

## Further Study of Accident Causation "2-4" Model

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**Abstract.** Case study shows that there is a defect in "2-4" model which will limit its application. The defect is the module of unsafe act is not classified. The classification method of unsafe act is proposed by means of feature and characteristics of unsafe act via analysis result of 201 cases of China coal mine gas explosion accidents. According to application research, unsafe act can be divided into 4 kinds: illegal operation, illegal command, illegal action and not illegal unsafe act. Demonstration of the definition and scope of these 4 types of unsafe acts has been done which can ensure the independence of content. The process of accident case analysis confirmed that this method of unsafe act can distinguish all kinds of unsafe acts in each accident, thus, can guide to recognizing accident liability and safety training work, so as to improve the effectiveness of it.

### Introduction

Accident causation chain is one of the most important theories in safety discipline, it mainly be used to analyze the causes of the accident and make prevention measures. Accident causation chain expressed the series of causes of the accident as dominoes, when a piece of dominoes fall for some reason in the chain, other dominoes will fall in turn, and then triggered the accident.

Accident causation chain have got considerable development through 100 years of continuous research and application [1]. Among them, the most represented chains are those which proposed by Heinrich [2], Bird [3], Reason [4], et al, but all of them have flaws and difficult to apply in accident causation analysis. At present, another new accident causation chain-"2-4" model (Gui Fu et al., 2005, 2013) has been proposed by China safety scientist FU Gui. The chain is deriving from the former research results and improving the accident causation research work. Although the "2-4" model is not proposed for a long time, there are a number of enterprises in China has used to guide the accident prevention and obtained a good safety performance currently. Even so, there is still a tiny flaw in this model that is we couldn't classify unsafe acts by a feature. In this paper, author will study and improve "2-4" model so as to convenient for application.

### Accident causation "2-4" Model

Accident causation "2-4" model also can be called behavior-based accident causation "2-4" model, as shown in Fig.1. The accident occurs at least in one community organization according to this model and the cause can be divided into internal and external causation. Internal causation, which has much closer relationship to an accident, contains 2-level: organizational behavior and individual behavior. Organizational behavior can split into two stages: safety culture and safety management

system. Individual behavior also can split into two stages: habitual behavior and one-off behavior and conditions. Among them, one-off unsafe behavior is the active cause/factor, and other three stages are latent causes. External cause contains unsafe psychological and physiological factors, unsafe supervision, natural factors and other factors. The 2-level and 4-stage behaviors comprise the “2-4” model[5,6]. This chain contains all the causes of an accident and could then be applied to the accident analysis for all industries and all types of accident. All the behaviors of 4 stages at the 2 levels are clearly defined. Even so it has a number of advantages, but we couldn’t classify unsafe acts by a feature so that we can’t count the analysis result by fixed way. In application, this will limit “2-4” model to guide the users in safety training and cognizing accident liability. Further study on unsafe act to classify is necessary. It would play an important role in accident cause analysis and counting, and safety hazard clearance. This also improving an organization in safety training by unsafe feature and solving problem of potential safety hazard checking.

