organizational action. Through the modular organizational platform, the water management responsibilities among upstream and downstream, different levels, and different departments, are coordinated, and the "written plan" is further effectively transformed into a "disposal action", the emergency disposal task is implemented, and the quality of emergency management is improved. At the same time, in the event of a major environmental pollution incident, it can also cause significant harm. The river, emergency materials, text precautionary measures, other related objects, and water pollution emergency processes involved in the area were analyzed, extracted, and designed, and then a digital precautionary measure for the area was designed and implemented in accordance with the digital approach of this paper.

In the emergency response, we extracted keywords based on the front-end event information, and searched for similar precautionary measures in the precautionary measure database, such as "water pollution", "Tianjin", and other event features and keywords. The precautionary measures library automatically gives the required structured words. The query results are shown in Figure 11.

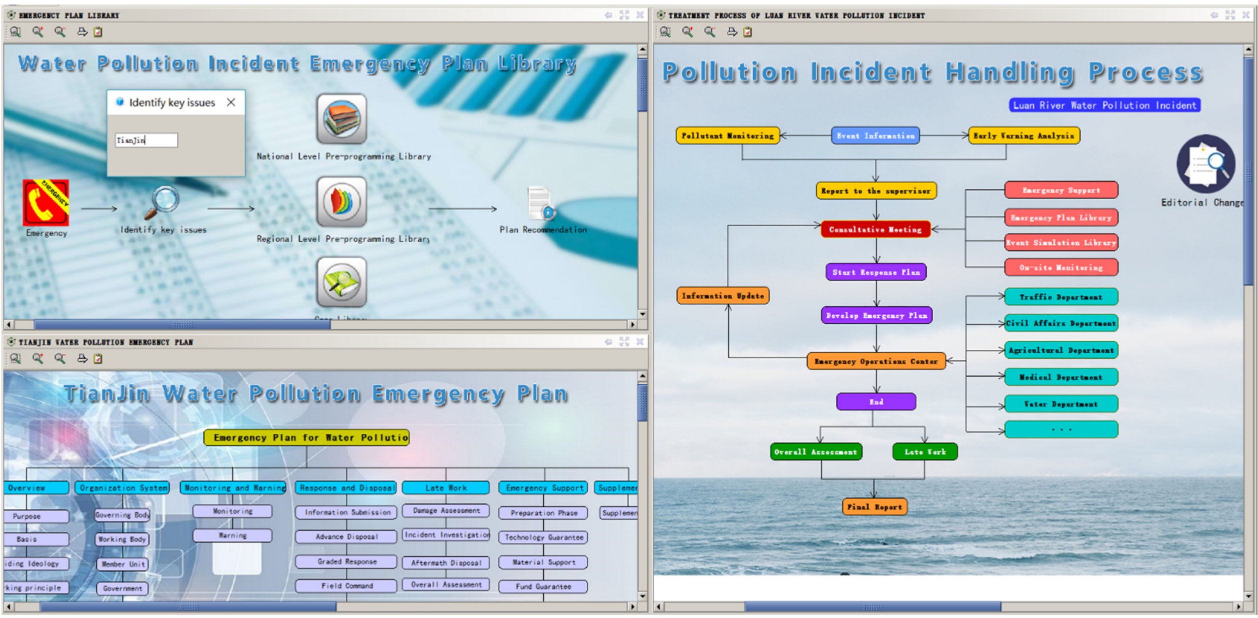
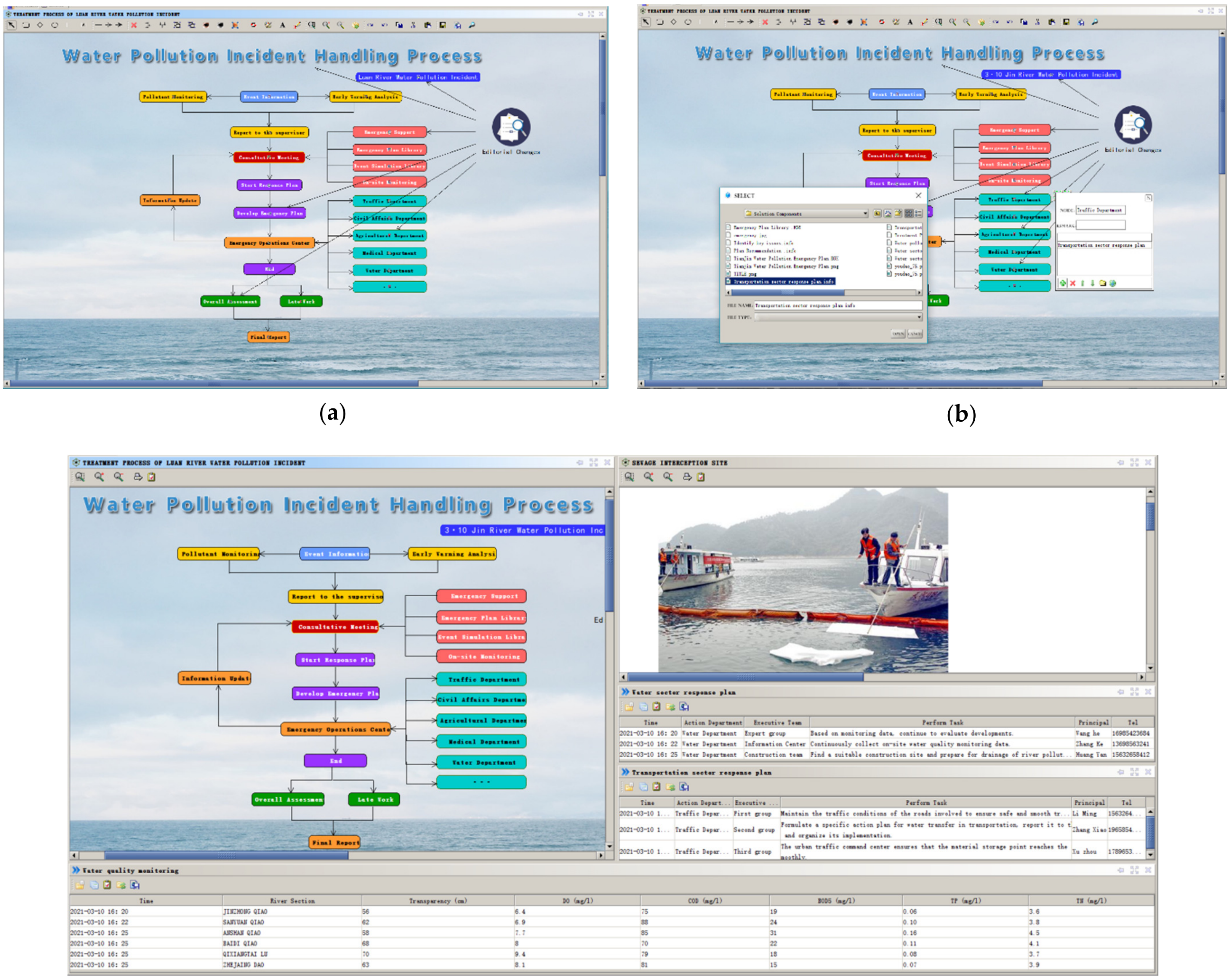


