Knowledge Modeling for Emergency Rescue of Maritime Hazardous Chemicals Accident

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ABSTRACT. The high-time urgency of emergency decision-making for maritime hazardous chemicals accidents requires the content and form of this knowledge to be organized in a way that facilitates decision-makers to resolve crises in a timely and creative manner. This paper proposes a CIA-ISM-based method for extracting the elements of maritime hazardous chemicals accidents, establishes a knowledge model for emergency rescue of maritime hazardous chemicals accidents, provides a more standardized and unified description of the knowledge relied on in the decision-making process of the emergency rescue of maritime hazardous chemicals accidents, further organizes the content and form of emergency rescue, and integrates the existing information advantages into decision-making advantages.

Keywords: maritime emergency; knowledge modeling; cross-impact analysis; interpretative structural modelling

1 INTRODUCTION

Knowledge structuring comes from Ontology, which was first introduced to the field of artificial intelligence by Neches and others in the 1990s to solve the knowledge-sharing problem. Neches [1] defines ontology as "the basic terms and relationships between terms that make up a vocabulary (set) of a subject area"; Gruber [2] proposes that "an ontology is an explicit specification of a conceptual model"; Studer [3] proposes that "an ontology is an explicit specification of a conceptual model ".

There are many elements in the emergency rescue of maritime hazardous chemicals accidents system, but it is an unstructured vocabulary, which requires knowledge of structured modeling. Firstly, the elements involved in the emergency rescue system for maritime hazardous chemicals accidents, emergency plans, and rescue operation methods are extracted and classified to obtain a comprehensive, representative and hierarchical set of elements; then the structural importance of the elements of the system is evaluated, and the elements of the emergency rescue system are concisely and critically expressed through this step; based on the results of element identification, the knowledge of the elements is structured. Finally, based on the results of the element identification, the knowledge of the elements is sorted out, the knowledge of emergency

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rescue of maritime hazardous chemicals accidents is structured and modeled, and the knowledge of emergency rescue of maritime hazardous chemicals accidents is standardized and described in a unified manner.

2 IDENTIFICATION OF ELEMENTS OF THE EMERGENCY RESCUE OF MARITIME HAZARDOUS CHEMICALS ACCIDENTS

Based on the three-stage model proposed by Davis [4-6], this paper divides the emergency response to waterborne hazardous chemical accidents into three stages: emergency preparedness, emergency response, and emergency recovery. Drawing on the US FEMA's Capability Assessment for Readiness (CAR) and Japan's "Disaster Emergency Response Capability Assessment Index System" [7,8], a total of 74 targeted elements in 17 groups were selected, and the secondary indicators in the emergency relief element assessment system were numbered to construct an emergency element assessment set (see the Table 1).

Table 1. Emergency element assessment set

Emergency Content	Index
Emergency Preparedness	Emergency Rules and Regulations(IE_1);Emergency Organization(IE_2); Emergency Skills Training(IE_3); Emergency Information Monitoring(IE_4); Emergency Plan Response(IE_5); Emergency Rescue Drills(IE_6); Emergency Education(IE_7)
Emergency Response	Emergency Coordination Linkage(IE_8); Communication Information Assurance(IE_9); Chemical Warfare Equipment(IE_{10}); Accidents Information(IE_{11}); Rescue Risk Identification(IE_{12}); Expert Skill Assistance(IE_{13}); Implementation of Rescue Measures(IE_{14}); Incident Control(IE_{15})
Emergency Recovery	Accident Investigation and Mitigation(IE_{16}); Post-Incident Reconstruction and Recovery(IE_{17})
Event Effect	Emergency Relief Effect(EE_{18})

2.1 Initial Assessment Matrix of Emergency Rescue Elements

Based on the results of the identification of emergency rescue of maritime hazardous chemicals accidents, the system of the emergency rescue of maritime hazardous chemicals accidents has been sorted out based on the assessment set of 17 emergency elements, and then the initial assessment matrix of the emergency rescue of maritime hazardous chemicals accidents has determined. To determine whether there is an influence of each element and the degree of influence, a group of 12 experts in the field of water emergency response has been invited to form an expert group to assess the influence of various elements, and the arithmetic mean of the expert rating results has used to construct the initial assessment matrix $R=(R_{ij})_{n\times n}$.