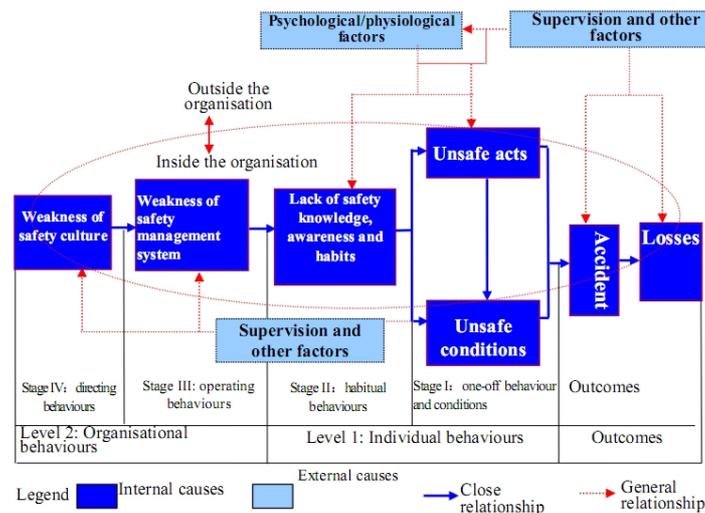


Fig.1. Accident causation "2-4" model

### Classification of unsafe act -further study of “2-4” model

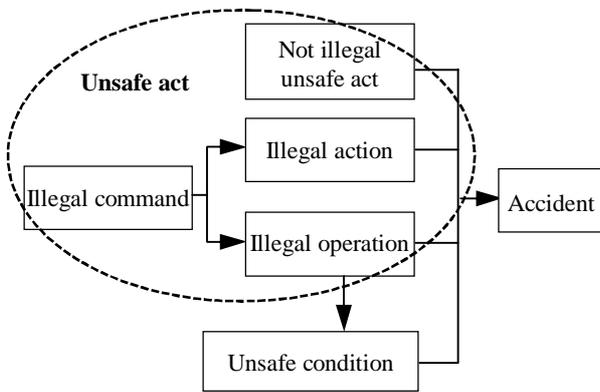
**Theoretical analysis of unsafe act.** Unsafe act is one-off behavior that directly causes an accident or has major impact on the occurrence of the accident. Unsafe acts could be conducted by individuals in any level of the organization, which are deemed as personal behaviors, so long as the acts are conducted by individuals and no matter which level in the organization they are involved.

China accident analysis reports often simply describe the cause of the accident as “operator’s violation”. Although this presentation concentrates the cause of accident mainly on the unsafe act, the content range of "operator’s violation" is too wide to show the exact type of unsafe act that lead to accident effectively. In a specific accident case, unsafe act will be shown as an active factor that lead to or relate to accident. People who conduct unsafe act and directly causing accident are called “accident trigger”, while other people in the same organization as “trigger” act out the unsafe act which may influence the trigger’s act are called “accident influencer”, the type of their unsafe acts will not completely be same, as well as the range of their influence .

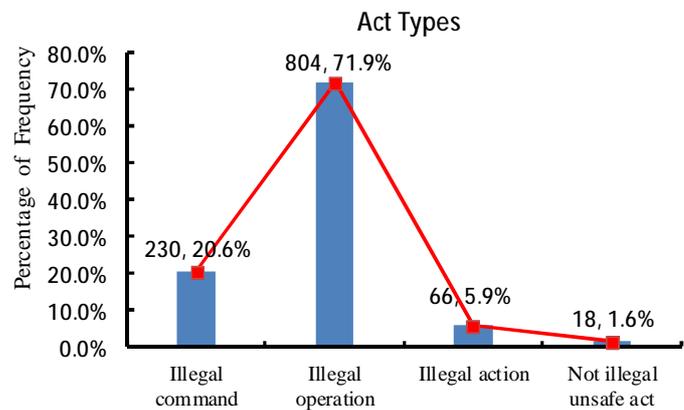
The existing two kinds of classification methods about unsafe act: the first method is conducted based on whether the unsafe act is conscious or unconscious, but this kind of classification is too non-specific to distinguish unsafe act strictly in the accident, and you may find it hard to use actually. Another method is by mean of enumeration method classification according to the China safety related regulation-- "Casualty accidents investigation and analysis rules of enterprise

employees" which has two main problems in application of China company: first of all, this method of classification of unsafe act is not comprehensive, its content must be constantly changing with the improvement of science and technology; secondly, by failing to illuminate the relationship among each type of unsafe act, This method of classification is difficult to use to analysis direct causes of accident and cognize accident liability, as well as safety training.

