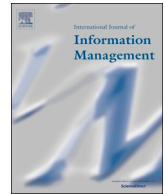




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Research Note

Knowledge model for emergency response based on contingency planning system of China



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ABSTRACT

China is severely exposed to natural hazards. Currently, there are more than 5.5 million contingency plans for handling various incidents. Similar to those produced in other counties, the paper-based plans in China are limited in that emergency responders cannot easily extract helpful information for them. In this paper, a knowledge-based system will be proposed for providing different stakeholders with helpful information in the emergency response. The conceptual model is the core for the whole system, which can link plans in the physical world and the ontology in the cyber world.

1. Introduction

China is severely exposed to natural hazards (Li, Zhang, Tian, & Wang, 2018). In recent ten years, the economic losses caused by disasters were nearly 300 billion dollars each year, which accounted for 3.8% of GDP. In 2008 Sichuan earthquake, 68,712 people lost their lives; 17,921 people were missing; more than 370,000 people were injured; about 150 million homeless people were in need of shelter and more than 450 million people were affected by this great earthquake. During this large-scale disaster relief operation, 5257 professional rescuers, 13,434 firemen, about 38,000 medical personnel and more than 130,000 volunteers implemented the whole emergency response (Ning, 2009; Waugh Jr, 2003). In addition to these rescuers on site, millions of people were involved in organization, coordination, transportation of material and the wounded. Currently, most of the knowledge of emergency management exists in unstructured data like documents (Pogrebnyakov & Maldonado, 2018; Ragini, Anand, & Bhaskar, 2018; Simon, Goldberg, & Adini, 2015). For different stakeholders, right information from distributed sources can be integrated and transferred by a knowledge-based system.

Much work has been done in the knowledge engineering (Altay & Pal, 2014; Singh, Dwivedi, Rana, Kumar, & Kapoor, 2017) for emergency management (Mendis, Karunananda, Samaratunga, & Ratnayake, 2007a; Yates & Paquette, 2011): ontology (Kollarits, Wergles, & Siegel, 2009), description logics (Grathwohl & de Beuvron, 1999), TTL (Hoogendoorn, Jonker, Popova, & Sharpanskykh, 2005), narrative networks (Constantinides & Barrett, 2012), fuzzy logic (Mendis,

Karunananda, Samaratunga, & Ratnayake, 2007b), object-oriented constraint networks (Smirnov, Levashova, & Shilov, 2015), linguistic model (Zhang, Wang, & Zhao, 2018), space modeling (Xie, Li, Wei, Jiang, & Xie, 2016) and so on. Commonly, emergency management (Aker & Wamba, 2017; Dwivedi, Shareef, & Mukerji, 2017; Sinha, Kumar, Rana, Islam, & Dwivedi, 2017) includes four phases: mitigation, preparedness, response and recovery. Emergency response is one of the most important parts in the planning system of China (Liu, 2011), and was invested in with considerable resource by governments worldwide (Perry & Lindell, 2003). In this paper, we will study the knowledge model for emergency response. A key to the successful application of knowledge system is the ability to provide different rescuers with the right information at the right time (Amailef & Lu, 2013; Arain, 2015).

Although the specification of the right information has not been discussed by previous studies, obviously, two kinds of them are most valuable including situation and operation. The first type is about the on-site losses, which is mainly stored in the documents of routine reporting. Multi-document summarization based on ontology can be employed to extract these knowledge from these unstructured data (Li & Li, 2014; Ren et al., 2016). The second one is about how to respond to these loss situations. Beyond doubt, emergency plans contains the integrated blueprint of how to handle incidents (Hoogendoorn et al., 2005), which is the combination of theories and experience. If professionals have a knowledge-based system built on past lessons, it would effectively assist management teams in emergency response (Arain, 2015). Furthermore, it can lead to a better understanding of the works that should be done if rescuers can compare actual situations (first type)

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with the theory model. This paper will focus on the knowledge model for the response information, and the knowledge source is the contingency planning system of China.

In China, there are two kinds of emergency plans (General Office of the State Council, 2013): government plans and institution plans, respectively formulated by various governmental agencies and other kinds of social groups (enterprises, urban and rural organizations). As a vast country, currently China has more than 5.5 million plans formulated by social organizations of different kinds (Liu, 2011). Similar to those produced in other countries (Adriaan ter Mors & Witteveen, 2005), the paper-based contingency plans in current China are limited in that helpful information cannot be easily extracted for emergency responders.

In the history of knowledge engineering, two kinds of research can be classified: form-oriented research and content-oriented research (Kitamura & Mizoguchi, 2004). The first one focuses on the theory topics like logic, reasoning, retrieval (Sutanto, Liu, Grigore, & Lemmik, 2018), and so on, while the second one investigates the application of the knowledge engineering. Obviously, there has been considerable interest in the former one to date. However, there are a lot of practical problems such as knowledge fusion, knowledge sharing and so on (Gupta, Altay, & Luo, 2017; Hwang, Lin, & Shin, 2018; Prasad, Zakaria, & Altay, 2016; Wamba, Edwards, & Akter, 2017; Wang, Huang, Davison, & Yang, 2018). Although the first kind of technology can inform us of how to represent knowledge, it is far from enough to know what will be needed before the stage of knowledge representation. As a result, besides representing and retrieving knowledge for emergency response, an important work in this paper is to reveal knowledge structure of real contingency planning system.

The contingency plan can be observed from two different perspectives. Firstly, the plan as a documentary is usually considered as the unstructured data. Secondly, the structure of planning system are depicted clearly by Chinese central government (General Office of the State Council, 2013). As a result, the challenge to a knowledge-based system is to switch the micro, distributed knowledge implied in the texts to the formal explicit knowledge framework.

The macro structure of the planning system is determined by the links among the basic units. Obviously, sentence is the basic knowledge element of the system. Its meaning of one sentence is determined by the subject-verb-object of itself, in which subject and object are usually the nouns. Further, these noun phrases are called terms in the ontology learning, which are linguistic realizations of domain-specific concepts (Buitelaar, Cimiano, & Magnini, 2005). Moreover, the relation in the ontology is very much related to verb arguments in the text (Buitelaar et al., 2005). The concept and relation (class and property in the OWL) are the skeleton of the ontology.

It seems possible to construct a knowledge model for planning system according to the processes above, and many tools or methods based on machine learning are applicable. Without taking into consideration the overall thinking of planning system, however, even if all sentences in plans are transferred to the RDF statement,¹ and it is unable to ensure that right knowledge can be provided to the right rescuers. The reason is that a system is different from a sum of basic units. For the planning system, the knowledge and its structure are not only decided by the cumulation of unique sentence, but semantic links among two or more sentences, paragraphs, sections and even many plans.

Our solution is that an overall thinking about real world planning system should be proposed before the stage of knowledge representation. The transition step is called conceptual model.

The framework of the knowledge model for China's planning system is indicated in Fig. 1, and this article will follow the bottom-up

¹ An RDF statement has a subject, a predicate and an object, whose structure is similar to the subject-verb-object for the sentence.

