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Risk Evaluation of Airport Safety during Non-stop Construction Using Fuzzy Analytical Hierarchy Process and Bayesian Belief Network

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ABSTRACT

During the non-stop construction, risk analysis is essential to ensure airport safety. This study aims to perform risk evaluation of airport safety during the non-stop construction using both Fuzzy Analytical Hierarchy Process (F-AHP) and Bayesian Belief Network (BBN). Risk assessment of airport during non-stop construction involves four risk factors of personnel, equipment, environment, and management. F-AHP is utilized to rank impact of risk factors while BBN is implemented to assess probability of risk occurrence. The combination of F-AHP and BBN is implemented to identify the most significant risk. The results have revealed that environmental factor imposes the most significant influence on risk of airport safety during non-stop construction while equipment factor has the lowest impact on airport safety. The outcomes of this study allow decision makers to manage potential risk and improve airport safety during the non-stop construction.

Keywords:

Airport Safety, Risk evaluation, Fuzzy Analytic Hierarchy Process, Bayesian Belief Network.

1. Introduction

With the development of civil aviation transportation, the number of airports and take-off flights have been increasing significantly in China. According to the Civil Aviation Administration of China's (CAAC) records, there are 241 large commercial service airports by the end of 2020 and three new airports are built in China. Although the number of aircraft take-off is considerably declined with the COVID-19 epidemic, the passenger and freight traffic flow of airports in China will increase dramatically from the perspective of long-term development. Accordingly, more airports are reconstructed and built to increase air transportation capacity. It is required that the safety and quality is ensured during non-stop construction of airport. Non-stop construction refers to the implementation of engineering operations in the flight area and meanwhile the airport is fully or partially operated according to the flight plan [1-3]. Under non-stop construction of airport, it is necessary to ensure both construction safety and airport safety. Therefore, it is of critical importance to evaluate airport safety during non-stop construction process. Risk analysis during the non-stop construction of airport enables the estimation and assessment of all potential risks that may arise during implementation process. The risk assessment of airport safety is an effective approach to ensure that the strategies used to control potential risks are beneficial. Risk assessment involves a series of steps to quantify impact of risks which are often encountered in construction process. The purpose of risk management analysis is to identify and estimate potential threats. The Fuzzy Analytical Hierarchy Process (F-AHP) was implemented to quantify the impact of risk factors. In the F-AHP method, each risk factor in the hierarchical framework is expressed as a fuzzy number, which reflects the likelihood of a failure event and the associated failure consequence. Therefore, the F-AHP is conducted to estimate weights required to identify hazards [4-7]. Furthermore, Bayesian Belief Networks (BBNs) are used to assess the probability of occurrence of undesirable events. This approach incorporates expert judgement about risk factors associated with critical risks to bridge the gaps in the available historical data. BBNs method is representative of complex and uncertain relationships among many factors that contribute to the occurrence of risks [8-11]. This study proposes the utilization of both F-AHP and BBN to evaluate airport safety during non-stop construction. Specifically, risk factors are firstly identified for airport safety during non-stop construction. Risk impact analysis with F-AHP is then presented. Finally, the risk probability estimation with BBN is described.

2. Identification of Risk Factors

By addressing information obtained from field investigation of the airport, risk factors for airport safety during the non-stop construction could be divided into four factors, including personnel factors, equipment factors, environmental factors, and management factors.

(1) Personnel factors involve unprofessional project managers, confused responsibilities of staff, unreasonable assignment between construction engineer and supervisors, ambiguous criteria for staff assignment, the insufficient emergency handling ability of the staff, and the illegal operation of the staff, etc.

(2) Equipment factors involve improper protection and maintenance of underground pipelines, equipment and facilities during construction, damaged construction signs or speed limit signs, limitations of airport site selection and design, improper parking of equipment and facilities in construction, and wrong setting of construction enclosure supporting non-stop construction, etc.

(3) Environmental factors involve the invasion of floating objects, dust and other substances during construction, schedule for non-stop construction, frequent overlapping during non-stop construction, poor nocturnal construction condition, challenging construction at critical site,

negative impact by unacceptable weather conditions, threats by improper stacking of construction materials, etc.

(4) Management factors involve inappropriate safety strategies for non-stop construction, insufficient supervision of construction quality and safety, tough coordination between departments, complex operation process, ineffective safety training for construction staff, improper update on the emergency plan for safety of non-stop construction, etc.