Figure 11. Pre-plan query matching results.

According to the event situation, the word components of the precautionary measure or the disposal components in the case are quickly added to the modular disposal process; the required digital precautionary measure is quickly assembled and built by combining to dynamically adapt to different events. Finally, the precautionary measure is transformed into an applicable and reliable knowledge graph scheme by combining with emergency resources. The result of the digital plan generation is shown in Figure 12.

As the situation progresses, the knowledge graph is continuously improved by adding and deleting components until the emergency situation is over. Finally, the completed knowledge map is uploaded into the example case library to reserve as experience for the next emergency.



(a) (b)

(c)

Figure 12. The result of the digital plan generation. (**a**) Emergency process knowledge drawing. (**b**) Add components and modify. (**c**) Save and generate a new plan.

5. Discussion

The contingency plan for traditional water pollution incidents is based on specific pollutants and events (Figure 2). This approach is often aimed at specific pollutants and pollution situations, with clear directionality. Once the event changes, such as the appearance of mixed pollutants that need to adjust the plan, it is difficult to continue to use the original plan at this time [29–31]. In response to this phenomenon, it is necessary to propose a solution based on the existing plan and quickly generate a new action plan.

The construction framework of the case library mentioned in this article is built on the basis of the incident disposal process. The case database can be applied to the entire process of event response; that is, clicking on the corresponding nodes of different links on the system can display the corresponding event information and the current proposed action plan (Figures 11 and 12).

Rapid response and adaptability are reflected in the concept of an "emergency plan database", where the knowledge graph can be edited, corresponding to changes in emergency processes. Similarly, the functions of each node can be changed and customized, corresponding to the creation of new components through programming. Each time a knowledge graph is saved, a new course of action is generated and stored in the database

(Figures 4, 5, 8 and 9). In this way, the more scenarios that accumulate in the database, the higher the value of the scenarios that can be referred to in the future.

In this article, we sought to establish a digital plan library and propose a model for the application of plans that are suitable for the whole process of emergency management. The matching accuracy and rapid response of the system will be studied in future work.

