A quantitative analysis pattern for regional risk conduction

Jie Su[1], Xinyue Zhang[1], Ling Zhou[2,4] and Yue Yin[3]

[1]School of Management Science and Engineering, Central University of Finance and Economics, Beijing, China
[2]School of Social Development and Public Policy, Beijing Normal University Beijing, Beijing, China
[3]China Minsheng Bank Corp., Ltd., Beijing, China

[4]E-mail: www.yueeaya@163.com

Abstract. Risk conduction refers to a certain risk can lead to the spread of risk accidents, causing other risks through many ways. Conductivity is a basic characteristic of risk, especially when the research object is regional risk. Aiming at the conductive characteristics of regional risk in scenic spots, based on Bayesian rule and total probability formula, this paper explored a regional risk conduction pattern. Firstly, risk management system consists of risk carrier, risk incentive and risk performance. The consequences of one risk may also be the risk environment of another risk, so the correlation between risks can be established. Secondly, construct regional risk transmission network with three layers of variables. Starting with the specific risks, analyzing the possible risk consequences, judging whether these risk consequences will lead to secondary risks and calculating the conditional probability of secondary risks based on conditional probability and full probability formula. Last, according to the conduction probability between risks, the comprehensive severity of the consequences is calculated after considering risk transmission. The conduction probability between risks and seriousness of risk after considering conduction can be obtained through this model. It provides a quantitative analysis tool for regional risk management and is helpful in two aspects: providing monitoring focus before risk occurs, and cutting off conduction path to prevent further risk expansion when risk occurs.

1. Introduction

With the continuous growth of China's economic development level and the improvement of people's quality of life, tourism has become the first vacation choice for thousands of families. However, in recent years, the frequency and scale of security incidents in scenic spots have been expanding. For risk accidents in scenic area, it is very likely that multiple safety incidents will occur in a short time. For example, in the summer of 2013, due to the high temperature in the past few days, the Xingshan rafting scenic spot in Hubei Province was overcrowded. Due to the chaotic work order of the management commanders, tourists rushed to log in to the kayak, causing vicious incidents such as fighting conflicts and eventually leading to stampedes. Such risk-conducting accidents are common in the safety management of scenic spots. When certain risks occur, the various regional routes lead to the spread of risk accidents in the scenic area, resulting in more serious consequences.

At present, a lot of scholars' research on regional risk of scenic spots has been relatively mature and have some safety management systems of scenic spots. Arbel's [1] scenic risk management article published in 1980 first studied the scenic area risk management and proposed a planning model for tourism scenic area risk management.

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Since then, some scholars have studied the regional risk of scenic spots from tourism and crisis management, disaster planning [2-4], tourism risk management [5,6], tourism risk assessment [7].

In China, domestic research on regional regional risks is still in its infancy. Although there is a small amount of quantitative analysis, most of them are macro-analysis of regional risk of scenic spots from a qualitative point of view, using AHP, expert scoring, GIS technology and other methods. These studies studied the regional risk of scenic spots from the perspectives of the management of tourism safety and mechanism [8,9], safety risk index system [10-12], and scenic spot risk evaluation [13-16].

Research on risk transmission is currently concentrated in natural disaster systems. Shi Peijun (2002) defined the disaster chain as a series of disasters caused by a disaster, and proposed the common typhoon-storm chain, cold wave disaster chain, drought disaster chain and earthquake disaster chain in China [17]. Zhang Weixing (2013) established a risk assessment conceptual model of natural disaster chain based on the risk measurement method of supply chain system [18]. In addition to the natural disaster system, there are also risk transmission studies on software systems [19] and supply chain systems [20].

It can be seen that the current research on the regional risk of the scenic spot pays more attention to the establishment of the scenic area risk management system, risk index system, and risk assessment system, but less attention is paid to the risk transmission in the scenic area. For articles about risk transmission, the focus is on natural disaster transmission, work chain risk transmission, etc., and lack of research on risk transmission in a certain region.

In order to make up for the problem that most researches of scenic area risk management are qualitative analysis, this paper systematically quantifies the regional risk relationship and deeply studies the transmission relationship of regional risk. Combined with the regional security risk transmission process and management characteristics, we are going to establish a regional risk conduction quantitative pattern.

