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An E-R model based formal description scheme for social emergency management system

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ABSTRACT

In order to take advantage of information technology to support social emergency management, it needs to describe emergency plans formally so that they can be correlated with emergency information systems closely. Formal description of emergency plans is the precondition and basis to establish the theoretical framework for emergency plans. Based on the analysis of emergency plans and emergency response processes, this paper proposes a formal description approach for social emergency management system, including the description of organization, the description of emergency resources and the description of emergency processes.

Keywords: Entity-Relationship model; Formal Description; Emergency management; Emergency information system;

INTRODUCTION

Emergency plans are Documents that describe principles, policies and methods to be applied in carrying out emergency operations and rendering mutual aid during emergencies, including such elements as continuity of government, emergency functions of government agencies, mobilization of resources, and public information[1][2][6][9][10]. They are established in the phase of preparedness.

Emergency plans , which are the basis of emergency decision-making .,are key protection for carrying out rescue work timely and effectively during emergencies(rendering mutual aid timely and effectively during emergencies).[1][7][8] In the past few years, emergency plans with their own characteristics have been compiled by Chinese government departments at all levels and lots of enterprises and institutions, meanwhile national framework for emergency plans has been initially established. However, based on the analysis of both domestic emergency plans and oversea emergency plans, there are some following problems:

- Emergency plans, usually based on paperbacked documents or electronic documents, are too long to be read[12]. Therefore, emergency personnel are hard to get emergency information related, when public incidents occurs.
- In the process of compiling emergency plans, editors usually list as many Standard Operation Procedures (SOP) as possible for foreseeable emergency response. However, during the practice of emergency response, it is difficult to implement first aids in accordance with emergency plans completely. All these have a direct influence on the effectiveness of emergency plans in the process of emergency responses.
- Emergency plans are inconvenient to read and use for command staff and first-aid personnel because of its insufficient contents and a relatively poor performance of characters. There may be synchronous, asynchronous or other dependent relationship between these tasks.

In order to make better use of information technology to support emergency management and link emergency plans and emergency information system more together, it is necessary to carry on formal description of emergency plans on the basis of which the theoretical framework for emergency plans can be established. Formal description of

emergency plans comes out from concrete emergency business workflow, and it can be expressed by a formalized, handled by computers way. Such a kind of formalize result is called plan model.

Based on the analysis of emergency plans and emergency response processes, this paper proposes a formal description approach for emergency plans. Firstly, related research is reviewed in this paper, then, it dissertates formal description approaches for emergency plans. Finally, this paper also proposes an evaluation for these approaches and points out the direction for further research.

II. FORMAL DESCRIPTION OF MODELING SOCIAL EMERGENCY MANAGEMENT SCHEMA

A. Related Works

Currently, no theoretical framework for emergency plans has been established in academic world. We usually rehearse a prepared emergency plan so as to test its operational characteristic and accuracy, however, simple exercise for testing the usefulness and accuracy of emergency plans is not enough. Therefore, it is difficult to acquire an in-depth analysis and quantitative evaluation of the quality of an emergency plan because of a lack of theoretical framework for emergency plans. In current studies, the analysis of emergency plans and formal description for emergency plans is not thorough enough.

In Reference [1], formal logic is put to use in disaster management and it also used by describing emergency knowledge and establishing logic model for emergency plans. Taking Heidelberg flood emergency command system as an example, that author discusses some questions about how to establish a logic model for emergence plans; meanwhile, the author bring up that the consistency of emergency plans can be tested by logical approaches when logic model for emergency plans has been established.

In Reference [2], M. Hoogendoorn and his colleagues discussed formal model for emergency plans and also analysed some problems about it. The approach for modelling is based on formal description language—Temporal Trace Language(TTL) [2][3][4][11] which, base on predication logic, is widely used in formal description for Multi-Agent System (MAS) and focuses on the description for architecture and dynamic characteristics of MAS.

In reference [5], the paper discusses the use of multimedia information (including graphs, texts, sound, and images), 3D model and animation describing emergency plans in order to resolve the problem that emergency plans are not easy to read and understand. Valencia (Spain) Metro emergency plans as an example, the author discusses a multimedia description for emergency plans.