By understanding four major risks, this study is to recognize the hidden risks during the non-stop construction of airport. As a result, 13 secondary risk factors are further formed. By integrating the primary risks and secondary risks, the risk system for airport safety is developed. By integrating the primary risks and secondary risks, the risk system for airport safety is developed and a comprehensive overview is conducted. To form secondary risks, this study conducts the questionnaire survey. This survey investigates risk factors for airport safety under the non-stop construction, which is distributed to people with different ages, educational backgrounds, professional titles, working years and job positions [12-14]. The results of the survey are analyzed with reliability and validity tests as well as principal component analysis, generating major risk factors. By comparing the arithmetic mean, standard deviation, full-score frequency and coefficient of variation of experts' scores, it is found that the 13 secondary risk factors are more profound than other risk factors. Thus, the corresponding risk evaluation indictor system for airport safety is formulated, as shown in Table 1.

Table 1. Summary on risk evaluation factors for airport safety during non-stop construction.

Indicators of primary risk factors	Indicators of secondary risk factors
Personnel factors	Clarity of job responsibility
	Rationality of staffing
	Awareness of safety
Equipment factors	Integrity rate of construction labelling
	Route of construction machine and equipment
	Enclosure setting of construction
Environmental factors	Overlapping schedule of non-stop construction
	Nocturnal operation conditions
	Difficulty coefficient of construction at critical sites
	Threats by improper stacking of construction materials
Management factors	Strategies implementation for construction safety
	Coordination of process between departments
	Evaluation and validation of pre-construction risk

3. Risk Impact Analysis with Fuzzy Analytic Hierarchy Process (F-AHP)

In this section, the F-AHP approach is implemented to analyze risk impact of factors for airport safety during the non-stop construction. It is divided into four steps: firstly, evaluation indexes are established according to industry information, laws and regulations; secondly, weight vectors are confirmed based on hierarchy process and professional experience; thirdly, affiliation function and evaluation matrix are built; finally, evaluation matrix and weight vectors are combined to yield results.

3.1. Establishment of Index Hierarchy

The AHP is a powerful tool to evaluate risk impact, which mainly consists of three hierarchical levels. The bottom, middle and top level are designed for target, criterion, and scheme level, respectively. The target level refers to specific targets which are expected to be achieved in risk assessment and the number of index factor is 1. Moreover, the criterion level is mainly composed of four risk factors, namely personnel risk, equipment risk, environmental risk and management risk. Finally, the scheme level reflects details of the criterion level and formulates index of secondary risk factors after analyzing four indexes of primary risk factors.

3.2. Calculation of Index Weight

After confirmation of index levels, the risk factors are further quantified for analysis. To realize quantification of risk factors, quantitative scale of risk factors is needed, as illustrated in Table 2. After that, the judgment matrix of risk evaluation index at target level is formed for airport safety during non-stop construction, as shown in Table 3.

Table 2. Quantitative scale of risk factors.

Scale	Meaning
1	Factor I is as important as factor J
3	Factor I is slightly more important than factor J
5	Factor I is more important than factor J
7	Compared with factor J, factor I is very important
9	Compared with factor J, factor I is extremely important

Table 3. Judgment matrix of risk evaluation indicators at target level.

S	Personnel factor	Equipment factor	Environmental factor	Management factor
Personnel factor	1	3	1/2	1/2
Equipment factor	1/3	1	1/3	1/2
Environmental factor	2	3	1	2
Management factor	2	2	1/2	1

Moreover, the judgment matrix of risk evaluation index at criterion level is determined for airport safety during non-stop construction. According to content at criterion level, it consists of five primary risk evaluation indexes, as listed in Tables 4-7.

Table 4. Judgment matrix of risk evaluation indicators on personnel factor at criterion level.

S	A1	A2	A3
A1	1	2	3
A2	1/2	1	2
A3	1/3	1/2	1

Table 5. Judgment matrix of risk evaluation indicators on equipment factor at criterion level.

S	A1	A2	A3
A1	1	1	1/2
A2	1	1	1/2
A3	2	2	1

Table 6. Judgment matrix of risk evaluation indicators on environmental factor at criterion level.

S	A1	A2	A3	A4
A1	1	2	1/2	1/2
A2	1/2	1	1/4	1/4
A3	2	4	1	1
A4	2	4	1	1

Table 7. Judgment matrix of risk evaluation indicators on management factors at criterion level.