2. Introduction of mathematical methods and formula derivation

The mathematical theory used in this paper includes Bayesian rule and total probability formula. The Bayesian rule is used to describe the relationship between two conditional probabilities. The mathematical expression is in equation (1):

$$P(B_i|A) = \frac{P(B_i)P(A|B_i)}{\sum_{i=1}^{n} P(B_j)P(A|B_j)} \tag{1}$$

The total probability formula can transform the probabilistic solution of complex event A into the summation of the probabilities of simple events in different situations. If events B_1, B_2, B_3... B_n constitutes a complete event group, that is, they are incompatible with each other, and their sum is a complete set, so formula (2) holds for any event.

$$\mathrm{P(A)} = \sum_{i=1}^{n} P(A, B_i) \tag{2}$$

According to above two formulas, we can deduce the conditional probability between events A and B.

$$\mathrm{P(A|B)} = \frac{P(A,B)}{P(B)} = \frac{\sum_{C_i} P(A,B,C_i)}{P(B)} = \frac{\sum_{C_i} P(A,B|C_i) * P(C_i)}{P(B)}$$

Suppose that A and B are independent under the condition of C, the above formula can be further simplified.

$$\begin{aligned} \mathrm{P(A|B)} &= \frac{\sum_{C_i} P(A,B|C_i) * P(C_i)}{P(B)} = \frac{\sum_{C_i} P(A|C_i)P(B|C_i) * P(C_i)}{P(B)} \\ &= \sum_{C_k} \frac{P(A|C_i) * P(C_i)}{P(B)} * \frac{P(C_i|B) * P(B)}{P(C_i)} \\ &= \sum_{C_k} P(A|\, C_i) * P(C_i|B) \end{aligned} \tag{3}$$

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According to formula (3), the conditional probability between two events can be written as the product of two conditional probabilities.

3. Quantitative analysis pattern of regional risk conduction

This chapter will specifically introduce the quantitative analysis method of regional risk transmission, which is divided into three parts: establishment of risk management system, establishment of transmission network and calculation of comprehensive risk severity.

3.1. Regional risk management system

When a risk occurs, the consequences of the risk, together with other factors in the environment, lead to other risks in the same region. This is the basic process of risk transmission. In order to study this process, we must clearly understand important factors in the process and construct regional risk management system. This paper constructs the regional risk management system from three perspectives: risk carrier, risk environment and risk performance (Figure 1).

Risk carriers, represented by symbol B, refer to disaster-bearing items in risk areas. They can be roughly divided into natural environment carriers, regional facilities carriers, item carriers, disaster prevention system and personnel carriers.

Risk environment, also known as risk incentives, is represented by symbol C. It refers to incentives that may lead to risks. It can be divided into four aspects: the property of items, natural factors, man-made environment and safety management.

Risk performance, expressed by symbol R, refers to the specific manifestation of risk, which can be divided into four categories: natural disaster risk, accident risk, public hygiene event and personnel risk.

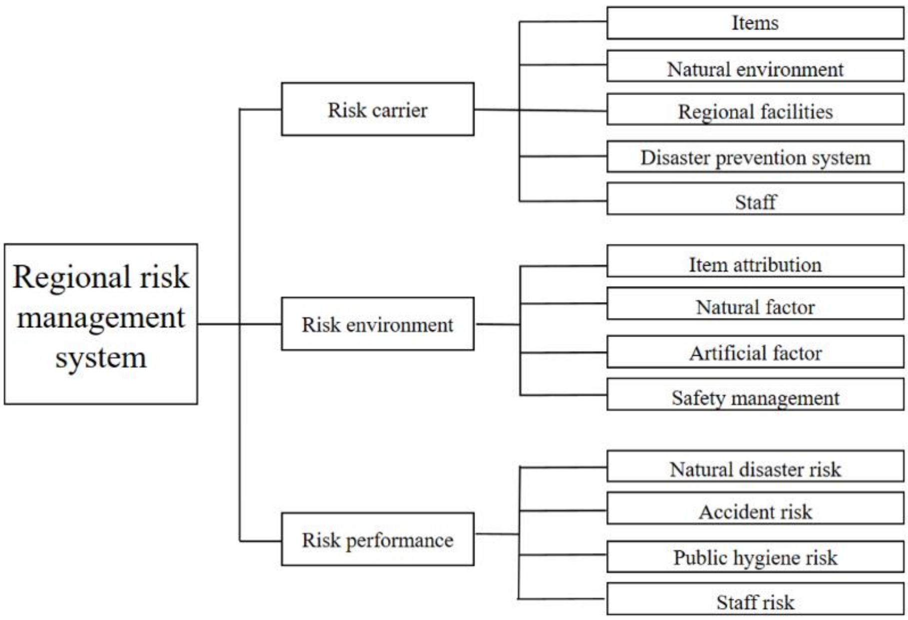

Figure 1. Regional risk management system.