Flow-Based Modeling: The EVACNET4 model employs a flow-based approach that models the density of nodes in continuous flows[13-15]. EVACNET4 enables the user to construct a simulated physical environm ent as a network of nodes. The nodes represent physical structures, such as rooms, stairs, lobbies, and hallw ays that are all connected and comprise a single structure from which an evacuation is executed. The user defines the “contents” of the all nodes-as-network, a step that involves the determination of how many people the particular node may contain. Certain nodes are designated as “destinati on nodes,” thus identifying all of the possible termi nal points of occupant egress. For each node, the usable area (UA) must be calculated and allowance is made for the presence of closets, equipment, and other such items , as well as the space which persons place between themselves and a wall. This latter feature entails the in ward projection of each node wall by 6 inches. Besides nodes, the model also requires the provision of specification for arcs. Arcs are passageways between building components. The user must supply a “traversal time,” or the a mount of time periods it takes to cross the passageway, and an “arc flow capacity,” which delim its the a mount of human occupants that can traverse the passage way per time period.

B. Description of organizaion structure in emergency management system

Description of the organization structure, a formal method, is used to describe defined in emergency plans, which is a main description of various entities in emergency organization system and relationship between them. Here, we illustrate emergency organization system structure in E-R model (Entity-Relationship model). As shown in figure 1, rectangular frame indicates entities and rhomboid indicates relationship between entities.

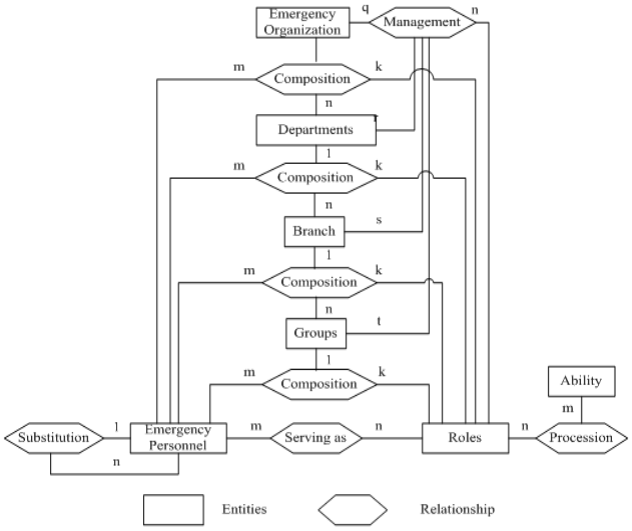

Fig.] Entity-Relationship Model for Emergency Organization Structure

In figure 1, the relationship between entities shows as follows:

- Entities

Emergency organization: It is an abstract description of emergency organization system structure in emergency plans, its attributes including organization name, description, characteristic, department, lists, role lists, personnel lists and address, etc.

Department: It is an abstract description of some function department in emergency organization, its attributes including name of department, description, branch lists, role lists, personnel lists, etc.

Branch: It is an abstract description of some branch in a department, its attributes including name of branch, description, group lists, role lists, personnel lists, etc.

Group: It is an abstract description of some group in a branch, its attributes including name of group, description, role lists, personnel lists, etc.

Role: It is an identifier which indicates some identity or authority, its attributes including name, department belonged (maybe branch or group), capability, lists and role personnel list, etc.

Capability: It is an identifier which indicates some kind capability, its attributes including capability ID, description, etc.

Emergency personnel: Emergency personnel are involved in emergency management personnel and emergency respond personnel (including command officers, staff, rescue personnel) in emergency plans, its attributes including name, gender, address, telephone number, department belonged and role lists, etc."

- Relationships

Composition relationship: Connecting two entities, it shows that one entity is a component of another entity.

Management relationship: Connecting role and emergency organization, department, branch, group. It indicates that some a role belongs to some an emergency organization or department or branch or group.

Substitution relationship: Connecting two emergency personnel, it indicates that one emergency staff can substitute another man to implement a certain task.

Serving as relationship: Connecting roles with emergency personnel. It indicates that an emergency staff serves as a certain role, and one emergency staff can play a number of roles, a number of emergency personnel can also serve as one role.
Possession relationship: Connecting the role with ability, it indicates that one role possesses certain ability.

1—N relationship: It indicates that there is a certain relationship between one entity and n other entities.

M—N relationship: It shows that there is a certain relationship between m entities and n entities.