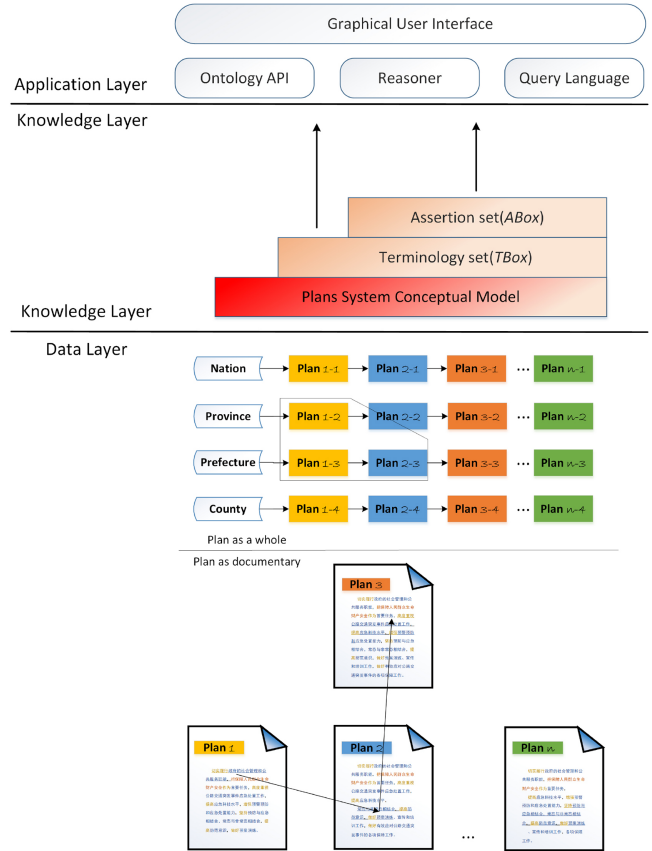


Fig. 1. The framework of the knowledge model for planning system.

structure. After discussion about the Chinese planning system in Section 2, the conceptual model will be proposed in Section 3. An ontological application is discussed in Section 5, for implementing the concept model in the computer. Finally, application cases will be discussed.

2. Planning system

In China, emergency plans are a kind of work program with the aim of minimizing various impacts and returning the society to a business as usual (General Office of the State Council, 2013). In fact, the development of the whole emergency planning system of China started in 2003 after the SARS (Severe Acute Respiratory Syndromes). It still needs a long time for developing a complete planning system because many social groups do not have their own institution plans for incidents. As a result, contingency plans only concern with the government plans in this paper.

2.1. Types of Chinese contingency plans

Government plans can be divided into three sub-types: the guideline plans, the agency plans and the catastrophe plans. They are respectively characterized by:

- Through formulating **guideline plans** by territorial and central governments, general principles and long-term goals for the disaster management are determined. The plan-makers of this kind should be the governments ranking above the county level in terms of the administrative structure.
- **Agency plans** can be employed to handle small incidents which require limited or no collaboration from other agencies. The examples are search & rescue plan (*fire department*), mass prophylaxis plan (*health ministry*) and so on.

- Some disasters (e.g. earthquake) will lead to a serious disruption, which needs cooperation among different sectors. So **catastrophe plans** are formulated by one chief agency combined with other sectors. In others words, responsibilities of each agency and cooperative mechanism among them are defined by this kind of plan.

In this paper, specific and explicit knowledge which is contained in the agency and catastrophe plans will be focused.

2.2. China's contingency planning system

Based on three sub-types of plan, there are two levels of China's contingency planning system. The first level is established relying on the administrative structure. However, the coordination among these functional agencies will be needed for handling large-scale disasters, which means contingency plan is not enough. So the second level of the system is the integration of some relevant plans for dealing with a certain type of disaster. The disaster-oriented planning system (second level) is part of the whole administrative-structure-based planning system (first level).

2.2.1. Based on the administrative structure

For illustrating this kind of planning system, we can compare the administrative structure of the USA and that of China. The key feature of local governments of America is complex and diverse, with most states in America having at least two tiers of local governments: counties and municipalities. But many rural areas and even some suburban areas in many states have no municipal government below the county level. In addition, the kinds and nature of municipal entities vary from state to state. As a result, executive agencies for the emergency response are different from state to state. So as one of three major tools for planning process, the Target Capabilities List (TCL) defines 37 core capabilities for major hazards events of America, but undermining who will be in charge of these capabilities (U.D. Homeland Security, 2007).

In contrast to the American governments, the whole territorial governments in China can be divided into four levels: province (*sheng*), prefecture (*diqu*), county (*qu* or *xian*) and township (*jiedao* or *xiang*). In common, every agency in local governments can find its competent department in the central government, known as an administrative structure called *Tiao-Kuai* system. In China, theoretically, under this framework, anywhere in China one kind of emergency incident will be handled by designated agencies of government. Namely, because the responsibilities of each sector are clarified, one plan can be formulated by a certain sector. So the first level of Chinese planning system is based on the administrative structure, which has two advantages:

- 1 A large number of emergency plans enacted by local governments cannot be found officially because of the uneven regional development in China. Within *Tiao-Kuai* system, however, there must be corresponding plans on the lower administrative level if the central government formulates a plan.
- 2 The useful information can more easily reach right stakeholders due to clearly hierarchical structure of administration.

The structure is indicated in Fig. 2. According to their responsibilities in the emergency response, each government sector represented by one cell formulates its plans. In horizontal direction, the duties are assigned to different sectors. In vertical direction, the content of plans will be defined from the abstract to the concrete. It should be noted that all the three kind of plans are contained in administrative-structure-based planning system represented by three types of icons in Fig. 2.

2.2.2. Orienting to disaster

As discussed above, it will need more than one agency plan when a large-scale disaster happens, so that a catastrophe plan is formulated to

integrate the series plans. An example of the disaster-oriented planning system is indicated in Fig. 3. A landslide usually causes more than one kind of losses such as, the wound, the death and people at risk, which badly calls for communication and transportation service. Duties and coordination patterns are determined by the landslide plan, which is the catastrophe plan. Details can be found in the rest of agency plans. In Fig. 3, the plans contained the five sides trapezoidal construct landslide-oriented planning system.

It must be noted that agency and catastrophe plans are formulated according to general principles and long-term goals in guideline plans, while disaster-oriented planning system only includes agency and catastrophe plans.

3. Conceptual model of China's contingency planning system

As mentioned above, formal languages such as OWL only can inform us of how to represent knowledge. It is also important, however, how to acquire knowledge from the source of reality source. Conceptual model is a transitional step from literal encoding in the documents to the formalized model in the computers.

3.1. Methodologies

The conceptual model, made up of concepts, is an abstraction of things in the real world. It can be used to facilitate the understanding of a complex system. Because of the elements (concepts and relations) of the conceptual model, this model can be easily switched to the OWL, which is constructed by classes and properties. Generally, the concept model can be constructed through two methodologies: induction and deduction.

Induction means that the whole research process goes from the particular to the general theories. Namely, the conceptual model for planning system will be constructed through an observation of a series of plans from local to central governments, known as a "bottom-up" method. However, in fact the emergency planning system of China is not perfectly complete even now (Liu, 2011; Zhang, 2013). Even some local plans are almost the same as their superior departments. In addition, some important information for emergency response cannot be found in some plans, leading to an inappropriateness study when the conceptual model is analyzed through induction.

In contrast, deduction is a "up-bottom" method, which means the whole constructing starts from a basic premise. The premise leads to conclusions which will become new premises. So the process of deduction is linking premises with conclusions repeatedly. With this method, the conceptual model is suitable not only for China but for other countries. As such, the conceptual model will be constructed by the deduction. The result will be verified by factual contingency planning system of China.

