

# Entropy Model For Safety Culture and Safety Performance

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**Abstract:** According to Maslow's Hierarchy of Needs, combined with the political attribute of safety management, the human's demand hierarchy and the development trend of our country's safety production management system in recent years, the realization path of security vision of port enterprises in China is proposed, including that (1) Taking safety vision as the objectives, the process of safety awareness is analyzed from the perspectives of safety perception, safety cognition, and safety decision-making, and the framework model for implementing safety awareness is established.(2) Based on the analytic hierarchy process and logical analysis, the factors with greater weight in safety performance are determined.(3) An entropy model for safety culture and safety performance are established.

**Key words:** Security Vision, Security Awareness, Security Performance, Entropy model, Analytic Hierarchy Process (AHP)

## 1. Introductions

With the development of science and technology, causes of safety accident due to the equipment and material factors are decreasing, and the human-caused factors are on increasingly proportion. Human roles in cognitive-intensive behavior are becoming increasingly crucial in maritime operations in addition to the existing labor-intensive behavior. The cross theory shows that, human-caused factors are as important as the equipment and material factors during the occurrence and development of safety accidents. Human-caused factors play a dominant role among the causes of accidents involving hazardous chemicals[1].

The research of intrinsic security management focuses on system security management for the present. Liao Guoli[2] divided the intrinsic safety into three dimensions, which are risk identification, risk monitoring and risk control. Shang Chuanghong[3] proposed that the essential safety can be realized by the enterprise essential safety culture pattern of the essential safety spirit culture, the essential safety system culture, the essential safety behavior culture and the essential safety material culture, based on a psychological contract theory. Xu Zhengquan[4] proposed that the harmony of the interaction among people, things and environment is the key point to realize the essential safety management.

In the present study, the analysis of people's active safety consciousness and the important role of safety goal in realizing essential safety are ignored. Besides, the measures of intrinsic safety management from practical operation and implementable level haven't been put forward for the Port Enterprises. The principle of entropy increase is used to construct a model depicting the relationship between port enterprise safety culture and safety performance, with a focus on individual autonomy and self-fulfillment, aiming to achieve a cooperative and developmental pattern of safety for both the enterprise and its employees through effective implementation and control within the organizational system.

## 2. Constructing Security Vision

### 2.1 Maslow's Hierarchy of Needs And Security Vision

According to Maslow's Hierarchy of Needs (Fig1), physiological and safety needs are the most basic needs of people, and belongingness and love, esteem, self-actualization needs are high-level requirement[5].

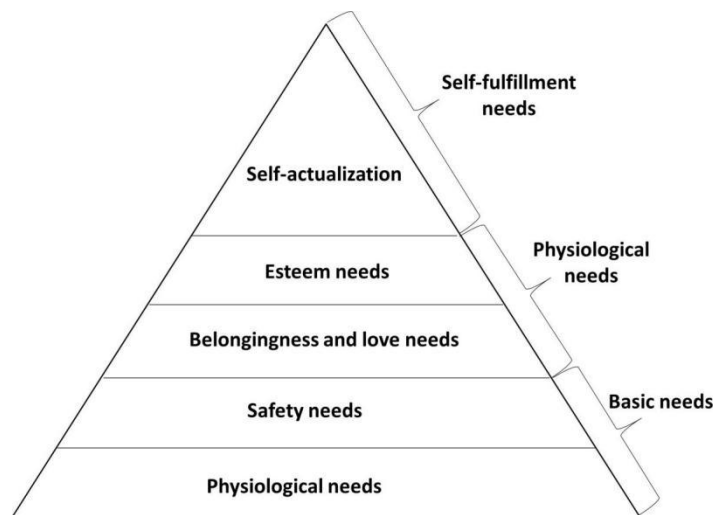


Fig1 Maslow's Hierarchy of Needs Model

Security Vision is a kind of description and prospect of Enterprise's Future Security Development, also, the kind of value guide and direction of Enterprise for safety development. A vision of security that is shared by all motivates and unites employees to work together towards a bright future of security[6].

The construction of security vision should aim at the current security situation and development, and make clear the mission, goal and values of the organization. The development of specific implementation strategies should be integrated with the security vision, including a range of technical and control measures, organizational implementation and promotion of the program.

