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Analysis to the systematic safety influence factors of petrochemical dock based on the ism model

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ABSTRACT

Aiming at the correlation relationship among eleven safety factors when petrochemical dock system is established, this paper deeply analyzes the lateral and longitudinal relations between these factors by using the Interpretative Structure Modeling (ISM) method of system engineering. And it also establishes four layers hierarchical explaining a structure model which reveals the influence level and the relationship among various factors on petrochemical dock system security. First, security management, which is the highest level of these effect factors in petrochemical dock system. The second level includes the technology and equipment of dock handling, the rear reservoir tank layout, transportation equipments, supply-distribution facilities and public support facilities; all of those belong to the middle level and interconnect with each other. The third level contains the dock building layout and channel water conditions, which belong to the intermediate level and interconnect with each other. The fourth level is the basic level, including meteorological and hydrological conditions, geological conditions and the surrounding buildings, which are the environmental conditions of building petrochemical dock. Distinguishing the functional levels and inter-relations of the main safety influence factors can provide theoretical guides and references for grasping the establishment, planning, design and construction of petrochemical dock system.

KEYWORDS

Interpretative structure modeling; Petrochemical dock system; Safety influence factors; Relations and levels.

INTRODUCTION

Petrochemical dock is a professional dock that loads and unloads crude oil, petroleum products, chemicals and other cargoes, which can be realized the conveying function from ships in the quayside to the rear tank yard. The cargoes unloading, storing or transporting in petrochemical dock have the characteristics of inflammable, explosive, easy diffusion flow and toxic, which can lead to accidents easily[1][2]. It is necessary to research the relations and structures of various factors in effecting systematic safety when petrochemical dock system establishment is demonstrated and planned. The system of petrochemical dock is composed of many functional elements, and each unit element is connected and restrained with each other, which forms a multi-level and multi-functional network structure. Interpretative Structural Modeling (ISM) is an effective tool to analysis the function, which has the character of decomposing complex system into several subsystems (elements) and makes use of people's practice experiences and knowledge, to be constructed eventually the system into a multilevel hierarchic structure by establishing a matrix model, in order to achieve the model for comprehensive and nature of the knowledge[3-5]. Focusing on the eleven safety influence factors of establishing petrochemical dock system, this paper deeply analyzes the inter-relations among these factors and establishing the explanation structure modeling of petrochemical dock system set up the safety influencing factors through ISM method of system engineering. In addition, the paper reveals vertical and horizontal relations among these factors which can provide some theoretical guides for the planning, design and construction of petrochemical dock system.

THE ESTABLISHMENT OF EXPLAINING STRUCTURE MODEL

Steps of Establishing Explaining Structure Model

ISM is developed by an American professor named John Warfield professor in 1973, which is used to analyze those complex problems related to social and economic system[6-7]. The basic idea is through the elements of extraction by a directed graph, matrix and computer technology to process the elements and their relationship and other information, then explaining and decomposing the complex system into several subsystems by the text, finally a systematic structure will be constructed as a multilevel hierarchic structure model to explicit overall structures and levels of issues, in order to improve the understanding and cognition of the problems [8-10]. The main steps are shown in Figure 1.

The security system influence factor established by petrochemical dock system and their interrelations

The authors directly participate in the establishment, design, construction and other processes of project management of petrochemical dock engineering in Nanjiang petrochemical district of Tianjin port. This paper will choose eleven main safety-related influence factors which are involved in the process of safety planning, environmental evaluation, and design of establishing the petrochemical dock system. These factors include channel water conditions (S_1), meteorological and hydrological conditions (S_2), geological conditions (S_3), building structures around the location (S_4), the dock build- ing layout (S_5), the technology and equipments of dock handling (S_6), the rear reservoir tank layout (S_7), transportation equipments (S_8), supply-distribution facilities (S_9) and public support facilities (S_{10})(including Sewage treatment facilities, boiler room, nitrogen gas station, refrigeration stations and other facilities),security management (S_{11}). This article uses ISM to analyze these eleven effect factors and then the intetions between each two factors are determined, which are shown in TABLE 1. In this TABLE, "V" represents that row factors have a direct influence on column factors, "(V)"represents that row factors have an indirect influences on column factors; "A" represents that column factors have a direct influence on row factors; "X" represents that row factors and column factors influence each other; Blank means that no influence on each other.

TABLE 1 : The interactions among various factors of petrochemical dock system

V			**(V)**		**(V)**	**X**			**S1**
				V		V		S2	
				V		V	S3		
V			(V)	V	(V)	V	S4		
V	V	V	V	V	V	S5			
V	A	A	X	A	S6				
V	A	A	X	S7					
V		X	S8						
V	X	S9							
V	S10								
S11									

The establishment of correlation matrix and the calculation reach-ability matrix

Regulations the relationship between any two factors as follows:

(1) S_iRS_j=1,if S_i has a direct influence on S_j,the element "a_{ij}" in adjacency matrix is "1".

(2) S_iRS_j=0,if S_i has no influence on S_j,the element "a_{ij}" in adjacency matrix is "0".

