Risk Assessment and Management of National Defense Engineering Construction Based on HHM-RFRM

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Abstract. The risk of the national defense engineering construction is generated under the influence of various factors such as personnel, mechanical equipment and environment. This paper uses Hierarchical Holographic Modeling ideas and Risk Filtering, Rating and Management theory (HHM-RFRM) research method, constructs a risk measurement model for multi-dimensional construction risk scenarios by using repeatedly iterative methods; combined with Bayes' theorem, filters and grades multi-dimensional construction risk scenarios qualitatively and quantitatively, and finally takes a national defense engineering construction as an example to verify the practicability of the proposed model and the feasibility of the method. The evaluation method overcomes the limitations of the traditional risk assessment method with a single perspective and a single model, and better expresses the authenticity of the risk and the complexity of the system, and provides a theoretical basis for the construction risk management and decision-making of the position and practical reference.

1. Introduction

As a special and important category in engineering construction, national defense engineering constructions the concrete embodiment of engineering technology applied in military field. Its construction achievements can provide basic support for peacetime training and wartime tasks of the army, play a key role in influencing and restricting the formation and promotion of the combat effectiveness of the army, and even affect the use of strategy and tactics and the victory or defeat of the war in the future\cite{1}. In recent years, with the increasing tasks of national defense engineering construction year by year, in addition to the strategic factors such as strict confidentiality requirements of engineering construction, high node requirements, and hidden geographical environment, the frequency and harm degree of construction safety accidents have increased compared with the past, causing equipment damage and property loss, affecting the morale of the army, and endangering the life and health of personnel, seriously restricting the progress of engineering construction.

Accurate identification, assessment and effective management of construction risks can not only provide theoretical guidance for the safety management of engineering forces, scientifically avoid potential risks, effectively reduce random risks, but also further lay a solid foundation for safety construction and realize the safety construction, safety management and safety development of the army\cite{2}. In view of this, this paper introduces the idea of hierarchical holographic modeling (HHM). By using risk filtering, rating and management, a multi-dimensional risk scenario risk measurement model is constructed. This model integrates the interactive assessment of various risk factors, which can form a new risk assessment perspective on the basis of risk filtering, rating and management of national defense engineering construction, and further reflect the risk sources generated by the interaction of key risk factors\cite{3}\cite{4}. In the single risk factor model, the methods of decision tree and
fault tree can be used to predict the adverse environmental factors, and the multi-dimensional risk scenario risk measurement model can integrate the assessment of personnel, machinery, environment, management and other risk factors, so as to analyze and assess risks more accurately.

2. Establishment of a multidimensional risk measurement model
Hierarchical holographic modeling is a comprehensive idea and methodology, which can capture and display the intrinsic characteristics and essence of a system in many aspects, perspectives, dimensions and levels. In view of the complexity and uniqueness of the risk of national defense engineering construction, this paper adopts a combination of objective analysis and subjective judgment, through case data and expert advice over the years, to analyze the elements of construction risk. The hierarchical holographic modeling process iterates over and over again, and gradually builds and improves the multi-dimensional hazard measurement model.

1) Case study. Through consulting the military accident cases in national defense construction over the years, the risk factors affecting construction safety are analyzed and refined.
2) Questionnaire survey. By conducting a questionnaire survey to a group of experts, enumerating other risk factors existing in engineering construction, and expand HHM framework components.
3) Analysis of risk factors. By using Delphi method, the risk factors of the HHM framework obtained from the questionnaire survey are analyzed, representative and targeted risk factors are screened out.

![Risk Management Factor of National Defense Engineering Construction](image)

Figure 1. The HHM framework of national defense engineering construction risk.

4) Expert review. The second group of experts evaluate the risk factors of HHM framework, verify its completeness and scientificty.

Through four iterations of risk factors and HHM framework of national defense engineering construction, a HHM framework based on six perspectives of personnel, machinery and equipment, organization and management, materials, environment and time is obtained, as shown in Figure 1.

3. Risk filtering and rating
The research method of RFRM is a revision and improvement of risk Ranking and Framework (RRF) method, aiming at providing priority for scenario analysis. It does not simply ignore the risk sources
that have been filtered out in the early stage, but grasps the more important risk sources in the risk system and reduces system complexity and increasing compatibility of assessment results in Risk Rating.