Example 1: Suppose the emergency respond command structure for an emergency plan of an enterprise is described as follows: emergency leading committee set up a commander in chief: appointee A, a vice-commander in chief of operation: appointee B, a vice-commander in chief of project: appointee C, a vice-commander in chief of logistics/finance/administration: appointee D, a vice-commander in chief of security: appointee E. Duty of the commander in chief include: (1) To be fully responsible for managing emergency rescue operations. (2) Sending message to emergency response rescue command of city and receiving instructions from command.

The E-R model corresponding with the description fragment above is showed in figure 2. There are four kinds of entities: department, command personnel, role, ability, which has their own attributes. The relationship between "enterprise emergency leading committee" and "role" is composition relationship which shows that the latter is a integral part of the former. The relationship between "A" and "commander in chief" is serving as relationship which shows that the present role of the former is the latter. The relationship between "A" and "B" is substitution relationship which shows that the latter can implement authority of the former when the former is absence. The relationship between "commander in chief" and "emergency decision" is possession relationship which shows that the former have authority that the latter describes. The relationship between "commander in chief" and "enterprise emergency leading committee" is management relationship which shows that the former is responsible for the management of the latter.

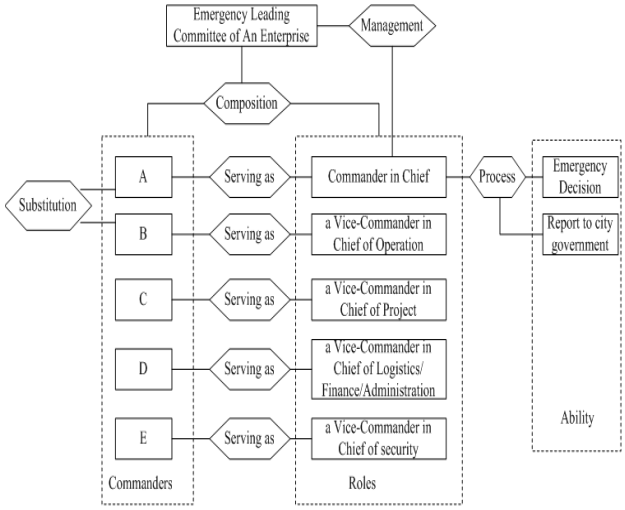

Fig2 The Entity -Relationship Model for Emergency Organization Structure of an Enterprise

Figure 2 is not a complete description of emergency organization structure in enterprise emergency plans, but a fragment of the description. Usually, a complete description of emergency organization structure is very complex in practical application. However, a whole organization structure of emergency plans is able to be described completely by E-R model defined above.

Main steps for describing the emergency organization structure are as follows:
(1) Recognising various entities define above in emergency plans.
(2) Describing its attributes for each type of entity.
(3) According to the above definitions of relationships, describing relationship between entities.

This kind formal description of emergency organization structure has the following advantages:
(1) The entities in emergency organization structure will be divided into departments, roles, personnel to help manage and maintain emergency plans, for departments and roles in an enterprise are relatively fixed while personnel are relatively changeable, so when the personnel change, we only need to revise the relationship between personnel and roles, which has the minimum impact on other parts.
(2) This description approach, which defines the various entities as well as semantic between them more precisely in emergency organization system, is convenient to test the analysis and correctness of emergency plans.

This description approach is also easy to implement by computer support system. It is very easy to change relationship between entities into semantic knowledge, which is able to be used to establish decision knowledge model for emergency decision support system.

C. Description of emergency resource

Description of emergency resource describes various types of resources used in emergency response process. Emergency resources are of different types, which are used in different types of emergencies. Here is a description of emergency resource which will possible be in use in an emergency plan.

Emergency resource is able to be divided into internal emergency resource and external emergency resource in accordance with their respective organization.

Internal emergency resource belongs to its own agency and is able to be use directly.
External emergency resource belongs to other agency and is able to obtain by expanding the scale of emergency respond.

In emergency process, first of all, internal emergency resource will be used. When internal resource does no meet emergency needs, it needs to expand the scale of emergency response and then the upper level emergency plans will be started in order to get necessary emergency resource. Therefore, whether emergency resource meets emergency needs or not can be regarded a judgment that the emergency response needs to be expanded or not. Furthermore, in everyday emergency management, checking out the condition of internal emergency resource is also regarded as a means to estimate emergency plans.

