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# Research on the coupling degree measurement model of urban gas pipeline leakage disaster system

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ABSTRACT

Under the changing and complex urban environment, gas pipeline leakage disasters are becoming increasingly complicated. In order to make a quantitative analysis of the coupling degree among each factor at different grades, this study adopts the comprehensive indexes of gas pipeline leakage disaster system based on AHP (Analytic Hierarchy Process) and Entropy method. The calculation model of coupling degree is then established in accordance with the coupling degree theory in physics. This study takes a region in Beijing as an example and calculates the coupling degree of urban gas pipeline leakage disaster system. The result shows the coupling degree of disaster system is 0.303, which indicates that the whole disaster system is in a status of moderately unbalanced development (acceptable interval). The occurrence of disaster is subject to disaster-inducing environment and disaster-bearing body, and the disaster-inducing environment is slightly more obstructive to occurrence of disaster. On the other side, controlling the disaster-inducing factors can reduce the coupling degree of disaster system. The model is helpful to evaluate the development state of the disaster system, and point out the direction of disaster control.

## 1. Introduction

Under the influence of complex social environment, urban gas pipelines leakage are likely to happen. If the gas leaks and interacts with the surrounding environment, both underground pipelines and pipelines on the ground may cause fires, explosion and gas poisoning. From the perspective of disaster system [1], the influencing factors can be divided to three types, including disaster-inducing environment subsystem, disaster-inducing factors subsystem and disaster-bearing body subsystem. It can be clearly seen that disasters are the results of the interaction of those three subsystems. At the same time, there are various forms of interactions in each subsystem, such as the interaction between fire and explosion in disaster-inducing factors [2] and the interaction between meteorology and topography in disaster-inducing environment [3]. Therefore, the interactions of internal elements of the urban gas pipeline leakage disaster system affect the occurrence and development of the disasters, and lead to the complexity and variability of disasters.

At present, studies about urban gas pipeline leakage disaster have been focused on risk identification, risk control and risk assessment [4–8]. Several risk management methods were applied in those studies, such as multi-attribute utility theory [4], utility theory and the ELECTRE TRI method [5,6]. However, these studies were mainly aimed at the pre-disaster prevention, and did not care for effective evaluation and analysis for the process of gas pipeline disaster.

Studies on main influencing factors of gas leakage and diffusion of urban gas pipeline have been performed. J.D. Young [9,10] carried out a detailed analysis of the gas hole model, H. Montie [11] analyzed the nozzle model and O. Levenspiel [12] developed the pipeline model. Meanwhile, gas leak detection and location technologies have been advanced by bio-detection system [13], acoustic emission and geometric connectivity [14], and infrared imaging technique [15]. These studies focused on the phase of the gas diffusion and were not concerned with the formation process of gas fire or explosion accident. Therefore, they still belong to the stage of disaster prevention.

Fire and explosion are the most serious consequences of urban gas pipeline leakage disaster. Many studies in this field focused on accident investigation [16], fire thermal radiation [17], explosive shock wave [18,19], and toxic gas damage criteria. A number of measures for disaster control were proposed [20,21]. Although there is a deep

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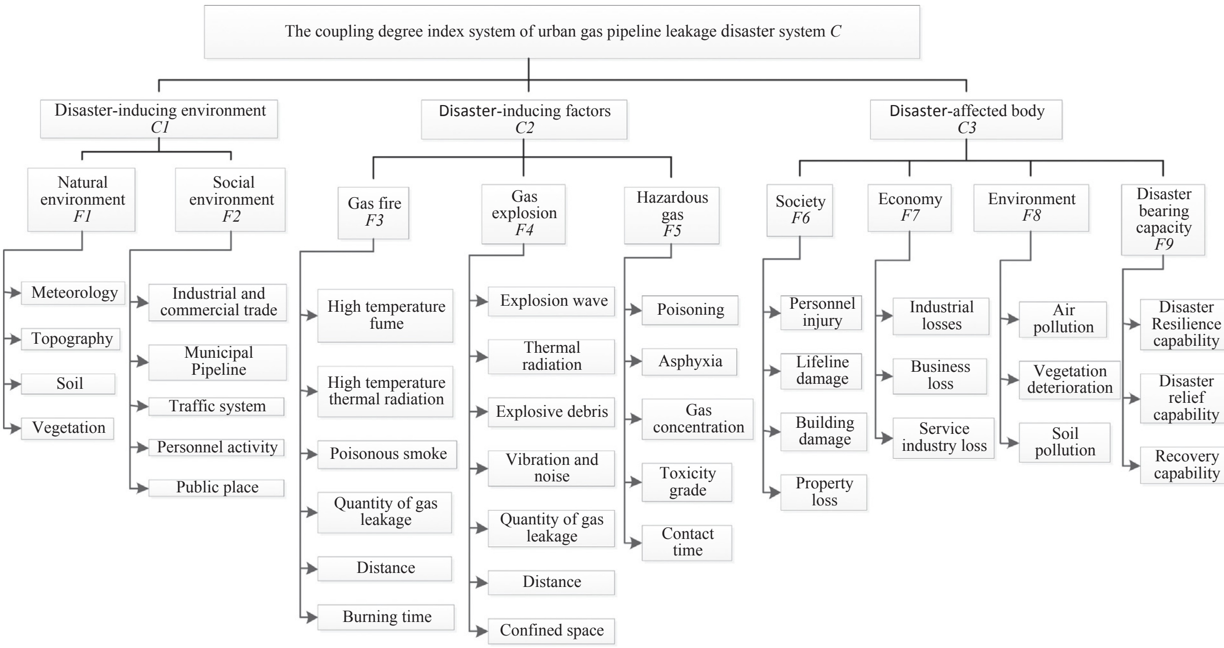