The adjacency matrix A can be established according to the relationship between each influencing factor.

$$A=\begin{pmatrix} 0&0&0&0&1&1&0&1&0&0&1\\ 0&0&0&0&1&0&1&0&0&0&0\\ 0&0&0&0&1&0&1&0&0&0&0\\ 0&0&0&0&1&1&1&1&0&0&1\\ 1&0&0&0&0&1&1&1&1&1&1\\ 0&0&0&0&0&0&0&1&0&0&1\\ 0&0&0&0&0&1&0&1&0&0&1\\ 0&0&0&0&0&1&1&0&1&1&1\\ 0&0&0&0&0&1&1&1&0&1&1\\ 0&0&0&0&0&1&1&0&1&0&1\\ 0&0&0&0&0&0&0&0&0&0&0 \end{pmatrix} \quad (1)$$

Then we calculate the summation "$A+I$" between A and unit matrix I, and perform power calculation for matrix "$A+I$" until the formula 2 is workable.

$$M=(A+I)^{n+1}=(A+I)^n\neq\ldots\neq(A+I)^2\neq(A+I) \quad (2)$$

In formula 2, I is an unitary matrix; n is integer; the calculation is Boolean calculation[3][11]. Matrix $M=(A+I)^n$ is called reachable matrix. "m_{ij}=1"means that factor S_i has a direct or indirect impact on factor S_i[3].

Reachable matrix M is obtained by calculating the adjacency matrix in formula 1.

$$M=\begin{pmatrix} 1&0&0&0&1&1&1&1&1&1&1\\ 1&1&0&0&1&1&1&1&1&1&1\\ 1&0&1&0&1&1&1&1&1&1&1\\ 1&0&0&1&1&1&1&1&1&1&1\\ 1&0&0&0&1&1&1&1&1&1&1\\ 0&0&0&0&0&1&1&1&1&1&1\\ 0&0&0&0&0&1&1&1&1&1&1\\ 0&0&0&0&0&1&1&1&1&1&1\\ 0&0&0&0&0&1&1&1&1&1&1\\ 0&0&0&0&0&1&1&1&1&1&1\\ 0&0&0&0&0&0&0&0&0&0&1 \end{pmatrix} \quad (3)$$

Division of reachable matrix and establishment of structure model

R (Si) is a reachable set of the factor Si, consisting of all the factors that can be reached from Si in reachable matrix or directed graph. A (Si) is an advanced set of the factor Si, consisting of all the factors that can reach Si in reachable matrix or directed graph. C (Si)=R (Si)∩A (Si), is a common part of the reachable set and advanced set. If R (Si)= C (Si), R (Si) is the element set in the highest hierarchy. Then the row and column elements corresponding to Si are crossed out successively, and the reachable set and advanced set in the second hierarchy can be obtained. Similarly, the element set in second, third,…, n hierarchy can be obtained.

TABLE 2 : The list of the reaching set, advanced set, common set and starting set of reachable matrix

Si	reachable set R (Si)	advanced set A (Si)	common sets C (Si)	starting set B (S)
S1	S1, S5,S6,S7,S8,S9,S10,S11	S1,S2,S3,S4,S5	S1,S5	
S2	S1,S2,S5,S6,S7,S8,S9,S10,S11	S2	S2	S2
S3	S1,S3,S5,S6,S7,S8,S9,S10,S11	S3	S3	S3
S4	S1,S4,S5,S6,S7,S8,S9,S10,S11	S4	S4	
S5	S1, S5,S6,S7,S8,S9,S10,S11	S1, S2,S3,S4,S5	S1,S5	
S6	S6,S7,S8,S9,S10,S11	S1,S2,S3,S4,S5,S6,S7,S8,S9,S10	S6,S7,S8,S9,S10	
S7	S6,S7,S8,S9,S10,S11	S1,S2,S3,S4,S5,S6,S7,S8,S9,S10	S6,S7,S8,S9,S10	
S8	S6,S7,S8,S9,S10,S11	S1,S2,S3,S4,S5,S6,S7,S8,S9,S10	S6,S7,S8,S9,S10	
S9	S6,S7,S8,S9,S10,S11	S1,S2,S3,S4,S5,S6,S7,S8,S9,S10	S6,S7,S8,S9,S10	
S10	S6,S7,S8,S9,S10,S11	S1,S2,S3,S4,S5,S6,S7,S8,S9,S10	S6,S7,S8,S9,S10	
S11	S11	S1,S2,S3,S4,S5,S6,S7,S8,S9,S10	S11	

The results of hierarchy are as follows: S_{11} is in the first hierarchy,S_6, S_7, S_8, S_9, S_{10} are in the second hierarchy,S_1,S_5 are in the third hierarchy and S_2,S_3,S_4 are in the fourth hierarchy. The interpretive structural model can be built, as shown in Figure 2.