3.2. Concepts in the model

Purpose

Obviously, no two disasters are completely the same and each one needs its own response process. However, the way that disasters impact people and the society may well be similar and responses are often transplantable between disasters (Othman & Beydoun, 2010). The reason is that the purpose of emergency response is always constant, which is to return the society to a state as usual (Waugh Jr, 2003), also a purpose of the basic premise of the conceptual model (Fig. 4).

Hazardous conditions & Capabilities

Obviously, the *purpose* of ERS, which is "returning to normal", can be divided into two parts: *hazardous conditions* and *response capabilities* for handling these conditions. In fact hazardous conditions can be enumerated, which can be divided into two kinds: population and secondary disasters. For the former one, it can be summarized as six types

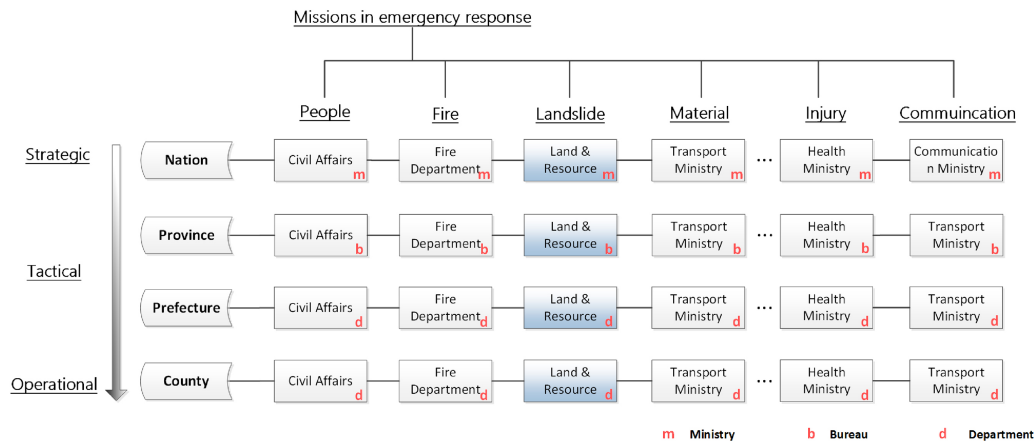


Fig. 2. Planning system based on administrative structures.

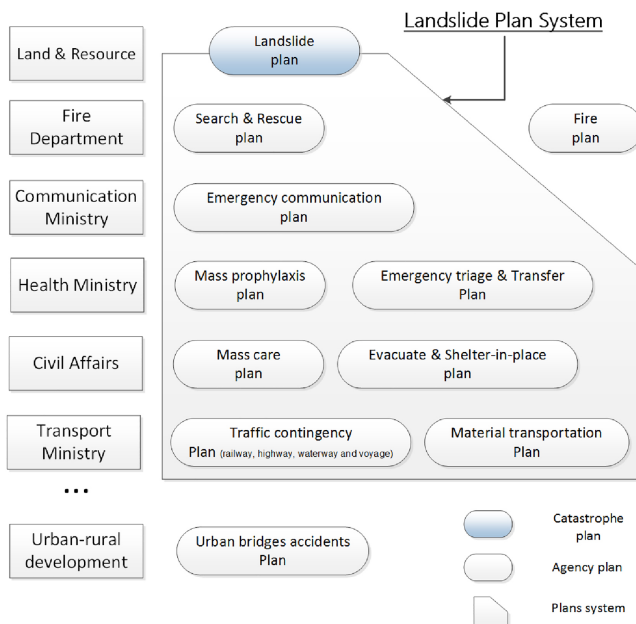


Fig. 3. Planning system for handling landslide.

at most: missing person, population at risk,² the homelessness, injury, infection and death. The latter one can be roughly divided into five kinds: fire, geology, CIs (critical infrastructure), environment and engineer. In one word, the amount of hazardous conditions is limited. So the capabilities for responding to these dangerous state can also be listed.

Capabilities can also be split into two kinds: the on-site and incident management. On site capabilities are those applied to directly handle hazardous conditions, with each dangerous state involving its corresponding capabilities. In addition, it is noticeable that more than one capability is needed for a single kind of hazardous condition. Capabilities for people and some secondary disasters are listed in Table 1.

According to the time length, the secondary disasters can be divided into two kinds. Some disasters, such as landslides, are transient. While others, such as fires, are relatively lasting. Different from fires, what can be responded to is the immediate losses rather than the disastrous process itself. As a result, an interesting observation of the final suffers caused by both kinds of secondary disasters are still people.

² The population at risk is the population that is exposed to the occurrence of disaster. Conditions of them need to be further identified and taken care.

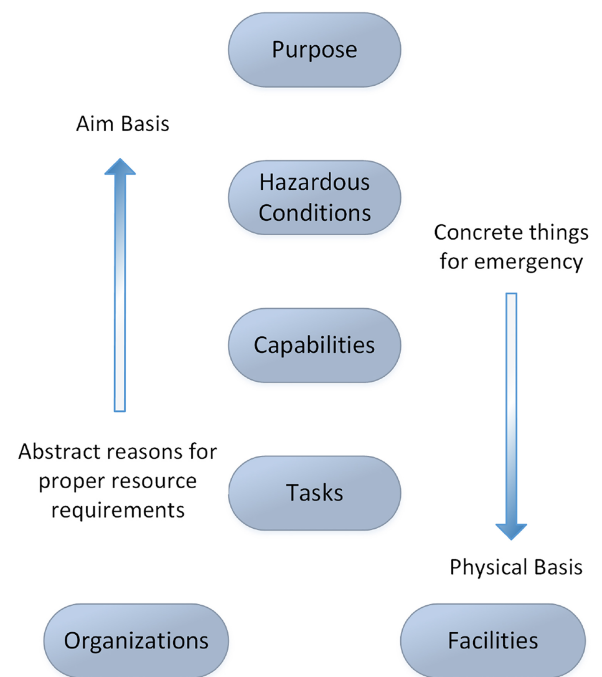


Fig. 4. The concepts in the conceptual model of contingency planning system.

Table 1 Response capabilities for hazardous conditions.

Conditions	Capabilities
Missing person	C1. Search & Rescue
Population at risk (PR)	C2. Evacuate & Shelter-in-place
The homelessness	C3. Mass Care C4. Mass Prophylaxis
Injury	C5. Emergency Triage & Pre-hospital Treatment C6. Medical Care
Infection	C7. Isolation & Quarantine
Dead	C8. Fatality Manage
Fire	C9. Fire Response
Landslide	1, 2

In almost every case, the emergency response system needs coordination of various public sectors, including private sectors and NGO (Non-Governmental Organization). So incident management, as the second kind of capabilities, needs to coordinate with the local emergency response to mobilize rapidly (Lindell, Prater, & Perry, 2006). The

functions of these capabilities include multi-agency coordination, logistics (Dubey et al., 2018; Papadopoulos et al., 2017; Ren et al., 2018), CIs guarantee and public information & warning.

Task

A task is an activity that needs to be accomplished within a defined period of time towards work-related goals (Wikipedia, 2016). So task itself is more meaningful in terms of starting time and deadline. Moreover, completing task usually needs the coordination with others. Coordinated interaction takes on the role of combining the integration of time, energy, effort, ability, and resources of multiple individuals to achieve a common goal. The top part of the conceptual model is one unchangeable purpose, which can be decomposed into certain number of hazardous conditions and more response capabilities. In comparison, tasks are more changeable and specific than capabilities.