2.2 The Cross-Impact Analysis (CIA) process

To obtain the coefficient of interaction between the emergency rescue elements, C_{ij} (representing the coefficient of influence of E_j on E_i), the cross-influence matrix is calculated using the initial assessment matrix of the emergency relief elements as the input matrix to the CIA.

$$C_{ij} = \frac{1}{1-P_j}\left[\left(\ln\frac{R_{ij}}{1-R_{ij}}\right)-\left(\ln\frac{P_i}{1-P_i}\right)\right] \tag{1}$$

Where Cij is the influence coefficient of element Ej on element Ei; Pi and Pj are the a priori probabilities of elements Ei and Ej respectively, taking Pi=Pj=0.5 [9]. When the value of Cij is greater than or equal to 3.802, 2.900, and 2.531, it represents the basic elements whose influence degree is in the top 10%, 25%, and 30% in turn.

2.3 Interpretative Structural Modeling (ISM) Construction

Based on the set of emergency elements identified earlier, to determine whether there is a direct influence relationship between two elements, the emergency relief element adjacency matrix A = (A_{ij})n x n is expressed as:

$$A_{ij} = \begin{cases} 1,\text{If } E_j \text{ has direct effect on } E_i \\ 0,\text{If } E_j \text{ has no direct effect on } E_i \end{cases} \tag{2}$$

The adjacency matrix A is extracted from the cross-influence matrix and the influence coefficient bounds to extract the set of elements. Here, Cij = 2.900 is used as the boundary value, and the basic element influence degree is at 25%, which can reflect the characteristic elements well, and the adjacency matrix A is calculated.

The power calculation of the sum of the adjacency matrix A and the unit matrix E of the emergency relief elements A+E is based on the Boolean algebraic method to study the interelement channels, with M being the emergency rescue element reachable matrix.

$$M=(A+E)^{n+1}=(A+E)^{n}\neq(A+E)^{n-1}\neq....\neq A+E \tag{3}$$

2.4 Hierarchy of Emergency Rescue Elements

Hierarchization of elements is based on solving for the intersection of the reachable set $R(E_i)$ and the antecedent set $N(E_i)$ of the set of elements and the intersection of the reachable set $R(E_i)$ and the antecedent set $N(E_i)$ based on the emergency salvage element reachability matrix M.

Calculate the reachable set R(Ei) and the antecedent set N(Ei) for each element, where R(Ei) denotes the set of all elements that are reachable by element Ei and N(Ei) denotes the set of all elements that are reachable by element Ei When the relationship equation is satisfied. (see figure 1).