3.2. Regional risk conduction network

Generally speaking, regional risk transmission can be summarized as a network model with input layer, intermediate layer and output layer. Taking the observed risk performance as the input layer of conduction pattern, the risk consequence which is also the risk incentive for other risk as the intermediate layer, and the secondary risk that first occurs as the output layer, the regional risk conduction network model is established. Figure 2 shows the results of regional risk conduction relationship.

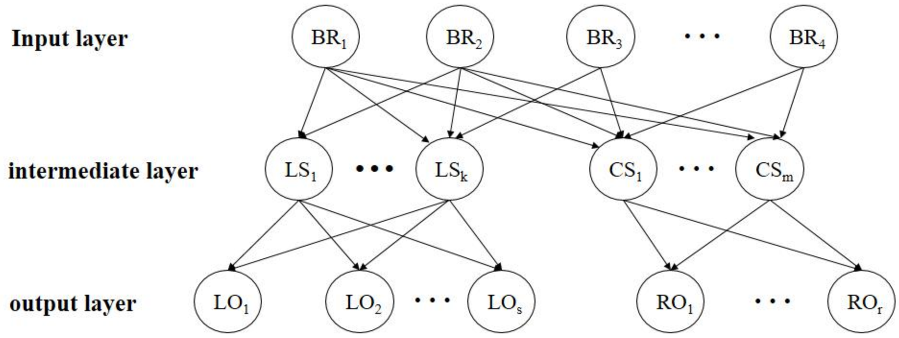

Figure 2. Regional risk conduction network.

The meaning of the variables in the figure is as follows:

Input variable BR: the starting point of regional risk conduction relationship, it's the observed risk performance.

State variable S: represents the risk consequences of the first risk, including loss state LS, which is directly expressed as loss, and incentive state RS, which forms the risk environment of other risks.

Output variable O: includes loss LO based on loss state and secondary risk performance RO based on incentive state.

After establishing the above regional risk conduction network, it is necessary to define two types of conditional probabilities for quantitative analysis: $P(C_i|BR_j)$ and $P(BR_i|C_j)$. $P(C_i|BR_j)$ indicates the probability of environmental factor C_i based on the risk BR_j, and $P(BR_i|C_j)$ indicates the probability of the risk BR_i based on environmental factor C_j.

Then, according to equation (3), the probability of risk BR_i based on risk BR_j can be calculated by formula (4).

$$\mathrm{P}\left(BR_i \middle| BR_j\right) = \sum_{C_k} P(BR_i|\, C_k) * P(C_k|BR_j) \tag{4}$$

Because the focus of this paper is the risk transmission relationship within a certain region, the geographical scope is limited, and the number of risk carriers in the region is limited, too, we can exhaust all risk in this region. Through risk questionnaires, on-the-spot investigation, expert opinions and other methods, all risk carriers, risk incentives, and risk performances in the region can be enumerated and graded, so the conditional probabilities mentioned above can be calculated.

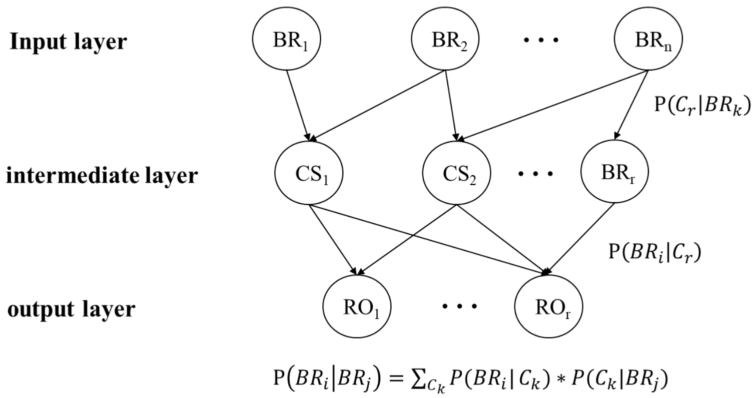

Figure 3. Regional risk conduction network with probability.

3.3. Comprehensive seriousness of risk taking risk transmission into account

According to the risk transmission network in last section, we can know when a risk occurs, which risk is more likely to be triggered, and we can accurately calculate the probability of being triggered. Knowing this probability, the severity of the secondary risk can be taken into account when assessing the severity of the risk.