RFRM consists of eight steps:

1) Scenario recognition. Based on the HHM framework, the concept of multidimensional risk factors is proposed to describe various risk scenarios in national defense engineering construction. It is assumed that the risk scenarios \( V^n \) consisting of \( m \) risk factors are represented as \( m \)-dimensional risk scenarios, and the \( k \)-th risk factor in the risk scenario \( D_j(k = 1, 2, \ldots, m) \) numbered \( n \) is represented, so

\[
V^n = D_j \Theta D_j \Theta \ldots \Theta D_j^n
\]  

2) Scenario filtering. Based on expert experience, the risk scenarios in HHM are preliminarily filtered to reduce the number of risk sources. In view of the complexity of the coupling analysis process when the risk factor \( m > 3 \) in the risk scenario, the analysis results are inaccurate, and the constraint \( m \leq 3 \) is added.

3) Multiple criteria assessment. The remaining risk scenarios are linked with the criteria of defense capability of defense construction system defeated by risk scenarios, and the scenario capability of defense construction system is judged comprehensively according to the three-level evaluation criteria of "high", "medium" and "low". The criteria and criteria of system security defense capability are shown in Table 1.

| Standard | Evaluation level |
|----------|------------------|
| Imperceptibility | Unknown or imperceptible | Delayed detection of damage | Early detection of damage |
| Uncontrollability | Unknown or uncontrollable | Imperfect control | Easy to control |
| Various ways | Unknown in many ways | Less ways to cause damage | Damage in a single way |
| Irreversibility | Unknown or irreversible | Partial reversible | Reversible |
| Impact duration | Duration unknown or long | Medium duration | Short duration |
| Cascade effect | Cascade effects unknown or numerous | Cascade effect minimal | No cascade effect |
| Operation environment loss | Unknown sensitivity or high sensitivity | Sensitivity to operating environment | Insensitive to operating environment |
| Complexity | Unknown or highly complex | Moderate complexity | Low complexity |

4) Quantitative Rating: Based on the ranking matrix of quantitative possibility and result ranking, combined with Bayesian Theorem, the multi-dimensional risk scenario is calculated quantitatively from two aspects of probability and consequence, and the definition is given

\[
D_j = P_r \times C_r
\]  

Among them, \( D_j \) is the risk degree of risk factors, \( P_r \) is the posterior probability of risk occurrence, and \( P_r \) is the consequence of risk factors: \( C_r = \{1, 0.8, 0.5, 0.3, 0\} \).

Assuming that \( A \) is a random variable, expressed as a risk scenario, \( E \) represents the relevant evidence at this stage. Without considering \( E \), the prior probability is obtained by historical case study, and the posterior probability is obtained by considering \( E \). The formula of Bayesian theorem is:

\[
P(A|E) = \frac{P(A) \cdot P(E|A)}{P(A) \cdot P(E|A) + P(A) \cdot P(E|\bar{A})}
\]  

By formula 3, the posterior probability of each risk scenario is calculated, simultaneous
formula 1 and 2, the risk degree of each factor and the risk degree of each risk scenario can be calculated.

5) Risk management. According to the evaluation results of key risk factors and risk scenarios, the focus of risk management and the management plan of risk scenarios are determined.

4. Case analysis

4.1. Risk Scenario Recognition

Taking a national defense project as an example, on the basis of the HHM framework constructed in Figure 1, a number of HHM risk scenarios are constructed by coupling two or three risk factors. The construction risks are identified, filtered and graded systematically from different perspectives and levels. The six main factors of national defense project construction risk interact with each other. Two or two combinations or any three combinations can form a HHM risk scenario. According to formula 1, in the framework of HHM of construction risk, personnel factors and mechanical equipment risk scenarios are numbered as 1. The expression is as follows: \( V^1 = P\Phi E \), as shown in Tables 2.