$$R\left(E_i\right)\cap N\left(E_i\right)=R\left(E_i\right) \tag{4}$$

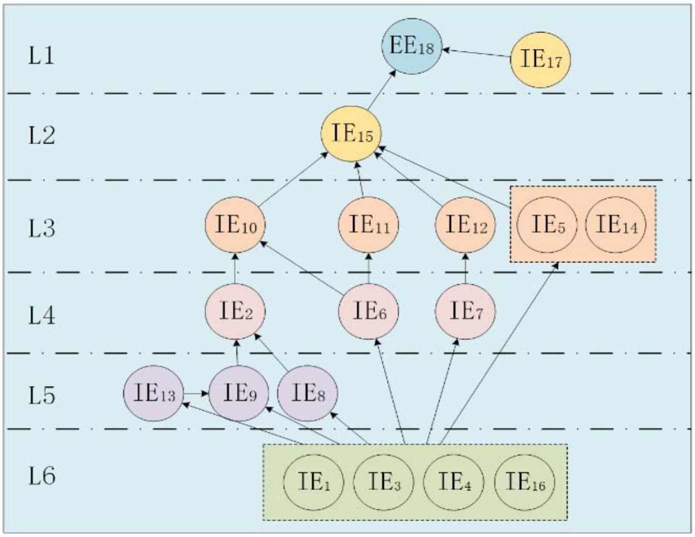

Fig. 1. Hierarchy of emergency rescue elements

3 STRUCTURED MODELING OF KNOWLEDGE FOR EMERGENCY RESCUE OF MARITIME HAZARDOUS CHEMICALS ACCIDENTS

The structured modeling of the emergency rescue of maritime hazardous chemicals accidents is based on the emergency rescue elements extracted in the previous section, i.e. emergency plans, hazardous materials information, chemical prevention equipment, operational risks, and rescue measures, to sort out the emergency rescue of maritime hazardous chemicals accidents, to carry out structured modeling of the emergency rescue of maritime hazardous chemicals accidents, and to obtain a classified expression of the emergency rescue of maritime hazardous chemicals accidents.

3.1 Knowledge Granularity of Emergency Rescue of Maritime Hazardous Chemicals Accidents

To analyze the knowledge of e emergency rescue of maritime hazardous chemicals accidents, a triad can be used to formally represent the knowledge granularity of emergency rescue of maritime hazardous chemicals accidents, where X, F, and S represent the five major elements of the emergency rescue of maritime hazardous chemicals accidents, the collection of attributes between the elements and the relationship between the elements respectively. The knowledge source, the core layer, the middle layer, and the basic layer are used to represent the knowledge hierarchy of emergency rescue of maritime hazardous chemicals accidents.

The core level of the emergency rescue of maritime hazardous chemicals accidents, with the different phases of emergency response according to the fire, explosion, and spill scenarios of maritime hazardous chemicals accidents.

$$G_{cl} = \{G_{cl1}, G_{cl2}, G_{cl3}, \cdots, G_{clm}\}, m > 1 \quad (5)$$

The intermediate level is based on the core level and extracts knowledge of emergency response such as detection, fire-fighting, and first aid.

$$G_{ml} = \{G_{ml1}, G_{ml2}, G_{cl3}, \cdots, G_{mln}\}, n > 1 \quad (6)$$

The basic layer of the emergency rescue of maritime hazardous chemicals accidents is based on the intermediate layer and extracts the properties of hazardous chemicals such as their classification, hazard, physical and chemical properties, toxicity, and other relevant properties.

$$G_{bl} = \{G_{bl1}, G_{bl2}, G_{bl3}, \cdots, G_{blk}\}, k > 1 \quad (7)$$

3.2 Knowledge Structure for Emergency Rescue of Maritime Hazardous Chemicals Accidents

The structured modeling of emergency relief knowledge is to categorize emergency rescue knowledge according to the characteristics of hazardous chemical accidents, emergency plans, and relief measures, to sort out the knowledge structure of emergency relief for maritime hazardous chemicals accidents, and to analyze the expertise and relationships of the emergency rescue of maritime hazardous chemicals accidents by summarizing the relevant knowledge and adopting a three-dimensional coordinate representation method, to realize the description and expression of emergency relief from multiple perspectives. As shown in Figure 2, the knowledge structure of emergency rescue of maritime hazardous chemicals accidents is shown, with the X-axis indicating the information about hazardous chemical accidents; the Y-axis indicating the response to emergency plans, and the Z-axis indicating the implementation of relief measures. (see figure 2).