Description of emergency plans is as follows:
(1) Classifying the emergency resources used in emergency plans, such as human resources, emergency equipments, rescue goods, living supplies, etc. And then each type can be further divided into sub-types, such as personal protective equipment, lifting equipment, breaking equipment, fire equipment and so on.
(2) Describing its attributes for each type of emergency resource, for example, attributes of lifting equipment including name, model, organization belonged to, lifting tonnage, principle, telephone number, etc.
(3) Setting up emergency resource database respectively in accordance with emergency resource types.

Ⅳ. DESCRIPTION OF EMERGENCY PROCESS

Description of Emergency process focuses on describing tasks as well as constraint relationship between them in emergency response process, demonstrated by E-R model as in figure 3:

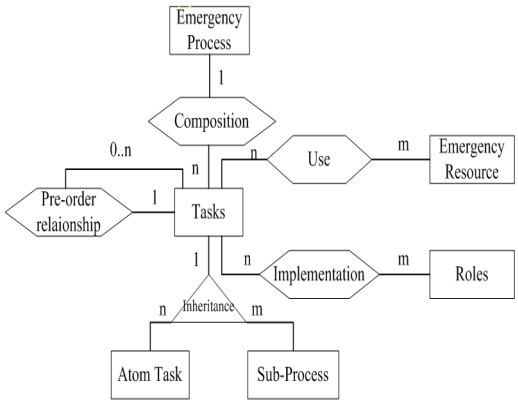

Fig. 3 Entity-Rlationship Model for Emergency Porcess

A.Entities

Descriptions of relationship between entities in figure 3 are as follows:
Emergency response process: It is an abstract description of emergency response process, its attributes including process name, task list, beginning of the tasks, end of tasks, time limit, etc.
Task: It is an abstract description of a step in emergency response process, which is an abstract entity, divided into two types: atomic task and sub-process.

Atomic task (Atomic task): Derived from the task, it is an non-decomposable entity which is able to be implemented directly in emergency process. Its attributes include name, description, roles, starting conditions, ending conditions, the use of resources, time limit and so on.

Sub-process (Sub-process): It continues to be divided into a series of tasks, corresponding to another emergency response process.

B.Relationship

Composition relationship: Connecting emergency process with emergency tasks, it shows that the emergency process is composed of several tasks.

Pre-order relationship: It shows that the execution time of tasks is in sequence.

Inherited relationship: The task is an abstract entity. So the task needs to be divided into atom task and sub-processes when it is described.

Use relationship: It shows the use of certain resources required in the implementation of emergency tasks.

Implementation relationship: Connecting roles with tasks, it needs roles involved in the implementation of tasks.

Example 3: The emergency process (shown as figure 4) of an explosion incident of a chemical factory includes eight tasks. t1 and t2 of eight tasks are sub-processes and each task is divided into three atom tasks. There may exist pre-order relationship between tasks, for example: t_{11} prior to t_{12}. Roles concerned with tasks are testing personnel and emergency resource used in the task is testing apparatus when t_{11} is being implemented.

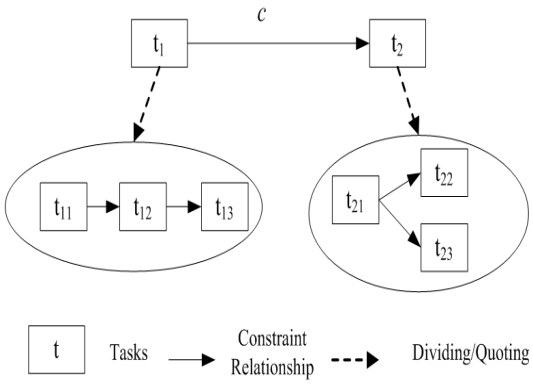

Fig 4 The Emergency Process of an Explosion Incident of a Chemical Factory

In practical implementation of a task, emergency personnel will be dynamically mapped to tasks according to serving as relationship between roles and emergency personnel in the structure description. Description of the emergency plan as following steps:

(1) Identifying various kinds of tasks in the emergency process from emergency plans.
(2) Describing its attribute information for each task.
(3) Describing constraint relationship between tasks according to relationship definition in emergency process

The main advantages of this kind formal description of emergency process are as follows:
(1) This approach for formal description define the emergency process more precisely, thereby the operability of emergency plans is improved.
(2) The more accurate description of semantic relationship between entities in the emergency response process is conducive to analyze and verify the correctness of emergency plans.
(3) This approach for formal description is convenience to be implemented by computer support system, and it is beneficial to the decision-making and command control.