6. Conclusions

Due to the rapid development of the economy, environmental pollution accidents are not uncommon, particularly sudden water pollution incidents. There are many problems in the current response process; because there is no systematic solution, blind responses to these events often miss their opportunities. In view of the complexity of emergency disposal work and the characteristics of the dynamic development of emergencies, based on summarizing and integrating conventional handling methods for emergencies, we conducted a visual emergency response plan for sudden water pollution incidents based on the emergency management platform, and realized the application value of the scheme in water pollution emergency response work through simulation of actual cases.

We explored and designed a digital emergency precautionary measure for water pollution emergencies. First, it analyzes the problems related to the construction and application of the traditional emergency precaution measure, and offers a process-oriented construction method for the emergency precaution measure of water pollution emergencies by splitting the principles of the preparation of the emergency precaution measure and the event disposal process. Second, in this paper, SOA and Java EE architecture were used to develop a pre-push system for sudden water pollution events, which could realize three levels of digital planning push. For events that have occurred before, the system can quickly push the existing disposal experience; for similar events, the system can use fuzzy query, or the CBR model can be artificially modified to participate in the plan for events that have not occurred; the system can push the plan template, the user, according to the development of the current event, quickly, to form a new plan. This method can support the rapid construction and dynamic changes of precautionary measures, and improve the practicality of precautionary measures in practical applications.

In the next step, we will continue to improve the digital precautionary measure system and further combine with GIS, simulation, the mock-up system, online evaluation, etc., to realize artificial intelligence methods, such as pollution state reasoning and comprehensive evaluation of disposal, to make decision support for the whole process of emergency response.

7. Patents

We applied for a Chinese computer software copyright using the relevant results of this article; the registration number is 2018SR788164.