**Fig. 1.** Index system of urban gas pipeline leakage disaster system.

understanding of the mechanism of urban gas pipeline fire and explosion disasters, these studies did not fully consider the impacts of the interplay of internal factors in the urban disaster system on the occurrence, development and consequences of urban gas pipeline leakage disasters.

The studies on disasters coupling were mainly about multi-hazard risk assessment, such as highway bridges subjected to earthquake and hurricane hazards [22], building structures in seismic zones subjected to blast [23], and physical vulnerability of buildings for multi-hazards [24]. These studies took into account the combined effects of multi-hazards, but there was a lack of systematic study for a specific disaster.

In summary, many literatures have shown that the researches mainly focus on pipeline risk management, gas pipeline leakage and diffusion, gas fire and explosion accidents. None of the studies reported so far are based on disaster science. However, disasters are problems of the whole system. Influenced by urban environment, the urban gas pipeline leakage disaster system has certain flexibility. Compared with other disasters happened in rural environment, the interactions among various disaster factors in urban environment are stronger. The interaction process of disaster factors is part of the system coupling process. The analysis of the intensity of the system coupling process can quantitatively reveal the state and the internal relationship of the system.

The calculation model of system coupling can achieve the quantitative analysis of coupling effect among the various factors by constructing the system coupling index system, and then show the coupling state of the whole system. There are several models for the calculation of system coupling, such as coupling degree model [25], Interpretative Structural Modeling method [26], Nonlinear Dynamics model [27] and N-K model [28]. Compared with other models, the coupling degree model has the advantages of low demand for samples and simple calculation, and it has been widely used in urban development [29] and the ecological environment [30].

The study intends to figure out the relationship between the coupling degree and the urban gas pipeline leakage disaster. First, the coupling degree of the disaster system at a particular time were obtained by the coupling degree model, and then analysis of the coupling degree can indicate the status of the disaster system and the main influential factors. Furthermore, it provides decision-making support for the gas pipeline disaster prevention and mitigation. Therefore, this study has important practical significance.

## 2. Model establishment

Coupling is defined as the interaction between two or more systems. As a method of quantitative analysis, the coupling degree refers to the extent of interaction among the systems. There are many interactions among urban gas pipeline leakage systems. The interaction intensity could influence disaster system function and disaster losses. For disasters that have happened, the key points of disaster systems coupling can be found according to the coupling degree.

When using the coupling degree model to calculate the coupling degree of urban gas pipeline leakage disaster systems, the system should first be analyzed to build coupling degree index system. Then the index weights can be gained through AHP and Entropy method. Finally, the coupling degree can be calculated by coupling degree function and expected utility function. The specific calculation method is as follows.

### *2.1. The establishment of coupling degree index system*

At present, several studies have demonstrated that the models of gas pipeline disaster mainly include leak models [9–12], diffusion models [31], fire models [32] and explosion models [33,34]. These models are based on actual accidents and include the main factors affecting disasters, which are also important components of the disaster-inducing environment and the disaster-inducing factors. Meanwhile, the urban gas pipeline accidents will bring to light the causes of the disasters and the main disaster-affected objects, which are the important components of the disaster-inducing environment and disaster-bearing body.

Therefore, this study draws on the relevant research results and 69 cases of gas leakage accident when setting up the coupling index system of urban gas pipeline leakage disaster. Integrated with the characteristics of modern urban construction, the index system has been complemented and improved, so that it can fully reflect the gas pipeline disaster system. As a result, the model consists of 3 first grade indicators, 9 s grade indicators and 40 third grade indicators (Fig. 1).