Organizations & Facilities

Generally accepted, it is humans who finish a tasks. In IBM Terminology,³ tasks refer to a unit of work to be accomplished by devices. So below the level of task, the relations of *organizations* and *facilities* are clearly defined.

It is important to note that the task will be accomplished by teams rather than the sector. This setting will keep the whole conceptual model independent of the emergency administrative structure. In reality, for the same kind of incident, the responsible departments vary from country to country. For example, in Japan the fire brigades are charged by Ministry of Internal Affairs. While in China the Ministry of Public Security is responsible for the team. In America, the situation is more complex, depending on the local municipal nature. Moreover, the administrative structure will change with time, for example, the ongoing reform of super ministries in China (Shi & Shi, 2008). Our conceptual model will suit for more countries because of the interconnection with the bottom level of administrative structure.

3.3. Relations in the model

There are two kinds of relations in the conceptual model: trans-concept relations and in-concept relations. The first one refers to the relations linking different concepts of the conceptual model, which will be discussed in Section 5.3. The second kind refers to the connection between the two units belonging to one concept.

Hazardous Conditions. Transformation is the general form of relation between two hazardous conditions. Because of people at risk can injured or even lose their lives. Also the secondary disaster can switch state of people.

Capability. Capabilities are linked by various flows. For on-site capabilities, the connection linking them is the flow of people. The example is that the injured are transported to designated sites for medical care after being searched and rescued. Through people, stuff and information flow, incident management capabilities provide different services for on-site capabilities.

Task. Dependency can be employed to describe the general relations between tasks, which means that most tasks rely on each other to get done. The method called narrative networks has focused on in this field (Constantinides & Barrett, 2012).

Organization. Coordination is the most usual connection linking the organization. Network analysis is an efficient tool for it.

4. Validating the conceptual model

This section will verify that our conceptual model can reveal key features of emergency response in the planning system. Firstly, the relationships between the model and two levels of planning system will

be discussed. Then our conceptual model is proven efficient in covering the content of single contingency plan.

4.1. Coverage to planning system

Overall structure of planning system

Similar to other complex system, the planning system of China should be of hierarchical structure. From top to bottom in Fig. 5, it can be divided into three levels: strategic, tactical and operational (Liu, 2011).

1. Strategic-level plans, at the top of the framework, concern general directions and long-term goals. For the planning system, guideline plans are on this level. To the conceptual model, the *purpose* namely “returning to normal” defines the fundamental goal of emergency response.

2. Tactical-level plans are for handling some certain kinds of disaster scenarios such as fire, earthquake and so on. Assignments, responsibilities and coordination mechanisms of government functional agencies are formulated on this level. For the planning system, agency plans and catastrophe plans enacted by ministries in the central government belong to this level. To the conceptual model, the *hazardous conditions*, *capabilities* and relations among them are employed to describe strategic transactions.

3. Operational-level plans are specifications for realizing emergency response in certain kinds of disaster scenarios. Work flows, staff, supplies, leadership and control mechanism should be settled on this level. For the planning system, agency and catastrophe plans for local governments and their functional agencies belong to operational plans. As for the conceptual model, the *tasks*, *organizations*, *facilities* and relations among them are used to describe specification of handling incidents.

Agency Plans

Agency plans are formulated according to responsibilities of departments in emergency. These responsibilities are decomposed into on-site capabilities and incident management capabilities in our conceptual model. The capabilities and their corresponding emergency plans of China have been included in Table 3 in Appendix B. The results can be summarized as follows:

- 1 Each capability can find corresponding contingency plans of China.
- 2 On website,⁴ 30 agency plans were enacted by central governments. Among them, 24 plans (80%) are contained in Table 3.

Catastrophe Plans

As discussed above, in order to integrate different agency plans for large-scale disasters, catastrophe plans are formulated. Beyond doubt, the earthquake is one of the most serious disaster, for which whole emergency management system has to be mobilized. The relations between emergency response of earthquake plan and our conceptual model will be discussed.

There are 11 sections in national earthquake plan of China,⁵ and the title of section 5 is the emergency response. This section covers 5 pages (total plan is 20 pages) and has 10 subsections. From Table 2, it can be found that 80% subsection in earthquake plan is covered by our conceptual model. In the same way, the most impacting disasters can be decomposed into hazardous conditions in the conceptual model.

Transformation of elements at risk forms needs objective connections between capabilities, which has been discussed in Section 3.3. Further, each kind of connective pattern between capabilities is a type of mechanism of coordination (Malone & Crowston, 1994; Mintzberg,

⁴ http://www.gov.cn/yjgl/2005-08/07/content_21051.htm, which is last opened on 05-16-2017.

⁵ http://www.gov.cn/yjgl/2012-09/21/content_2230337.htm, which is last opened on 05-16-2017. Reversed on 08-28-2012.

³ <http://www-01.ibm.com/software/globalization/terminology/p.html>

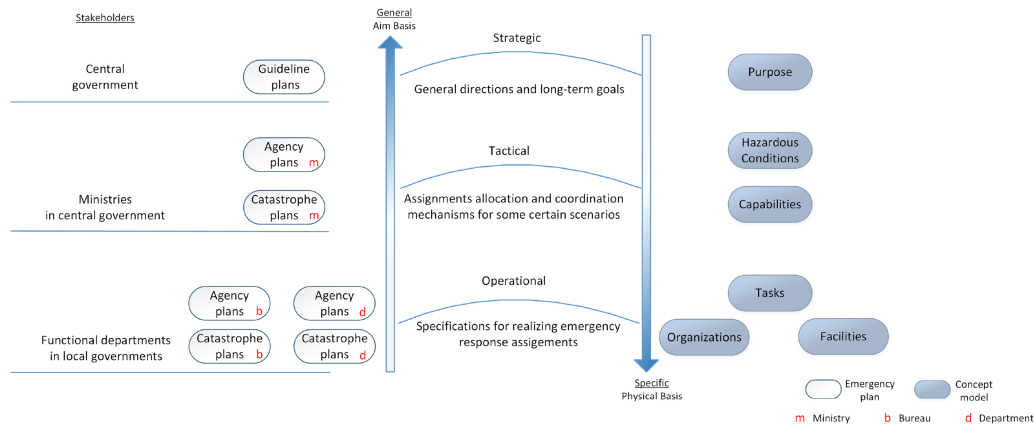


Fig. 5. The key features of Chinese planning system, which is from general to specific, can be revealed by our conceptual model. At the same time, administrative structures can be attached to this corresponding relations.

Table 2

The correspondences between capabilities and titles of subsections in national earthquake plan.

Capabilities	Subsection in plan
C1. Search & Rescue	5.1 Search and rescue people
C4. Mass Prophylaxis	5.2 Medical care and epidemic prevention
C5. Emergency Triage	
C6. Medical Care	
C3. Mass Care	5.3 Placement persons affected by disaster
C11. CIs	5.4 Repair infrastructures
Uncover	5.5 Field monitoring
C10. Secondary Disasters	5.6 Prevent secondary disasters
Uncover	5.7 Maintain public order
C3. Mass Care	5.8 Social mobilization
C1. Search & Rescue	5.9 Management of foreign rescuers and volunteers
C3. Mass Care	
C12. Information	5.10 Publish information

1979; Tolksdorf, 2000). Our conceptual model is open to different cooperative modes.