**Category of unsafe act.** By means of case study, there are a total of 201 gas explosion cases which caused a deaths of 10 or more in each accident occurring between January 2001 and December 2012 were obtained and submitted to further analysis according to behavior-based accident causation “2-4” model, we can extract more than one unsafe act in each accident. The information of these 201 accident cases used in this analysis were obtained from reports submitted by the State Administration of Coal Mine Safety in China. Many unsafe acts were got from the analysis result and these acts are usually quite different in feature. According to the characteristics and unsafe acts, they can be classified into 4 categories[7]: illegal operation, illegal command, illegal action and not illegal unsafe act. The study of definition and scope of content of 4 categories of unsafe acts are going to be done based on the theoretical and practical research in the following. The accident causation logical relationship between them is presented in Fig.2.



**Fig.2.** Categories of unsafe act



Note: an accident contains several unsafe acts

**Fig.3.** Distribution of categories of unsafe act

1 ) *Illegal command*: referring to violation managerial behavior(like order, command, dispatch, etc.). In actual process of production, illegal command often exists in a group of people that have leader-member relations, but in some cases also exist in workers. Illegal command does not directly lead to accidents, but can lead to illegal operation and illegal actions.

2 ) *Illegal operation*: referring to violation acts that aimed to complete a work and has a characteristic of having operating entities. Additionally, illegal operation is the direct source of unsafe condition. Thus, nearly all of the unsafe condition can be eliminated if illegal operations of workers are erased in production.

3 ) *Illegal action*: referring to violation act of moving or having an unsafe activity that not aimed to complete the work. This category mainly have two features: first is refers to the unsafe moving in a physical space; second is refers to the activities that not aimed to complete the work although they have the feature of operation.

4 ) *Not illegal unsafe act*: referring to acts that not violation but dangerous and may lead to

accident. With the development of science and improvement of technology, some new unsafe acts will not update in corresponding rules and regulations timely.

**Application and discussion.** Statistics of 4 categories of unsafe act causes which analyzed from 201 accident cases have been worked out (Fig.3). 201 cases of china coal mine gas explosion accident have been thoroughly analysed by human factors specialists and a total of 1118 frequency of unsafe acts were obtained by “2-4” model. Among them, the frequency of illegal command is 230, accounted for 20.6% of the total proportion, similarly, illegal operation appearing 804 times and accounted for 71.9%, illegal action appearing 66 times and accounted for 5.9%, not illegal unsafe act appearing 18 times and accounted for 1.6%. Illegal operation occurs 4 times per each incident, followed by illegal command, then the illegal action. Meanwhile, based on case study, all 4 categories often appeared out a characteristic of chronological order. For example, (manager)

illegal command→(work team or group)illegal action→(first-line operator) illegal operation→

accident (→: refers to time sequence). Typically accident like "10.26" gas explosion at Xinyu

Coalmine, the coal mine managers arranged workers to a mining workface where the ventilation system was damaged (illegal command), then a group of workers entered into this assigned dangerous workplace (illegal action). Finally, because of workers not checking the gas and make sure the surrounding is safe before blasting(illegal operation), the gas explosion happened(accident). In order to prevent this kind of accident, the most effective measure can we make is the way to break "unsafe act sequence chain". Along with the process of actual case analysis, the advantages of this distinction method of unsafe act can be found. On the one hand, the categories of unsafe act can provide a guidance for accident analysis, prevention and liability cognizance. On the other hand, when applied in safety training, different types of unsafe acts usually refer to different levels of people in an organization and can be used to guide safety training.

## Conclusions

Failing to classify the unsafe act module restricts “2-4” model to guide the accident analysis and prevention application. The study divided unsafe act into 4 categories referring to illegal operation, illegal command, illegal action and not illegal unsafe act, that can used for improving "2-4" model. The strict definition and range of each category were done based on the theoretical research and practice. Case analysis results confirmed that unsafe act can be effectively classified by this method and the analysis results can provide a guidance for accident analysis, prevention and liability cognizance, as well as to improve the efficiency and pertinence of safety training.

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