Table 2. 2-D risk scenario of national defense engineering construction.

| Risk scenario | Expression | Risk scenario | Expression | Risk scenario | Expression | Risk scenario | Expression |
|---------------|------------|---------------|------------|---------------|------------|---------------|------------|
| \( V^1 \)    | \( P\Phi E \) | \( V^2 \)    | \( E\Phi O \) | \( V^3 \)    | \( \Phi O \) | \( V^4 \)    | \( \Phi E \) |
| \( V^5 \)    | \( P\Phi O \) | \( V^6 \)    | \( \Phi O \) | \( V^7 \)    | \( \Phi E \) | \( V^8 \)    | \( \Phi E \) |
| \( V^9 \)    | \( \Phi O \) | \( V^10 \)   | \( \Phi O \) | \( V^11 \)   | \( \Phi O \) | \( V^12 \)   | \( \Phi O \) |
| \( V^{13} \) | \( \Phi E \) | \( V^{14} \) | \( \Phi E \) | \( V^{15} \) | \( \Phi E \) | \( V^{16} \) | \( \Phi E \) |

In the coordinate system shown in Figure 2, the edge length of the geometric figure formed by the coupling of risk factors represents the probability or consequence of the influence of each factor. The area or volume of the geometric figure is used to measure the risk degree of two-dimensional or three-dimensional risk scenarios, that is

\[ P_x = P \cdot P \cdot P \]  

Among them, \( P_x \) is the risk degree of risk situations \( V_m \), \( P \cdot P_x \) is posterior probability of single risk factor, the posterior probability of a single risk factor is represented by the edge lengths of the geometric figures in the risk coordinate system, when \( m = 2, P \cdot P_x = 1 \).

4.2. Risk Double Standard Filtering

Through the process of risk identification, a total of 46 risk factors of engineering construction are
identified. In order to find out the key factors affecting construction safety, this paper consults 20 experienced builders through questionnaires, and carries out double standard filtering combined with the two criteria of risk possibility and consequence. The results are shown in Table 3.

Table 3. Double standard filtering risk ranking matrix.

| Possibility | Consequence | Impossibly | Very seldom | Occasionally | Probably | Often |
|-------------|-------------|------------|-------------|-------------|----------|-------|
| Disaster    | P₁, M₄₁     | E₃₂, E₄    | P₄, O₁₂, S₃₃ | S₁₁        |
| Seriousness | S₁₃, S₃₄, M₁ | E₄₁, T₁   | P₃, E₃₃, S₃₂ | S₁₂, T₂   |
| Common      | E₃₅, O₃₃, O₃₄, S₃₅, M₂₄, T₄ | P₂, O₂₃, O₃₂, M₂₃, T₃ | O₁₁, O₂₂ | O₂₃, O₄, S₂₅, M₄₃ |
| Slight      | S₂₁, S₂₂   | E₃₁, P₃₁, P₃₂ | E₂, S₂₃, S₂₄ |
| Negligible  | S₁₁        |            |             |            |

4.3. Quantitative Rating

By studying the safety accident cases of the national defense engineering construction of a certain army and the cases of relevant medical departments and other relevant historical data, the causes of accidents are analyzed and the prior probability of construction risk is determined. Taking the safety accident caused by the safety personnel's mistake as an example, the prior probability is 0.600. Secondly, considering the factors of current construction personnel, machinery, organization and management, environment and so on, the possibility of safety accident is small when the safety personnel work normally, and its conditional probability is 0.100, among which E₁ indicates the implementation. The situation of the project related to the safety personnel. So, \( P(E|P) = 0.400 \), \( P(P) = 0.900 \), according to formula (3), calculate the posterior probability:

\[
P(P|E) = \frac{P(E|P)P(P)}{P(E|P)P(P) + P(E|P)P(P)} = 0.143
\]

Similarly calculate the posterior probability of other risk factors, as shown in Table 4.

Table 4. The probability of construction risk factors.

| Pro | P₃ | P₄ | E₃₂ | E₃₃ | E₄ | O₁₂ | O₂₃ | O₄ | S₁₁ | S₁₂ | S₂₅ | S₃₂ | S₃₃ | M₄₃ | T₂ |
|-----|----|----|-----|-----|----|-----|-----|----|-----|-----|-----|-----|-----|-----|----|
| prior| 0.600 | 0.600 | 0.200 | 0.500 | 0.350 | 0.500 | 0.650 | 0.500 | 0.700 | 0.300 | 0.550 | 0.500 | 0.260 | 0.200 | 0.600 |
| conditional | 0.100 | 0.150 | 0.050 | 0.200 | 0.150 | 0.100 | 0.250 | 0.200 | 0.250 | 0.080 | 0.150 | 0.150 | 0.040 | 0.040 | 0.150 |
| posterior | 0.143 | 0.247 | 0.013 | 0.200 | 0.087 | 0.120 | 0.382 | 0.200 | 0.438 | 0.036 | 0.177 | 0.150 | 0.014 | 0.010 | 0.209 |