4.2. Coverage to the content of single plan

It has been discussed that capabilities in the conceptual model correspond to agency plan itself, and the catastrophe plan is an integration of some capabilities. As a matter of fact, the rest of elements are employed to realize the capability, which include tasks, organizations and facilities. In other words, the capability is reified by the three elements just as the content of plan is a reification of the headline.

Commonly, the structure of main content of single plan can be summarized by the titles of chapters and sections in documents. Through an analysis of 3000 contingency plans,⁶ the pattern of content for plans was summarized by a Chinese researcher (Li, 2011), which is listed in Fig. 6.

The percentage in Fig. 6 refers to the proportion of plans with the section or subsection with that title (or synonyms) in total 3000 plans.

- *Guideline* only contains general principles of this plan and has not details of the response.
- *Responsible organization* corresponds to the organizations in the conceptual model.
- *Monitoring* is the content about the protection phase.
- *Emergency response* corresponds to the tasks in the conceptual

Contingency Plans

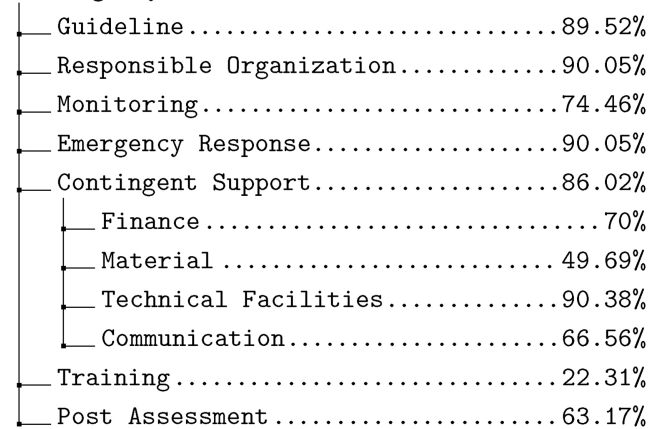


Fig. 6. The content pattern of Chinese contingency plans.

model.

- *Material and Technical facilities* correspond to the facilities in the conceptual model.
- *Training* is the content about mitigation phase.
- *Post assessment* is the content about recovery phase.

This section shows that our conceptual model covers vast majority of response content of Chinese planning system.

5. Application ontology for planning system

The conceptual model in Section 3 is the core for this knowledge model. In the analysis above, the contingency plan is considered as a whole. Further, the conceptual model will be formally specified by the ontology language in this section. The relationship between the content of the plans and the conceptual model will be discussed.

In essence, the plan is a text constructed by a series of sentences. Commonly, the meaning of the sentence is determined by the subject-verb-object (SVO) of itself. As discussed in Section 1, the SVO structure can be formally represented by RDF statement in the assertion set (ABox). From the opposite direction, the conceptual model can be extended to the terminology set (TBox). The whole process is indicated in Fig. 7. In this section, an application ontology (Serna & Serna, 2014) for planning system will be discussed.

5.1. Method for constructing ontology

In the field of information and knowledge science, there are a

⁶ Most of them are national and provincial plans.

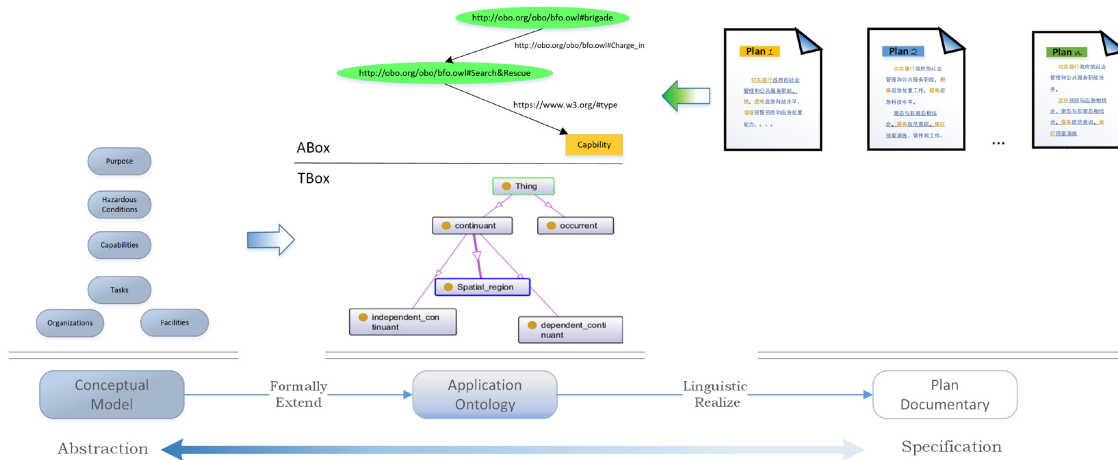


Fig. 7. From conceptual model to the content of one contingency plan.

variety of classification methods for ontology (Arp, Smith, & Spear, 2015; Bimba et al., 2016; Menzel, 2003). We tend to select 3 categories of ontologies in this paper, which are the application, domain and top-level ontology.

- An application ontology (AO) is an ontology that is created to accomplish some specified tasks. Our planning system ontology belongs to this type and will be represented by OWL (Web Ontology Language).
- A domain ontology is designed to be a canonical, comprehensive representation of the entities in a given science field. Commonly, the knowledge in one domain ontology can be found in a scientific textbook. Gene Ontology and Cell Ontology are classical examples for this kind of ontology.
- A top-level ontology is an ontology that is meant to cross the chasm among different domains or application. It consists of very general terms (such as object, property, event and process) in the top-level ontology. The example is Basic Formal Ontology (BFO), Descriptive Ontology for Linguistic Cognitive Engineering (DOLCE), etc.

It is not as easy to convert from the conceptual model to AO because of crossing domains. In the ontology, the sets of individual in real-world is formally described by classes. Further, in TBox the relationships between these sets can be revealed by the concepts with different constructors (such as intersection, conjunction). In other words, it is impossible to construct terminological axioms without inter-related individuals between two classes. And there is less overlap between two concepts in different domains. The example is the six main concepts in our conceptual model. There are not intersection between individual sets referred by organizations and facilities. A solution is to construct this AO based on a top-level ontology. It can be understood to link discrete nodes to a well-formed tree of categories. This method has been employed to construct domain ontology because of its advantages (Spear, 2006).

Moreover, because of the design for some sort of computational application, the expressive power of AO is limited. The n-ary relation, for example, cannot be formally described by OWL directly. But it has to be needed in representing 5W1H patterns. These problems will be discussed below.

5.2. Planning system ontology based on BFO

Our AO is constructed based on a top-level ontology called BFO.⁷

The structure is listed in Fig. 8. The classes with n_ as prefix are categories for planning system, which attach to the BFO skeleton.

For the sake of brevity, the complete definitions of the categories in BFO and detailed explanations for why a class belongs to a certain category have to be omitted. The specification with some philosophy can be found in this work (Spear, 2006).

With a simplified dichotomy, the general BFO categories which includes our plans classes will be discussed here.