S	A1	A2	A3
A1	1	1	1/2
A2	1	1	1/2
A3	2	2	1

To determine weight of risk evaluation index, the eigenvector method is implemented as follows:
1-The product of ranking vectors in judgment matrix is firstly calculated:

$$\mathrm{Xi} = \sum_{j=1}^{n} (A_{11} \times A_{12} \times \ldots \times A_{1n}) \quad (1)$$

2- The nth root of ranking vector product is then calculated:

$$X_i = \sqrt[n]{X_i} = \sqrt[n]{(A_{11} \times A_{12} \times \ldots \times A_{1n})} \quad (2)$$

3- Characteristics vector is finally calculated:

$$W_i = \frac{X_i}{\sum_{i=1}^{n} X_i} \quad (3)$$

$$W_i = [W_1\ W_2\ \ldots\ W_n] \quad (4)$$

With the above-described formula, the specific weight values of risk evaluation index are calculated, as summarized in Table 8.

Table 8. Weight values of risk evaluation index for airport safety during non-stop construction.

Primary index of risk factors	Weight	Secondary index of risk factors	Weights
Personnel factor	0.22	Clarity of job responsibilities	0.54
		Rationality of staffing	0.30
		Awareness of safety	0.16
Equipment factor	0.13	Integrity rate of construction labelling	0.25
		Route of construction machine and equipment	0.25
		Enclosure setting of construction	0.50
Environmental factor	0.38	Overlapping schedule of non-stop construction	0.18
		Nocturnal operation conditions	0.09
		Difficulty coefficient of construction at critical sites	0.36
		Threats by improper stacking of construction materials	0.36
Management factors	0.27	Strategies implementation for construction safety	0.25
		Coordination of process between departments	0.25
		Evaluation and validation of pre-construction risk	0.50

To ensure effectiveness of risk evaluation values, the consistency on weight values of risk evaluation factors is assessed with the following equation:

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{\sum_{j=1}^{n} a_{ij}w_{ij}}{W_i} \quad (5)$$

The maximum eigenvalue for each risk factor at target level is obtained and shown in Table 9.

Table 9. Maximum eigenvalue at target level.

Value	Personnel factor	Equipment factor	Environmental factor	Management factor	Target level
λ_{max}	3.01	3	4	3	4.14

When assessing consistency, the reference values (RI) of random consistency index are taken into account, as listed in Table 10.

Table 10. Reference values (RI) of random consistency index.

Matrix order	1	2	3	4	5	6	7	8	9
Reference value	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46

The consistency index (CI) represents consistency index of judgment matrix, which is calculated using the following formula. The results are listed in Table 11.

$$CI = \frac{(\lambda_{max} - n)}{n - 1} \quad (6)$$

Table 11. Consistency index (CI) results.

Value	Personnel factor	Equipment factor	Environmental Factor	Management factors	Target layer
λ_{max}	0.02	0	0	0	0.06

The consistency should satisfy the following criterion:

$$CR = \frac{CI}{RI} \leq 0.1 \tag{7}$$

The consistency on primary risk factors in the criterion level should meet the condition before continuing the subsequent calculation.

3.3. Fuzzy Comprehensive Evaluation

Comprehensive evaluation is to make qualitative and quantitative evaluation on the objects affected by multiple factors, while fuzzy theory is to precisely deal with fuzzy phenomena and issues with mathematical methods. Accordingly, fuzzy comprehensive evaluation is to qualitatively and quantitatively assess the objects with multiple affecting factors based on fuzzy theory [15-16]. In order to ensure accuracy of risk evaluation at the scheme level, the expert assignment method was selected for calculation. In order to ensure comprehensive evaluation, it is suggested to conduct the survey on risk factors of airport safety under the non-stop construction. The survey involving in 13 secondary risk factors is distributed to personnel at various positions. In this study, 220 questionnaires have been distributed and 206 effective questionnaires are analyzed to obtain assignment values, as listed in Table 12.

Table 12. Assignment values of risk evaluation indictors at schematic level

Risk evaluation indictors	Assignment values by experts				
Clarity of job responsibilities	0.4	0.5	0.1	0	0
Rationality of staffing	0.7	0.1	0.1	0	0.1
Awareness of safety	0.6	0.1	0.1	0.1	0.1
Integrity rate of construction labelling	0.6	0.1	0.1	0.1	0.1
Route of construction machine and equipment	0.6	0.1	0.1	0.1	0.1
Enclosure setting of construction	0.5	0.2	0.2	0.1	0
Overlapping schedule of non-stop construction	0.6	0.2	0.2	0	0
Nocturnal operation conditions	0.6	0.1	0.1	0.1	0.1
Difficulty coefficient of construction at critical sites	0.7	0.2	0.1	0	0
Threats by improper stacking of construction materials	0.5	0.5	0	0	0
Strategies implementation for construction safety	0.7	0.1	0	0.1	0.1
Coordination of process between departments	0.5	0.3	0.1	0.1	0
Evaluation and validation of pre-construction risk	0.4	0.5	0.1	0	0

By applying analytic hierarchy process and fuzzy comprehensive evaluation method as well expert assignment approach, weights of risk evaluation indexes at criterion and scheme levels are calculated, expressed as evaluation matrix R:

$$\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & & r_{2n} \\ \vdots & & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \tag{8}$$

Meanwhile, to quantify risk evaluation results of airport safety under non-stop construction, it is necessary to utilize the following equation and review sets shown in Table 12.

$$V = [V_1\ V_2\ \dots\ V_n] \tag{9}$$

Table 12. Review sets on risk evaluation indicators of airport safety under non-stop construction.