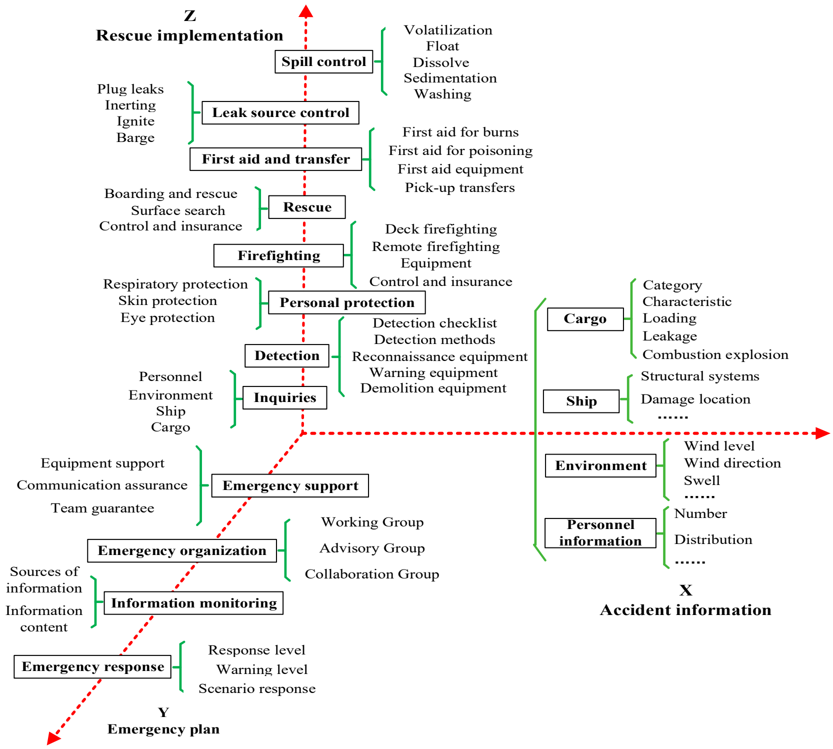

Fig. 2. Knowledge structure of emergency rescue of maritime hazardous chemicals accidents

The knowledge of emergency rescue of maritime hazardous chemicals accidents is reflected in the three-dimensional perspective of hazardous chemical accidents, emergency plans and relief implementation, the five major elements of emergency plans, hazardous chemical information, chemical prevention equipment, rescue measures, and operational risks, the response level, warning level, plan response, cargo information, ship information, environmental information, personnel information, detection equipment, protective equipment, fire-fighting equipment, monitoring and risk control, fire-fighting and risk control, search and rescue and risk control, decontamination, inquiry, detection, firefighting, search and rescue, spill source control, spill pollutant control and 33 other indicators. A formal expression of the HCER (Hazardous-chemicals-accident Emergency-rescue) knowledge system for waterborne hazardous chemical accidents.

$$\mathrm{HCER} = \left\{\mathrm{HCA}, \mathrm{EP}, \mathrm{RM}\right\} = \left\{\begin{array}{l} \mathrm{HCA}_i = \left\{\text{Cargo- inf}, \text{Ship- inf}, \text{Envir- inf}, \text{Person- inf}\right\} \\ \mathrm{EP}_i = \left\{\mathrm{EmR}_n, \mathrm{InfD}_m, \mathrm{EmO}_s\right\} \\ \mathrm{RM}_i = \{\underbrace{\mathrm{Process}_1, \mathrm{Process}_x}_{\mathrm{subEvent}_1}, ..., \underbrace{\mathrm{Process}_y, ..., \mathrm{Process}_z}_{\mathrm{subEvent}_n}\} \\ \mathrm{Process}_x = \{M, R, E\} \end{array}\right\} \tag{8}$$

HCA indicates hazardous chemical accident information, which includes the inherent nature of hazardous chemicals, ship structure, systems, etc., as well as specific accident information obtained through detection, etc. HCA is generally grouped into four categories, including Cargo-inf, Ship-inf, Envir-inf, and Person-inf. EP indicates emergency plan response, including emergency response (EmR), information monitoring (Inf), and emergency organization (EmO); RM indicates the implementation of rescue measures, in the process of emergency rescue measures, are not a single implementation, the steps are sometimes closely linked, such as the need to understand the location, tonnage, and nature of cargo loading, reconnaissance of fire and leakage, familiar with the fire risks in specific situations before carrying out firefighting, etc. Therefore, the rescue measures (RM) are a cross between the rescue operations (Process); M indicates rescue behavior, R indicates rescue risk and E indicates rescue equipment.

4 CONCLUSION

There are many types of knowledge, complex knowledge structures, and large amounts of knowledge data for emergency rescue of maritime hazardous chemicals accidents, and this knowledge plays an important role in accelerating the emergency decision-making process and the formulation of relief plans. In the face of maritime hazardous chemicals accidents, the integration of existing information advantages into decision-making advantages, the organization of emergency relief content and forms, and the standardization and unified description of the relied knowledge can provide decision-makers and operators with timely and creative risk resolution, which is of great significance in enhancing the emergency disposal capability of maritime hazardous chemicals accidents and improving the emergency management of maritime hazardous chemical accidents.

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