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References

1. Claborn, D.M. Review of Security and Emergency Planning for Water and Wastewater Utilities. *J. Homel. Secur. Emerg. Manag.* **2011**, *8*. [CrossRef]
2. Jiang, R.; Han, H.; Xie, J.; Li, F. The new response mode of urban storm flood under changing environment. *J. Catastrophol.* **2017**, *32*, 12–17. [CrossRef]
3. Robert, H.; Wang, C.; Song, B.; Jin, E. Translation. In *Crisis Management*; CITIC Press: Beijing, China, 2004; pp. 35–36.
4. Deroux, J.M.; Gonzalez, C.; Cloirec, P.L.; Roumagnac, A. Long-term extractable compounds screening in surface water to prevent accidental organic pollution. *Sci. Total Environ.* **1997**, *203*, 261–274. [CrossRef]
5. Shafiee, M.; Zechman, E.M. An Agent-Based Modeling Approach to Evaluate Protective Action Strategies in a Water Distribution Contamination Event. *Am. Soc. Civ. Eng.* **2011**, *414*, 276–282. [CrossRef]
6. Yu, Z.; Xia, J.; Ren, H. Water Pollution Accident Emergency Response and Early-Warning Model in Gansu-Ningxia-Inner Mongolia section of the Yellow River. *Yellow River* **2014**, *36*, 37–40.
7. Liu, D.; Liu, M. Research progress on risk analysis and emergency management of sudden water pollution accidents. *China Public Saf. Acad. Ed.* **2009**, *1*, 167–170. [CrossRef]
8. Shao, Y.; Ingo, B. Crisis prevention information system in Germany. *Inf. Constr.* **2005**, *8*, 46–48.
9. Li, X. The characteristics and implications of British emergency management. *Adm. Manag. Reform* **2010**, *3*, 54–59.
10. Fan, W.; Yuan, H. Current Situation Analysis and Countermeasures of Emergency Platform Construction in China. *Inf. Constr.* **2006**, *9*, 14–17.
11. Deng, S. American Emergency Management System and Its Implications. *J. Chin. Acad. Gov.* **2008**, 102–104. [CrossRef]
12. Timperio, G.; Tiwari, S.; Lee, C.K.; Samvedi, A.; de Souza, R. Integrated Decision Support Framework for Enhancing Disaster Preparedness: A Pilot application in Indonesia. *Int. J. Disaster Risk Reduct.* **2020**, *51*, 101773. [CrossRef]
13. Scaioni, M.; Alba, M.; Rota, R.; Caragliano, S. A GIS-Based SW Prototype for Emergency Preparedness Management Applied to a Real Case Study. In *Proceedings of the International Conference on Computational Science & Its Applications, Seoul, Korea, 29 June–2 July 2009*; Springer: Cham, Switzerland, 2009.
14. Hoogendoorn, M.; Jonker, C.M.; Popova, V.; Sharpanskykh, A.; Xu, L. Formal modelling and compering of disaster plans. In Proceedings of the 2nd International ISCRAM Conference, Brussels, Belgium, 18–20 April 2005; pp. 98–107.
15. Tecuci, G.; Boicu, M.; Hajduk, T.; Marcu, D.; Barbulescu, M.; Boicu, C.; Le, V. A Tool for Training and Assistance in Emergency Response Planning. In *Proceedings of the Hawaii International Conference on System Sciences, Waikoloa, HI, USA, 3–6 January 2007*; IEEE Computer Society: Washington, DC, USA, 2007.
16. Cahn, M. Managing the human impact on the natural environment: Patterns and processes. *Appl. Geogr.* **1993**, *13*, 285. [CrossRef]
17. Fu, L.; Wang, J.; Peng, Z.H. Simulation of Wastewater Discharge in a Coastal Plain River Network Considering Different Boundary Conditions. *J. Coast. Res.* **2020**, *104* (Suppl. S1), 529–534. [CrossRef]
18. Ding, H.; Tong, J.; Wang, Y.; Zhang, L. Development of emergency planning zone for high temperature gas-cooled reactor. *Ann. Nucl. Energy* **2018**, *111*, 347–353. [CrossRef]
19. Li, W.; Zheng, Y.; Chao, Y.E.; Li, H. Emergency Plan for Water Supply in Consecutive Droughts and Sustainable Water Resources Management in Beijing. *Acta Geol. Sin.-Engl. Ed.* **2018**, *92*, 14. [CrossRef]
20. Long, Y.; Yang, Y.; Lei, X.; Tian, Y.; Li, Y. Integrated Assessment Method of Emergency Plan for Sudden Water Pollution Accidents Based on Improved TOPSIS, Shannon Entropy and a Coordinated Development Degree Model. *Sustainability* **2019**, *11*, 510. [CrossRef]
21. Duan, W.; He, B. Emergency Response System for Pollution Accidents in Chemical Industrial Parks, China. *Int. J. Environ. Res. Public Health* **2015**, *12*, 7868–7885. [CrossRef]
22. Long, Y.; Xu, G.; Ma, C.; Chen, L. Emergency control system based on the analytical hierarchy process and coordinated development degree model for sudden water pollution accidents in the Middle Route of the South-to-North Water Transfer Project in China. *Environ. Sci. Pollut. Res.* **2016**, *23*, 12332–12342. [CrossRef]
23. Zhang, X.J.; Ding, K.S.; Hao, M.R.; Long, M. Emergency water supply and water resources management in Tongzhou District, Nantong City, China. *Int. J. Environ. Stud.* **2017**, *74*, 412–427. [CrossRef]
24. Ni, J.; Zhang, C.; Ren, L.; Yang, S.X. Abrupt Event Monitoring for Water Environment System Based on KPCA and SVM. *IEEE Trans. Instrum. Meas.* **2012**, *61*, 980–989. [CrossRef]
25. Xie, J.; Luo, J. Integrated Service Platform for the Information Explosion Process in Water Resources Industry and its Application Pattern. *Water Resour. Informatiz.* **2010**, *5*, 18–23. [CrossRef]
26. Zhang, X.; Luo, J.; Zhang, X.; Xie, J. Dynamic Simulation of River Water Environmental Capacity Based on the Subsection Summation Model. *Water Environ. Res.* **2019**, *92*, 278–290. [CrossRef] [PubMed]

27. He, X.; Luo, J.; Xie, J. Research and implementation of the strictest water resources assessment management system in Shaanxi Province. *J. Water Resour. Water Eng.* **2016**, *27*, 55–60. [CrossRef]
28. Luo, J.G.; Xie, J.C.; Wang, N. A CBR-based flood scheduling model for reservoirs. *Syst. Eng. Theory Pract.* **2008**, *28*, 122–130. [CrossRef]
29. Sun, B.; Ma, W. An approach to evaluation of emergency plans for unconventional emergency events based on soft fuzzy rough set. *Kybernetes* **2016**, *45*, 461–473.
30. Aureli, F.; Prost, F.; Vacondio, R.; Dazzi, S.; Ferrari, A. A GPU-accelerated Shallow-Water Scheme for Surface Runoff Simulations. *Water* **2020**, *12*, 637. [CrossRef]
31. Wu, X.; Zhang, J.; Chen, Y.; Tang, Z. A System Methodology and Its Application in Developing an Emergency Response Plan for Natural Gas Leakage on an Offshore Platform. *J. Coast. Res.* **2020**, *111* (Suppl. S1), 89–92. [CrossRef]