In order to raise the public awareness and attention of the safety management, to improve the overall level of safety management, to reduce the occurrence of safety accidents, the emphasis of safety management has changed from accident-type safety management to social responsibility and sustainable development. According to relevant research[7], the safety management system in China has changed from accident control and prevention to pre-accident prevention and systematic control of accidents.

### 2.2 The realization path of security vision

The realization path of security vision is proposed based on the above analysis, which is shown in Fig 2, including:

(1) Security concept of keeping pace with the times should be established, such as "People First, life first", "Security and sustainable development" and so on. A mechanism that can fundamentally prevent major risks and hidden dangers should be established, including construction of safety culture, improvement of safety awareness, strengthening of risk assessment and hierarchical control, improvement of emergency response capacity, implementation of safety training, etc.

(2) Improve the mechanism of the implementation and the supervision of the work safety responsibility system, through co-construction, sharing, co-governance and other means. Improve the management mechanism and strength collaboration and information sharing by means of scientific and technological innovation, taking the coupling degree between the high-quality economic development and the safety production demand in the production management as the focus. Clear and unified security values could be merged to carry out safety activities, participate in

safety affairs, quantitative incentive and assessment mechanism, and should be improved constantly.

(3)Laws and regulations on security development should be strengthened, to improve the risk management and control system, and to strengthen supervision and enforcement at the legal level.



Fig 2 Realization path of security vision

### 3. Constructing Security Awareness

The process of safety awareness activities includes:

- (1) Sense the potentially dangerous state by using the feeling, perception and other skills;
- (2) Recognize danger by using the skills of experience, learning, memory and wisdom;
- (3) Make avoidance decisions based on personality, motivation, experience, and risk propensity[8].

#### 3.1 Security Awareness

Generally speaking, security awareness includes: safety perception, safety cognition and safety decision-making. Safety perception refers to the perception of potential risks and their impacts in the work environment and activities. Safety cognition refers to the ability of risk and accident assessment and early warning based on safety perception, through the learning of relevant skills, accumulation of knowledge and experience. Safety decision-making is the ability to take active measures to deal with and Control Risks and hazardous factors on the basis of safety cognition.

So, there are some dependencies among safety perception, safety cognition and safety decision-making. Safety perception is the premise of safety cognition and safety decision-making. Without safety perception, it is difficult to carry out subsequent safety cognition and safety decision-making. Safety cognition provides theoretical support and operational guidance for decision-making, and it is difficult to make wise decisions without it. Safety decision-making is the embodiment of safety cognition and the extension of perception. Without safety decision-making, safety perception and safety cognition can't be translated into practical actions. According to the theory of behavioral psychology[9], the process model of safety awareness activity is constructed in Fig 3.

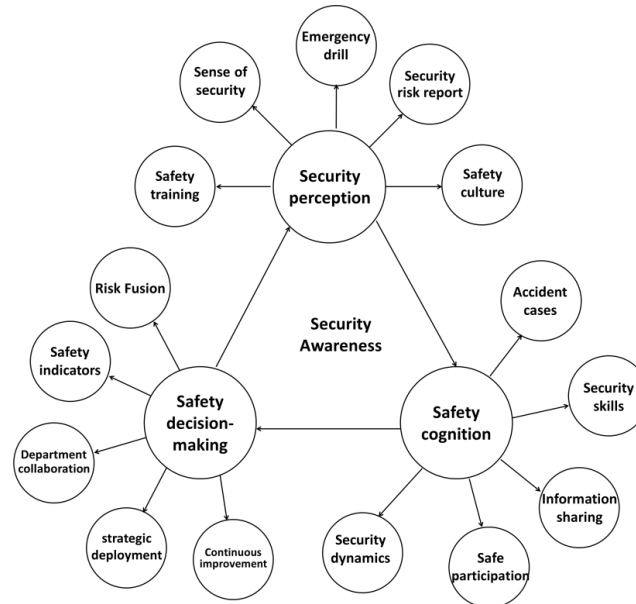


Fig 3 The activity process of safety awareness and construction model

The theoretical basis for building security awareness includes social cognitive theory, decision-making theory, self-efficacy theory, and traditional education theory. These theories are applied in the field of security from different perspectives. For instance, social cognitive theory emphasizes providing relevant information and creating a conducive environment to improve people's security awareness. Decision-making theory advocates increasing individuals' awareness of risk to enhance their attention to security. Self-efficacy theory advocates improving individuals' security skills and knowledge to increase employees' confidence in successfully completing tasks. Traditional education theory advocates for enhancing security awareness through security education and training for employees.