- 1 Two basic categories are in the first level of BFO structure including the continuant and occurrent. The entities belonging to the first category can maintain its identity through time. In contrast to the continuant, the entities in the occurrent happen, unfold, or develop in time. As a result, obviously only the task (n_Task as class name) is in the second category.
- 2 The inheritance means that the state of being a fixed characteristic. Three major categories can be found in the continuant, and two of them are opposite. The first one is the independent continuant which cannot inhere in something else (facility and organization). The second one (dependent continuant) is the state of entities (hazardous condition and capability).
- 3 A material entity is a matter whose material part can make its identification, while immaterial entity cannot. For example, one human can be considered as the material, but the organization is not equivalent to a set of human.
- 4 The quality entities are natural attributes, which does not need a further processing for implementation. The example is the state of the victim. For capabilities, it needs many training and practice to realize.

5.3. Relations among different categories

In Section 3.3, the relations within one category have been discussed. The relations among different categories will be discussed here, which are called the formal relation (Smith & Grenon, 2004) as a part of the BFO. Our conceptual model is a highly abstract model, while the content of plans is specific. The gap between them can be further bridged through the formal relations (Fig. 9).

The nouns (classes in the ontology) in the contingency plans can be divided into six categories in our conceptual model. Also the verbs in the plans (relations in the ontology) need to be classified. Most of them can be included by the formal relations in Fig. 10. Namely formal relations can be understood as a generalization of semantic relations in the planning system.

For the sake of brevity, only one formal relation called participation will be discussed here. The rest of them will be listed in Appendix A.

⁷ Its new version is 2.0.

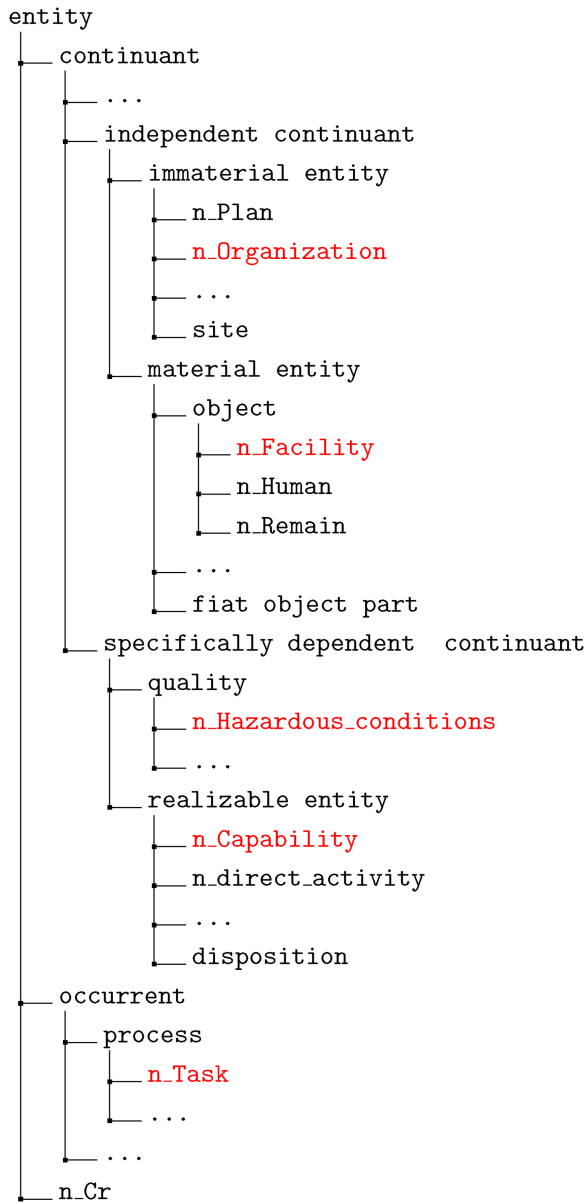


Fig. 8. The structure of planning system ontology. The classed named with n_ as prefix is ours for application ontology.

There are about six kinds of participation in planning system marked as leaf nodes in Fig. 11. ACTION means that a matter directly participates in the process: *firefighters perform rescue*.

- INITIATION. A matter starts a process: the examples are verbs such

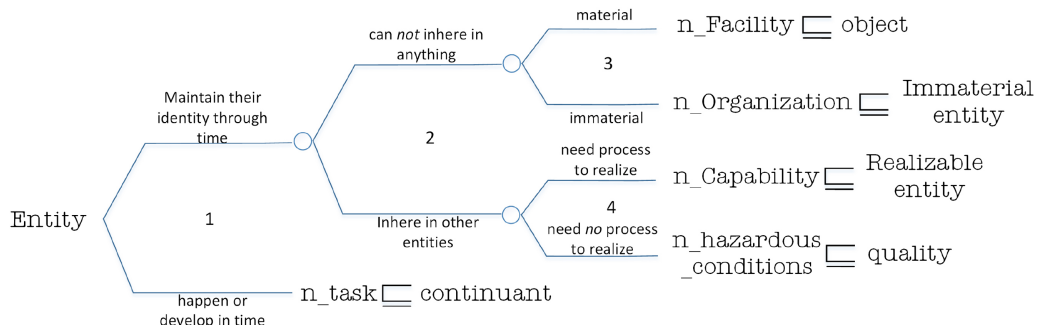


Fig. 9. The relationships between 6 major concepts for planning system and categories in BFO.

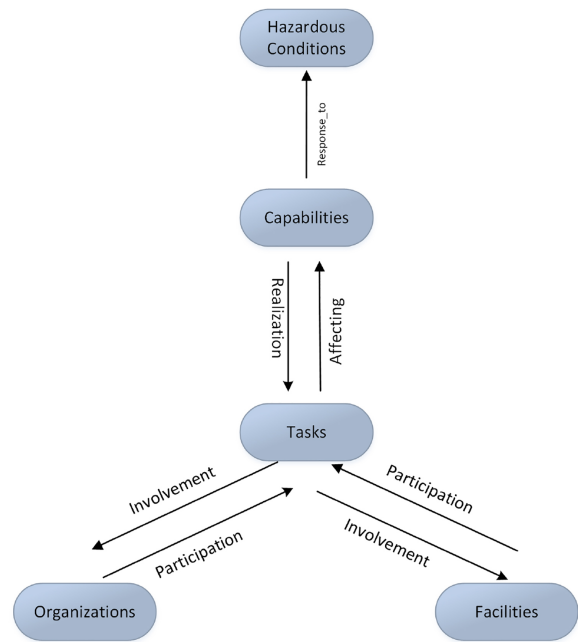


Fig. 10. The formal relations linking categories in the conceptual model.

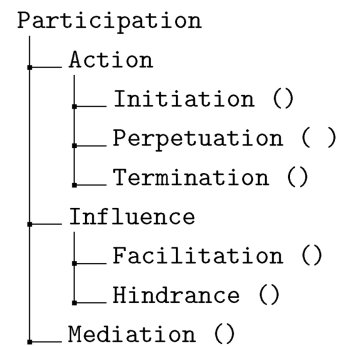


Fig. 11. The formal relation called participation from independent continuant to process. Corresponding Chinese words are listed behind.

as *initial, restart*.

- TERMINATION. A matter ends a process: such as terminate, break off.
- PERPETUATION. A matter sustains a process. The verbs of this kind are part of this process rather than a relation. Most of the verbs in plans belong to perpetuation such as *rebuild, monitor*.
- INFLUENCE. A matter influences a process.
- FACILITATION. A matter plays a minor role: such as *assist*.
- HINDRANCE. A matter has a negative impact on a process, such as *reduce, prevent*.