Ⅴ. CASE STUDY

In this section, we introduce an concrete case named Emergency management system with E-R model based formal description, which has been carried out with practical use in case of environmental extortion explosion cases.

This emergency management system include E-R model based formal description database module, spatial geographical data and social-economic data and they all have spatial andtemporal characteristics. Geographic Information System (GIS) has great functions of collection, management, analysis and output of spatial information and it can blend figures and database. The framework of emergency management system on abrupt environmental pollution accidents can be established based on GIS. The spatial data management and analysis functions of GIS can provide good technical support platform for the implement of the system. Information on accidents can be seamlessly integrated and well managed.

A.Design of the System

Based on computer technology and GIS, this paper de veloped an emergency management system on abrupt environmental pollution accidents, includi ng basic database (including historical database , background database, assessment database, and so on), methods and models database, graphics database, emergency plans database, results display and query database.

With the support of GIS technology, database technology, multimedia technology and virtual reality technology, the research results can be visualized. The information on loss assessment results, accidents simulation and emergency response measures can be shar ed and applied to related departments and governments timely, exactly, authorita tively and dramatically.

B.Platform of the System

This system is developed based on the Window XP operation system, and uses the products of ESRI Company, such as ArcGIS Engine, ArcSDE and so on. The database system is built upon SQL Server2000, and the developing tool is Microsoft C#. The followings are the main application flow charts of the system (Fig.5, Fig.6).

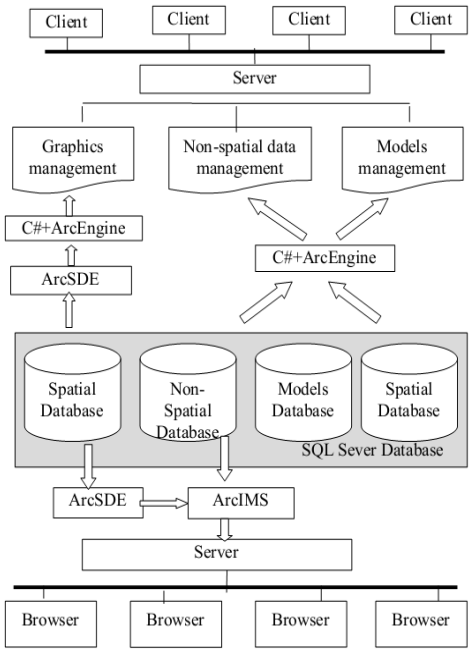

Fig 5. Framework of Emergency Management System

C. Design of Database

When making emergency management on abrupt environmental pollution accidents in counties of China, it is necessary to get its social-economic information in detail and exactly. So this system chooses the administrative map of Xinzhuang Town, Changshu City, Jiangsu Province with the scale of 1:200,000 as the basic map, and a vector map of counties is built.

When the system is operated, layered data can be overlay to form the background map, and based on monitoring results, scene of accidents is displayed on the map. Then emergency management and spatial analysis such as distance analysis, area analysis, route analysis and buffe r analysis on abrupt environmental pollution accidents in counties are made.

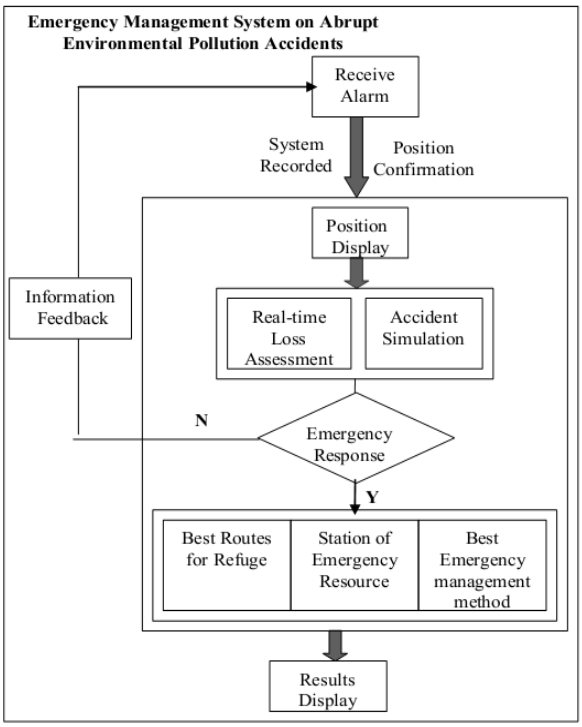

Fig 6. Workflow of Emergency Management System in an environment pollution accident

Layers include: 1) residential areas, enterprises and other point objects; 2) medical treatment organizations, rescue centers and other point objects; 3) roads, rivers and other line objects; 4) buildings, factories and other polygon objects. Because of fast de velopment of counties, the locations of some objects may be changed, so short-term update must be promised.