According to the analysis above, a model for security awareness is build.

### 3.2 The implementation method of security perception

The implementation method of security perception includes:

- (1) Ensure the effective implementation and quality of safety knowledge education and training.
- (2) Standardize work safety responsibilities and requirements for rewards and punishments, establish safety self-discipline and safety responsibility.
- (3) Ask and encourage employees to participate in emergency drills for safety incidents, to improve self-help and mutual help ability.
- (4) Encourage employees to observe and report potential safety problems or defects.
- (5) Develop and advertise safety culture, to enable employees to take proactive safety actions in their daily work.

### 3.3 The implementation method of safety cognition

The implementation method of safety cognition includes:

- (1) Learn safety knowledge and safety accident cases, to know about common accident types and risk characteristics.
- (2) Able to use the safety operation standards and operation skills in actual work.
- (3) Strengthen the exchange and sharing of security information, with the help of safety production database construction and safety production information platform, to improve the ability of comprehensive safety analysis and overall risk judgment.

### 3.4 The implementation method of safety decision-making

The implementation method of safety decision-making includes:

(1) Before making a security decision, the enterprise production, the risk characteristics, the latest security technology and measures should all be considered.

(2) Provide quantitative data support for safety decision-making with clear safety objectives and indicators.

(3) Put the security decision in the frame of overall strategy, to ensure consistency and effectiveness of safety decisions with overall development planning.

(4) Strengthen cooperation with relevant departments and interest-related organisations, to work together to improve the decision-making ability and level.

(5) Evaluate and improve safety management continuously, to follow up safety accident and hidden trouble in time, to optimize security decisions as well.

#### 4. Constructing safety performance for port enterprises

Referring to the experience of excellent enterprises, combining with the characteristics of the port industry and closely integrating with the current situation of safety production in the port industry, based on the current situation of safety management and performance assessment of Chinese port enterprises, a safety production performance evaluation system for port enterprises is established from three levels: source prevention, process management, and result control, as shown in Table 1. The weight of safety performance evaluation indicators is determined by using analytic hierarchy process and mathematical models.

Tab1 Safety performance evaluation index	
Indicators Level 1 (B)	Indicators Level 2 (C)
Source Index (B1)	Security objectives (C1)
	Safety commitment (C2)
	The importance of safety (C3)
	Active participation (C4)
	Cost of safety in production (C5)
	Organizational learning (C6)
	Exchange of security information (C7)
	Continuous improvement (C8)
	Management of equipment and facilities (C9)
Processmanagement indicators (B2)	Risk Identification and management (C10)
	Potential safety hazard investigation and management (C11)
	Accident statistics (C12)
	Occupational Health (C13)
Outcome Control Index (B3)	Contingency management (C14)
	Safety Production Index (C15)

##### 4.1 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) was proposed by Professor Thomas Saaty, an American operations researcher from the University of Pittsburgh in the early 1970s. It is mainly used to determine a small amount of quantitative information in decision-making with multiple influencing factors and objectives.

The calculation steps of AHP are as follows:

1. Establish a hierarchy: Identify the problem and its objectives, criteria, and alternatives.
2. Pairwise comparison: Compare each criterion to another, using a scale from 1 to 9, where 1 represents equal importance and 9 represents extreme importance. Repeat this for each criterion pair, as well as for each alternative against each criterion.

3. Calculate the weights: Using the pairwise comparison results, calculate the relative weights of each criterion and alternative, by dividing the sum of each row of comparison scores by the number of columns.

4. Check consistency: Evaluate the consistency of the pairwise comparisons by calculating the consistency ratio (CR). CR should be lower than 0.1 for a consistent AHP matrix.

#### 4.2 Determination of Safety Performance Weighting Indicators

The results of the weight calculation of the first-level indicators are shown in Table2, and the second-level indicators are shown in Table3.