Represent the original consequence severity of risk BR_i with the symbol Φ_i, the severity of risk BR_i after considering risk conduction is γ_i, which can be calculated by formula (5).

$$\Upsilon_i = \sum_k \phi_k * P(BR_k|BR_i) + \phi_i \quad (5)$$

4. Example: risk conduction relation of cultural relics in exhibition hall based on XX scenic spot
This chapter applies the regional risk conduction analysis method proposed in the previous chapter to the risk management of XX scenic spot, and illustrates the application of the above theory in the actual management.

4.1. Data preparation
The data of this part is from the questionnaire of the XX scenic spot management personnel and second key interview.

The respondents were the management staff of 13 administrative departments in scenic spots. The questionnaire contains three types of questions, namely, whether the risk environment of scenic spots plays a role in risk performance, the possibility of risk occurrence, and the severity of risk consequences. 58 valid questionnaires were collected. Then the results of the questionnaire survey were sorted out, and the experts of the relevant conclusions were interviewed to collect opinions. Finally, the data of XX scenic area risk management system is obtained. According to the questionnaire and interview, XX scenic area risk management system contains 16 types of risk carriers, 42 types of possible risk performance, and 69 kinds of risk incentives. As mentioned before, B_i and C_i respectively represent risk carriers, risk performance, and risk incentives. BR_i is used to indicate a specific risk on a carrier.

The number of valid questionnaire is 58, so number of sample is N = 58. Use variable θ_i to indicate the seriousness of risk BR_i, θ_i = 0,1,2,3,4,5, 0 means no impact, 1 means the impact is very small, 2 means risk BR_i may cause some impact but not serious, 3 means the impact is a little serious, 4 means serious impact and 5 means the impact is very serious. Use binary variable η_{ij} to indicate whether the incentive C_j has an effect on BR_i. Define the conditional probability $P(C_i|BR_j)$ and the consequence severity of risk BR_i.

$$\phi_i = \frac{\sum \theta_i}{N}, \mathrm{P}\left(C_i \middle| BR_j\right) = \frac{\eta_{ij}}{N} \quad (6)$$

The other kind of conditional probability $P(BR_i|C_j)$ is given by risk experts in combination with specific environment and risk manifestations.

4.2. Data analysis
Taking the fire of cultural relics in the exhibition hall of XX scenic spot as an example, the above-mentioned regional risk conduction management model is used for risk conduction analysis.

According to the expert assessment, when the exhibition hall's cultural relics get on fire, it may cause several risk incentives, including damage of safety monitoring facilities, open fire, crowd crowding and inadequate managing workers, the probability of damage to safety monitoring facilities is 12.8%, the probability of open fire is 91.5%, the probability of crowd crowding is 77.1%, and the probability of insufficient managing workers is 19.6%.

According to the results of the questionnaire survey, when the security monitoring facilities are damaged, it may lead to the loss of exhibition cultural relics, and the probability of this risk is 32.7%. The probability of building fire caused by open fire is 1.7%. When crowds are crowded, cultural relics may be lost and stampede may occur, the probability is 5.1% and 20.6% respectively. Insufficient management may lead to a variety of risks, the probability of building on fire is 1.7%, the probability of cultural relics loss is 13.6%, and the probability of stampede is 6.8%.

Substituting possible risk environment, secondary risk and probability mentioned above into the regional risk conduction network. Result is showed in figure 4.

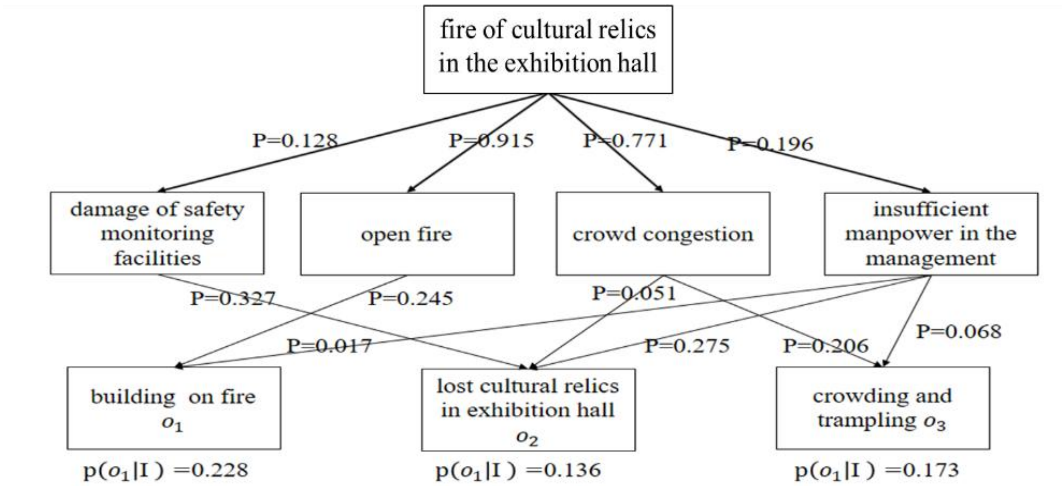

Figure 4. Regional risk conduction relationship based on fire of cultural relics in the exhibition hall.