Besides, non-spatial data, such as the county's po pulation density, property allocation, emergency rescue vehicles and instruments, and simulation models on abrupt environmental pollution acci dents should also be input in the system.

Based on the characteristics of the data needed in the system, this system uses database management system such as SQL Sever 2000 as the background database. This system has the functions of storing and managing attributes and spatial data, sharing data among departments, dealing with data, maintaining the system, outputting results, and so on. The database for this system is divided into four sub-databases (Fig.5): spatial database, non-spatial database, models database and temporal database. Spatial database can store figures, images and maps, such as remote sensing images, them atic maps, regionalized maps, risk assessment maps on abrupt environmental pollution accidents, and so forth. Non-spatial database stores historical accidents data, environmental background data and regional social-econom ic data (such as the property, population density, the amounts and categories of emergency response resources, and so on). Models database stores loss assessment models, resource optimizing allocation models, accident simulation software models and so on. Temporal database is used to store data produced when operating the system and the users can not see it. Spatial data and non-spatial data can associate with each other. With the organization of program, they can be integrated with the models and the functions of the system can then be carried out.

D. Specification of System function modules

The system is divided into seven modules, including files operation module, data collection module, layered display module, thematic maps query module, abrupt environmental pollution accidents models module, accidents simulation module and emergency plans query module. These modules are separated to each other on the screen, but they are connected to each other from the point of logical framework and database.

Files operation module includes the function of opening files, database connection, printing, print review, and so on. Data collection module can support the system to quickly collect basic data on the study area in time.

Layered display module includes the function of adding layers, decreasing layers, zooming, legend display, overlay display, eagle eye, map output, and so on. Thematic maps query module supports the query on thematic maps, e.g. influence areas caused by abrupt environmental pollution accidents, accidents simulation maps.

Abrupt environmental pollution accidents models module can use existing models to calculate the results caused by abrupt environmental pollution accidents. With this module, it can easily get the pollution concentration in different area. Accidents simulation module mainly uses the abrupt environmental pollution accidents models to simulate pollution situation and display the results visualized on electronic maps. Accident status under any possible situation ca n be simulated. With this module, clients can know about the accident visually. It can support the governments to make emergency response as early as possible. Emergency plans query module is mainly used to query emergency plans and emergency management measures on any environmental pollution accidents in counties.

CONCLUSION

Formal Description of emergency plans is the prerequisite and foundation of the establishment of the theoretical framework for emergency plans. Based on the analysis of emergency plans, emergency response process, and a concrete case study of emergency management system, this work discusses the formal description of emergency plans. Compared with other approaches for formal description, Main features of the approach described in this paper are as follows:

(1) The description of emergency plans is divided into three areas: description of emergency organization structure of emergency, description of emergency response process and emergency resources, which is more fully described emergency plans.
(2) The description of emergency plans is divided into three areas, which minimize the impact of some changes in the contents on other parts of emergency plans in order to manage and maintain emergency plans easier.
(3) A more accurate, clear description of emergency plan semantics is conducive to verify the correctness of emergency plans.
(4) The use of Entity-Relationship model is conducive to deal with a sudden incident supported by information technology.

The study of formal description of emergency plans in this paper is still at the primary stage and needs to be gradually improved in subsequent studies; further research including:
(1) The study of emergency plan description language. It needs to develop an emergency plan description language in order to facilitate the establishment of emergency plan model libraries and the timely maintenance and update of emergency plans.
(2) The semantic representation of emergency plans. In order to make right decision by emergency commander, it needs to do further research on the semantics of emergency plans to obtain emergency semantic knowledge.
(3) Analysis of the correctness of emergency plans. In order to compile a complete emergency plan, it needs to verify the correctness of emergency plans from both syntax and semantics of two levels, which ensures the accuracy and operability of emergency plans.
(4) Based on previous theoretical studies on emergency plans, verifying tools for emergency plans and knowledge-based emergency decision support system need to be developed in order to be applied effectively in emergency response process.

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