**Tab2 First-class index judgment matrix and weight calculation results**

	B1	B2	B3	Weight (Wi)	Consistency
B1	1	1/3	3	0.2583	CR=0.0332<0.1, pass the consistency check
B2	3	1	5	0.6370	
B3	1/3	1/5	1	0.1047	

**Tab 3 Second-class index judgment matrix and weight calculation results**

B1	C9	C10	C11	C12	C13	C14	W i	Consistency check
C9	1	1/3	1/3	5	5	1	0.1417	CR=0.0299<0.1, pass Consistency check
C10	3	1	1	7	7	3	0.3297	
C11	3	1	1	7	7	3	0.3297	
C12	1/5	1/7	1/7	1	1	1/3	0.0398	
C13	1/5	1/7	1/7	1	1	1/3	0.0398	
C14	1	1/3	1/3	3	3	1	0.1195	

According to the weight of the first-level indicators calculated results, the Process Management index weight is 0.6370, which shows the importance of process management in safety production.

According to the weight of the second-level indicators calculated results, among the Process Management indicators, risk identification and management (C10) and hidden danger investigation and treatment (C11) are of the same highest weight. The concept of risk management is the most important factor of Process Management, guided by the philosophy of risk management.

#### 4.3 Entropy Model For Safety Culture & Safety Performance

According to the definition in physics, entropy measures the disorder of a system, and the process of increasing entropy is a spontaneous transition from order to disorder. Modern science uses it to indicate the orderliness of a system; the more ordered the system, the lower the entropy.

Considering the relationship between safety vision, safety awareness, and safety performance, the clearer the safety vision, the more concentrated the safety awareness. This leads to stronger organizational cohesion, optimal utilization of human resources, and a higher degree of control over risks and hazards, resulting in a lower likelihood of accidents, hence decreasing entropy. Conversely, with an organization being disorganized and individuals lacking a sense of responsibility, entropy increases.

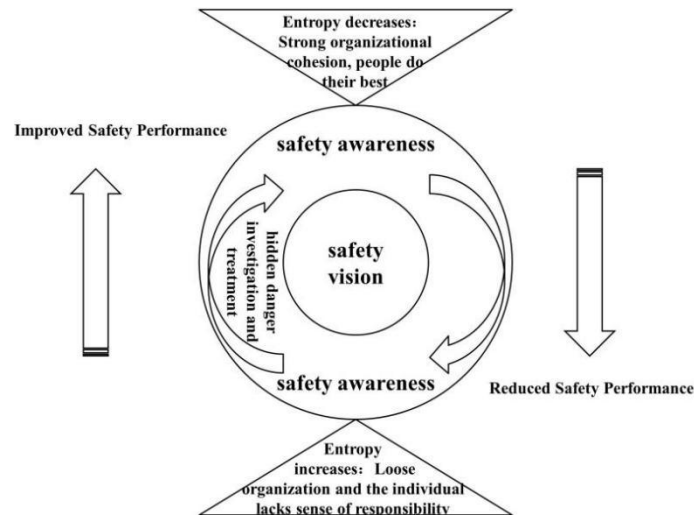


Fig4 Entropy Model For Safety Culture & Safety Performance

## 5. Conclusions and Recommendations

In the process of implementing safety management, port enterprises need to consider not only economic development, but also environmental protection and social responsibility. Therefore, it is necessary to carry out all safety work from a sustainable development perspective. Considering the current economic and technological development situation, collaboration and sharing are important mechanisms to improve the systematic safety of port enterprises. Integrating resources from all departments is a system engineering, which requires a stable, orderly, and reliable internal foundation to promote better cross-integration, mutual reliance, and mutual promotion among various elements of safety management.

This article draws the following conclusions through the analysis of various macro and micro implementation elements of safety management:

- (1) The construction of the safety vision of port enterprises should highlight mechanisms for sustainable development, collaboration and sharing, and legal construction.
- (2) In terms of cultivating organization and employee safety awareness, efforts should be made to strengthen the positive reporting of safety hazards, integrate enterprise risk characteristics, and guide awareness penetration based on safety goals and indicators.
- (3) Safety performance management should focus on the implementation, supervision, and assessment of risk identification and management and hazard investigation and governance.
- (4) Applying the principle of entropy increase to safety management: a clear safety vision helps to enhance the concentration of safety awareness, thus fostering organizational cohesion and safety performance, corresponding to a state of low entropy.

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