5.4. N-ary relation

According to the losses and scope, in China, the disaster situations are divided into different levels. At different levels, in Chinese planning system, different tasks should be finished by different stakeholders. For example, in the national earthquake plan, at level I (more than 300 dead), the disaster assessment is charged by provincial government. Which at level II (50–300 dead), the same work will be finished by prefectural government. In our previous work (Ni, Rong, & Qie, 2015), this mechanism has been discussed.

Ternary relations will be needed to represent the cases above, namely, some tasks will be finished by somebody in one certain loss situation. But a well-known limitation of OWL is that only binary relation can be represented directly. One common solution to the n-ary relation is representing it as a class rather than a property, which is called reification (Noy, Rector, Hayes, & Welty, 2006). In our AO, a root class (n_Cr at bottom of Fig. 5) is constructed for these relation classes.

But this method will cause some problems, such as most of these new relation classes do not stand on their own but merely function as auxiliaries to group together with other objects. As a result, too many meaningless relation classes defined in ontology will lower down the system. It has been discussed how to reduce the redundancy by our previous works (NI & Lili, 2013).

6. Application cases

As discussed above, it is hard to extract helpful information from paper-based contingency plans. For different stakeholders, in fact, the obstacles are different.

- Currently, according to the responsibilities in emergency, different government agencies formulate their own contingency plans, which, no doubt, can prove the expertise of plans. However, the superior officer has to know all of these agency plan so that the whole response framework can be understood. Although details can be neglected, it is still time-consuming to most senior government officers.
- To rescuers at operational level, graph-based knowledge visualization is much better than natural language.

Our conceptual model breaks boundaries among plan documentaries and construct hierarchical knowledge framework. Then the conceptual model can be formally extended to the ontology. With these OWL statements and tools (API (Dotsika, 2010), reasoner, Query language), finally, the applications will be constructed. Note that SPARQL the query language will be employed in our cases. An OWL statement can be understood as directed edge with two nodes (source-edge-target vs. subject-predicate-object). So if one node and edge can be known, the rest will be, too.

Strategic View

Senior government officers only need to know the disaster type ((1) in Fig. 12), as this form can provide a global view of the emergency response. So even if one does not read any contingency plans, the default hazardous conditions caused by a certain kind of disaster and response capabilities for them will be indicated ((2), (3)). Also other losses states can be added. The relationships between these selected capabilities are depicted in (4), which include people, staff and information flow (discussed in Section 3.3). Moreover, if a capability is selected (in red), the direct connecting capabilities will be painted in yellow. Finally, in (5) the organizations in charge of the capability will be indicated.

In fact, the logic in the application layer can easily find corresponding entities in the conceptual model and AO.

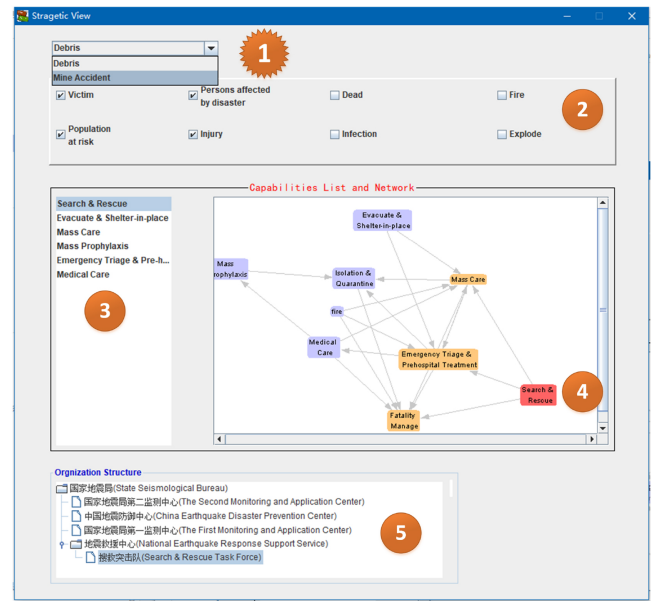


Fig. 12. The response knowledge for senior government officers.

Tactical View

To officers in functional departments, they need to select the sector name of their own firstly ((1) in Fig. 13). Then, the capabilities of the departments in the emergency response are listed in (2). The task flow will be indicated in (3) if a capability is still enough. Finally, the interactions with other functional departments, which include information, people and staff, will be listed in (5).

Note that the reification will be applied here. In the table of this view (5), without the content the binary relation is enough. Otherwise, the ternary relation should be needed.

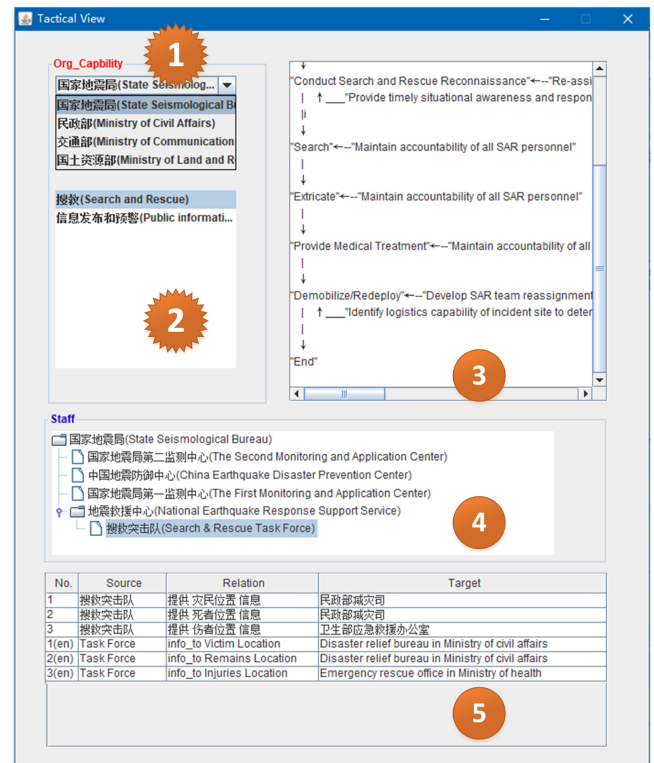


Fig. 13. The response knowledge for functional departments officers.

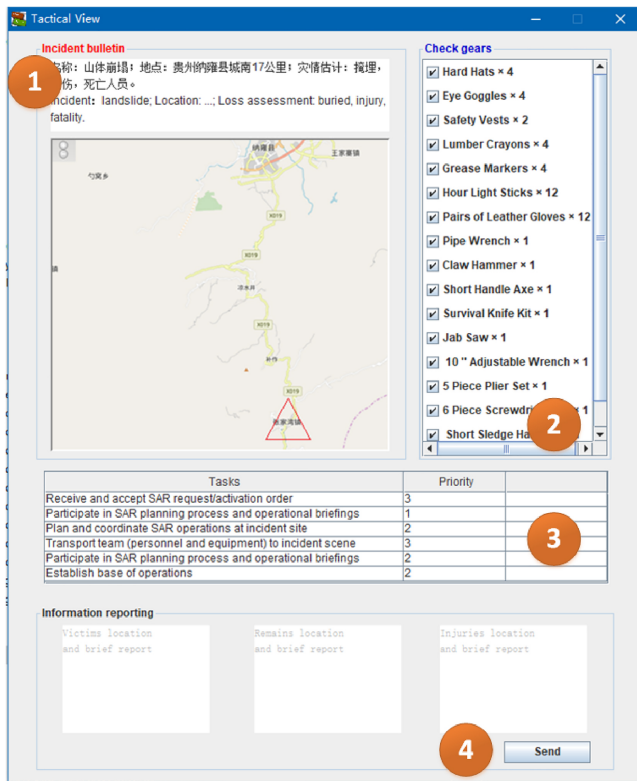


Fig. 14. The response knowledge for rescuers.