According figure 4, we can see that when the fire happens in the exhibition hall of scenic spots, the risk consequences include the damage of safety monitoring facilities, open fire, crowd congestion and insufficient manpower in the management. These consequences result in the risk environment of the building on fire, the loss of cultural relics in exhibition hall and the occurrence of stampede event. Through the calculation, the conditional probability of building on fire is 0.228, the conditional probability of the loss of cultural relics in exhibition hall is 0.136, and the conditional probability of crowding and trampling risk is 0.173.

Next, according to the conditional probability of three kinds of risk and equation (5), the comprehensive seriousness of cultural relics fire in exhibition hall can be calculated. The severity of fire is showed in figure 5.

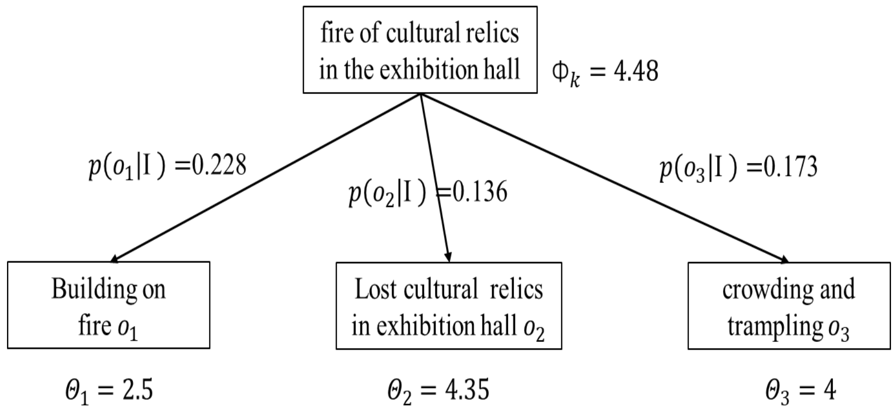

Figure 5. Severity of risks.

After calculation, the comprehensive risk consequence seriousness of the fire risk of cultural relics in exhibition hall is 6.33.

$$\gamma_k = 4.48 + 2.5 * 0.228 + 4.35 * 0.136 + 4 * 0.173 = 6.33$$

So, in the actual work of scenic area risk management, once the fire risk of cultural relics in the exhibition hall of scenic area occurs, it may lead to many other risks, among them, the most likely secondary risk is stampede. In addition, after knowing the conditional probability of risk transmission, risk conduction factors should be taken into account when evaluating the seriousness of risk. Considering the secondary risk, the severity of cultural relics fire in exhibition hall increased to 6.31.

5. Conclusion and contribution

In a limited area, the occurrence of risk often has the nature of conduction, and one risk may lead to other risks. Based on this, this paper explored a regional risk conduction pattern. The regional risk conduction pattern consists of three parts.

First, establish regional risk management system, have an intimate knowledge of specific environment from the risk carrier, risk incentives and risk performance. Second, establish regional risk conduction network, calculate conditional probability of secondary triggered by first risk. Based on this, we can know accurately which risk is more likely to be triggered with specific probability. Last, according to conduction probability between risks, calculating comprehensive severity of risk taking conduction factor, which can reflect possible losses more thoroughly.

This model can help regional risk management from two aspects.

First, providing monitoring focus before risk occurs. When assessing the consequence of a risk, we should consider not only the seriousness of the impact caused by the risk itself, but also its possible secondary risk consequences. Update risk consequence severity assessment according to conditional probability of secondary risk and consequence severity of secondary risk. The improved risk consequence assessment can reflect the seriousness of risk consequence more comprehensively, help to distinguish the focus of pre-management.

Second, cutting off conduction path to prevent further risk expansion when risk occurs. By calculating the conduction probability, managers can have a better control of risk conduction chain. The staff should deal with the direct loss, and at the same time, effectively deal with the transmission chain of secondary risk which may be caused by the fire, to avoid risk spreading. Knowing which risk is more likely to triggered by risk consequence help managers to know what risk and risk incentive need to be check preferentially and make risk management work more orderly when risk occurs.

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