4.4. Key Risk Scenario Assessment

On the basis of constructing HHM framework and RFRM method of national defense project construction risk, combining with the actual situation of the project construction, the seven main risk factors are further coupled and analyzed, and the key risk scenarios composed of the main risk factors are evaluated to provide the basis for the safety management of the project construction. The main risk factors are shown in Figure 3.
Risk Management of National Defense Engineering Construction

Personnel factor $P$

Mechanical Equipment $E$

Organizational Management $O$

Environmental factors $S$

Time factor $T$

Figure 3. The HHM of construction main risk factors.

Formula 2 calculates the risk degree of risk scenarios. Because the risk components of scenarios are catastrophic, so $C = 1$. The risk degree of key two-dimensional risk scenarios composed of seven main risk factors can be obtained by formula 4, as shown in Table 5.

Table 5. Key 2-D risk scenario risk.

| Sub scenario | Risk degree | Sub scenario | Risk degree | Sub scenario | Risk degree | Sub scenario | Risk degree |
|--------------|-------------|--------------|-------------|--------------|-------------|--------------|-------------|
| $P_1 \Theta E_{33}$ | 0.0286 | $P_4 \Theta S_{32}$ | 0.0215 | $E_{33} \Theta O_{23}$ | 0.0764 | $O_{23} \Theta S_{32}$ | 0.0573 |
| $P_1 \Theta E_{32}$ | 0.0494 | $P_3 \Theta S_{21}$ | 0.1082 | $E_{32} \Theta O_{23}$ | 0.0876 | $O_{23} \Theta T_2$ | 0.0798 |
| $P_1 \Theta O_{33}$ | 0.0546 | $P_4 \Theta S_{32}$ | 0.0371 | $E_{33} \Theta S_{21}$ | 0.0300 | $S_{11} \Theta O_{23}$ | 0.0915 |
| $P_4 \Theta O_{23}$ | 0.0944 | $P_4 \Theta T_2$ | 0.0299 | $E_{32} \Theta T_{32}$ | 0.0418 | $S_{11} \Theta T_2$ | 0.0314 |
| $P_4 \Theta S_{31}$ | 0.0626 | $P_3 \Theta T_2$ | 0.0516 | $O_{23} \Theta S_{31}$ | 0.1673 |

Generally speaking, for 2-D risk scenarios, according to Table 5, 8 of the 2-D risk scenarios in construction projects have a risk degree greater than 0.06, which respectively reflects the risk of 2-D risk scenarios in construction risk management, especially when the constructors, construction sites, operation locations and extension time factors are coupled, the risk degree is greater than 0.9, which belongs to extremely high risk, and should be focused on improving the implementation. Workers' safety skills, standardization of construction site, strengthening safety protection of high-altitude operation and scientific arrangement of construction plan can reduce the probability of high-risk factors and avoid the occurrence of construction high-risk scenarios.

5. Conclusion

On the basis of HHM-RFRM theory, the risk HHM framework of national defense engineering construction is constructed through repeated iterations. The risk scenarios based on HHM framework are identified by RFRM method. The construction risk factors are qualitatively filtered by double standard filtering matrix and multiple standard evaluation matrix. Bayesian theorem and risk are applied. The ranking matrix filters and classifies the construction risk factors quantitatively, determines the key risk factors, puts forward the risk scenario based on the coupling of two-dimensional key risk factors, further finds out the high-risk scenario of construction risk, provides a new way of thinking and new method for risk management of national defense engineering construction, and provides security matters. Therefore, prevention has certain guiding significance. Finally, taking a national defense project as an example, the analysis results conform to the actual situation of the construction. However, the security management of national defense construction itself is a complex system engineering. The HHM framework of national defense construction risk is not unchanged, and needs to be dynamically analyzed and adjusted according to local conditions. At the same time, this method does not solve the overall risk assessment of national defense construction, which needs further study.
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