Operational View

To on-site rescuers, the location and brief report of the incident should be obtained first ((1) in Fig. 14). Then the working facilities should be checked in (2). The tasks and their priority will be listed in (3). Finally, the information need to be reported ((4)).

7. Conclusion

Emergency response is a complex system involving all kinds of stakeholders. In this paper, a knowledge model is proposed to assist the

Appendix A

A.1 Relations < SPAN Process, SNAP Dependent >

There are 3 main patterns for realization in Fig. 15. Because independent substance must inhere in a dependent continuant, subtypes of realization are like participation. Commonly, a realization is a ternary relation including: (1) a dependent continuant, (2) a substance and (3) a process. And the mode of this kind of relation is that (1) then inheres in (2) in virtue of the fact that (2) participates in (3).

A.2 Relations < SPAN Process, SNAP Independent >

INVOLVEMENT. Sometimes the relation involvement only inverse relation of participation such as: rescuers *participate in* the rescue, so the rescue *involves* rescuers. But there are some other kinds of involvement: the earthquake involves people which denotes a passive affection by a substance rather than active participation (Fig. 16).

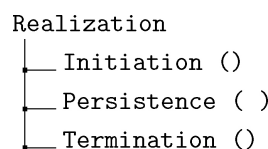


Fig. 15. The formal relation called realization from dependent continuant to process. Corresponding Chinese words are listed behind.

whole process. These knowledge is acquired from China's contingency planning system. The conceptual model is the core for the whole knowledge-based system, which can link plans in real world and the ontology in the cyber world. Although the data come from China, we believe that the model has much value to other countries.

But how to construct this kind of model is a relatively little studied topic. The knowledge source in real word is complex and enormous. Suppose a China's plan has 30,000 characters on average, for example, it is impossible to read and comprehend all of 5,500,000 documents. As a result, more than depicting what exists, the key of the conceptual model is to represent a view of what could exist (Gregory, 1993). Without a novel point of view, it is inevitably getting lost in the oceans of data. In the process of deduction, if one of key feature of a system can be included by big premise, with rational logic the whole model can offer a perspective of this system. And the deduction may be a novel way to construct the conceptual models.

Additionally, there are also a number of open research problems. Modularity emergency plans are the first one. The contents of agency and catastrophe plans in the same administrative level but different regions have a lot in common. It will be efficient to reuse the similar components in the process of enacting. Hazardous conditions, capabilities and tasks are a rational way for partition. And knowledge based models are good tools.

Statements concerning quantification should be appended in the next version, which will prove the operability of the knowledge model. Currently, most of explicit knowledge in the top-level of the response system is covered by our framework, but action plans should be further discussed.

Especially for on-site rescuers, the information of loss situation should be integrated into the knowledge model. As discussed above, this kind of knowledge is in the routine reports, which is extracted by statistical methods. The problem of these theories, however, is that measurement for all kinds of elements in the documents is the same. The importance and influence of the component in planning system are obviously different. The system analysis should be performed before the calculation.

Acknowledgement

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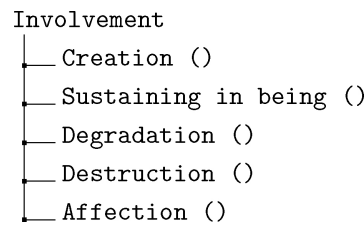


Fig. 16. The formal relation called involvement from process to independent continuant.

A.3 Relations < SPAN Process, SNAP Dependent >

The subtypes of relation affecting are depicted in Fig. 17. The examples are a earthquake process changed the river orientation, the process of rain raised water level of the river.

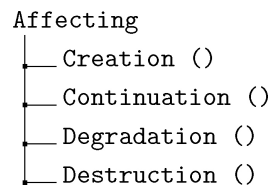


Fig. 17. The formal relation called affecting from process to dependent continuant.

Appendix B

Table 4

Table 3
Relations between capabilities and emergency plans of ministries in the central government – Part I.

Capabilities	Emergency plans	Ministries
C1. Search & Rescue ^a	1. Marine search and rescue plan	Transport Ministry
C2. Evacuate & Shelter-in-place	1. Personnel evacuation and shelters open in emergency plan	Governments
C3. Mass Care	1. China federation of the Red Cross natural disasters and public emergency contingency plans 2. National natural disaster relief plan	Federation of the red cross Civil Affairs Ministry
C4. Mass Prophylaxis	1. National health emergency plan for natural disasters	Healthy Ministry
C5. Emergency Triage	1. National health emergency plan for natural disasters 2. Nuclear accident and radiation accident contingency plans	Healthy Ministry Healthy Ministry
C6. Medical Care	1. National health emergency plan for natural disasters 2. Nuclear accident and radiation accident contingency plans	Healthy Ministry Healthy Ministry
C7. Isolation & Quarantine	1. Influenza pandemic preparedness and contingency plans 2. Human avian influenza contingency plans 3. Railway public health emergency plans 4. Airplane public health emergency plans	Healthy Ministry Healthy Ministry National Railway Administration Civil Aviation Administration
C8. Fatality Manage	1. National health emergency plan for natural disasters 2. National natural disaster relief plan	Healthy Ministry Civil Affairs Ministry
C9. Fire	1. Fire emergency rescue plan 2. Prairie fire emergency plan 3. Forest fire emergency plan	Fire Department State Forestry Administration State Forestry Administration

^a As a matter of fact, the planning system of China still needs to be improved. The example is from the web site of National Earthquake Search and Rescue Center which can be found, but the emergency plan for search & rescue cannot be found in it.

Table 4
Relations between capabilities and emergency plans of ministries in the central government – Part II.

Capabilities	Emergency plans	Ministries
C10. Secondary Disasters	1. Earthquake plan for construction departments 2. Agriculture major natural disaster emergency plan 3. Mine accident emergency plan 4. Storm surges, tsunamis, sea ice emergency plan	Construction Ministry Agriculture Ministry Land & Resource Ministry State Oceanic Administration

(continued on next page)

Table 4 (continued)

Capabilities	Emergency plans	Ministries
C11. CIs	<ol style="list-style-type: none"> 1. Railway flood emergency plan 2. Railway earthquake emergency plan 3. Railway geologic hazard emergency plan 4. City gas supply system of major accidents emergency plan 5. City water supply system of major accidents emergency plan 6. City bridges of major accidents emergency plan 7. Railway traffic casualty emergency plan 8. State communication support plan 9. Railway fire emergency plan 10. State communication support emergency plan 11. Sanxia Gezhouba cascade hub emergency plan 	National Railway Administration National Railway Administration National Railway Administration Construction Ministry Construction Ministry Construction Ministry National Railway Administration National Railway Administration National Railway Administration Ministry of Industry and Information Technology China Gezhouba Group Corporation
C12. Information	1. Xinhua news in public emergency plan	Xinhua News Agency
C13. Environment	1. State emergent environmental incident	Ministry of Environmental Protection
C14. Transport	1. State highway traffic emergency plan	Ministry of Communications

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