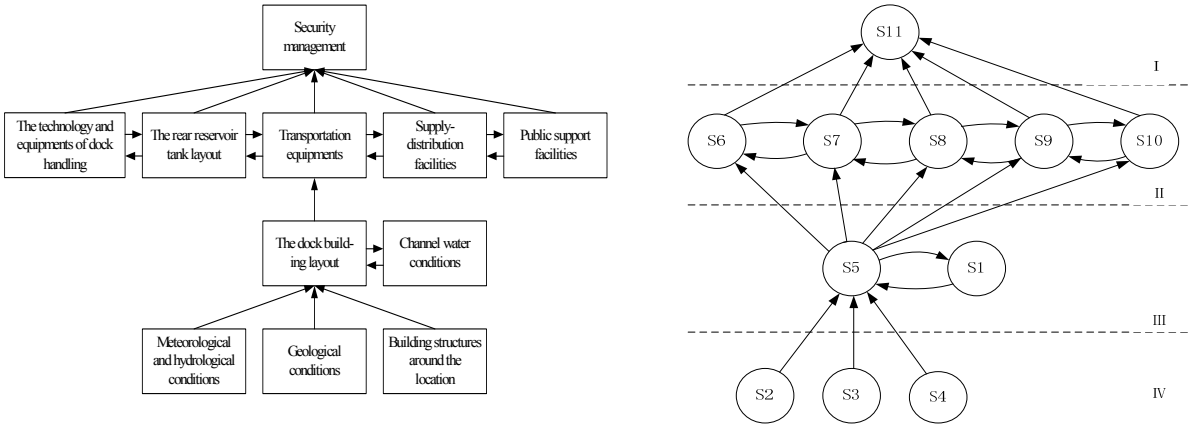

Figure 2 : The ISM of safety influence factors of petrochemical dock system

ANALYSIS ON THE EXPLAIN STRUCTURAL MODEL

As is shown in Figure 2, the indexes that affect the safety of petrochemical dock system are a four layer hierarchical model. In this model structure, the potential of various influence factors in petrochemical dock system safety are as follows:

(1)The first hierarchy: S_{11}(security management). In view of all the goods which are carried by the petrochemical dock system are inflammable, explosive, toxic of the hazardous chemical materials, so safety management will be placed in the highest position which is accorded with the actual condition of the whole system. In order to guarantee the safety operation of the whole system, the level and ability of safety management play important roles in this system. At present, China's ports have built a large number of petrochemical terminals and bulk cargo terminals. The trends of automation and enlargement of the loading and unloading mechanical equipment put forward a higher technology and management requirements for the operators. So the safety management has been of great importance in petrochemical dock system[12].

(2)The second hierarchy includes five factors: S_6(the technology and equipments of dock handling),S_7 (the rear reservoir tank layout), S_8(transportation equipments), S_9(supply-distribution facilities)and S_{10} (public support facilities). Those five factors lie the inner levels of this system, because the materials of the whole system of petrochemical dock transports are dangerous chemicals. In the purpose of realizing systemic function, these five factors can interrelate and influence each other, also related petrochemical those dangerous goods or energy are needed to flow rationally among those five elements. If any of these elements are affected, others may be influenced. Once there are some serious accidents such as fire, explosion or dangerous chemicals leaked diffusion, that will likely cause a catastrophic "dominoes" chain effect. So, during the planning and the design, these five factors must be considered comprehensively, scientifically and reasonably. Based on the comprehensive evaluation of the risk of these five factors, all the relevant areas, facilities and equipment arrangement must meet the relevant provisions of the separate safe distance.

(3)The third hierarchy: S_1 (channel water conditions)and S_6 (the technology and equipments of dock handling) is influenced and restricted each other mutually. In the building layout, petrochemical dock must be kept a certain safe distance

away from channel waters and other piers. At the same time, once petrochemical dock is built, the condition of waterway waters around would be affected. For this reason, in our national policy regulation, before the construction of petrochemical terminal, the effect of petrochemical terminal to navigation environment should be demonstrated, and maritime department's approval is essential. Meanwhile, if a certain scale petrochemical terminal needs to occupy some sea coast areas, it should also be authorized by relevant state department.

(4)The forth hierarchy includes S_2 (meteorological and hydrological conditions), S_4 (building structures around the location), S_5 (the dock building layout). The first thing should be considered is location problem in the security planning of petrochemical dock system. The key point of location is the environmental condition. The proposed petrochemical dock should be constructed in the sea environment with appropriate meteorological hydrological conditions and geological conditions, and stable cross-bred. It should be avoided in the complex sea area with typhoon, storm surge, thunder, geological conditions. In addition, it is also affected by the building structures around. If the petrochemical dock is built in the address with complex and fragile environment, once the construction accidents happened, it will cause serious consequences on the surrounding buildings and environment. so it should be prohibited that the regional environment with fluidity big population and the densely populated as a location.

CONCLUSION

(1)This paper deeply analyzes the lateral and longitudinal relationships between these factors by using the system engineering related theory, which is of great significance to evaluate safety situation of petrochemical dock and make safety measures.

(2)The interpretive structural model of safety influence factors of petrochemical dock was established. This model reveals the safety influence factors of petrochemical dock can be divided into four hierarchies, which provides general theoretical guidance and reference for planning, design and management when petrochemical dock is established.

(3)Using ISM method of systems engineering can analyze the safety situation of various complex systems, which provides new techniques and methods for system safety analysis.

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