Comment set	Significant impact	Mostly impact	General impact	Minor impact	Negligible impact
Assigned values	86-100	71-85	56-70	31-55	0-30

If the final value is larger than 85, it is confirmed that this risk factor imposes significant impact on airport safety, which should be receive great attention to control risk. If the final value is lower than 31, this risk factor has negligible effect on airport safety during non-stop construction. After that, the values of risk evaluation factors at criterion level are calculated as follows:

$$G_i = W_i \times R_i \times V^t \tag{10}$$

Specifically,

$$G_1 = W_1 \times R_1 \times V^t = [0.54 \quad 0.30 \quad 0.16] \begin{bmatrix} 0.4 & 0.5 & 0.1 & 0.0 & 0.0 \\ 0.7 & 0.1 & 0.1 & 0.0 & 0.0 \\ 0.6 & 0.1 & 0.1 & 0.1 & 0.1 \end{bmatrix} \begin{bmatrix} 100 \\ 85 \\ 70 \\ 55 \\ 30 \end{bmatrix} = 88.30$$

$$G_2 = W_2 \times R_2 \times V^t = [0.25 \quad 0.25 \quad 0.50] \begin{bmatrix} 0.6 & 0.1 & 0.1 & 0.1 & 0.1 \\ 0.6 & 0.1 & 0.1 & 0.1 & 0.1 \\ 0.5 & 0.2 & 0.2 & 0.1 & 0.0 \end{bmatrix} \begin{bmatrix} 100 \\ 85 \\ 70 \\ 55 \\ 30 \end{bmatrix} = 85.25$$

$$G_3 = W_3 \times R_3 \times V^t = [0.18 \quad 0.09 \quad 0.36 \quad 0.36] \begin{bmatrix} 0.6 & 0.2 & 0.2 & 0.0 & 0.0 \\ 0.6 & 0.1 & 0.1 & 0.1 & 0.1 \\ 0.7 & 0.2 & 0.1 & 0.0 & 0.0 \\ 0.5 & 0.5 & 0.0 & 0.0 & 0.0 \end{bmatrix} \begin{bmatrix} 100 \\ 85 \\ 70 \\ 55 \\ 30 \end{bmatrix} = 91.08$$

$$G_4 = W_4 \times R_4 \times V^t = [0.25 \quad 0.25 \quad 0.50] \begin{bmatrix} 0.7 & 0.1 & 0.0 & 0.1 & 0.1 \\ 0.5 & 0.3 & 0.1 & 0.1 & 0.0 \\ 0.4 & 0.5 & 0.1 & 0.0 & 0.0 \end{bmatrix} \begin{bmatrix} 100 \\ 85 \\ 70 \\ 55 \\ 30 \end{bmatrix} = 88.50$$

It is found that the value of risk evaluation index is 88.30, 85.25, 91.08, and 88.50 for personnel factor, equipment factor, environmental factor, and management factor, respectively. Therefore, environmental factor induces the most significant impact on airport safety under non-stop construction while equipment factor has the lowest impact on airport safety.

4. Risk Evaluation of Airport Safety based on Bayesian Belief Network (BBN)

The Bayesian Network (BN, also called Bayesian Belief Network (BBN)) is based on Bayesian formula and probabilistic calculation, which presents correlation between various factors through graph framework and establishes probabilistic network among variables through probabilistic calculation models. Probabilistic calculation is to derive probabilities of remaining variables from information of some variables, which converts complex and uncertain complex problems into simple and complete problems. Bayesian network is composed of unicycle graph and probability table. Unicycle graph could not make up closed cycles and has only one direction. Moreover, unicycle graph consists of node variables, which represent factors. The line between nodes represents causal relationship between variables and the starting node is called as parent node variable. In each node, there is a conditional probability table, which represent variables.

4.1. Establishment of Topological Diagram of Bayesian Network with Risk Factors

By combining causal relationship between airport safety and risk factors, risk factors and observation indictors, the topological diagram of risk evaluation of airport safety under non-stop construction is built. To simplify the network model, the secondary risk indexes with larger expert assignment values are selected.

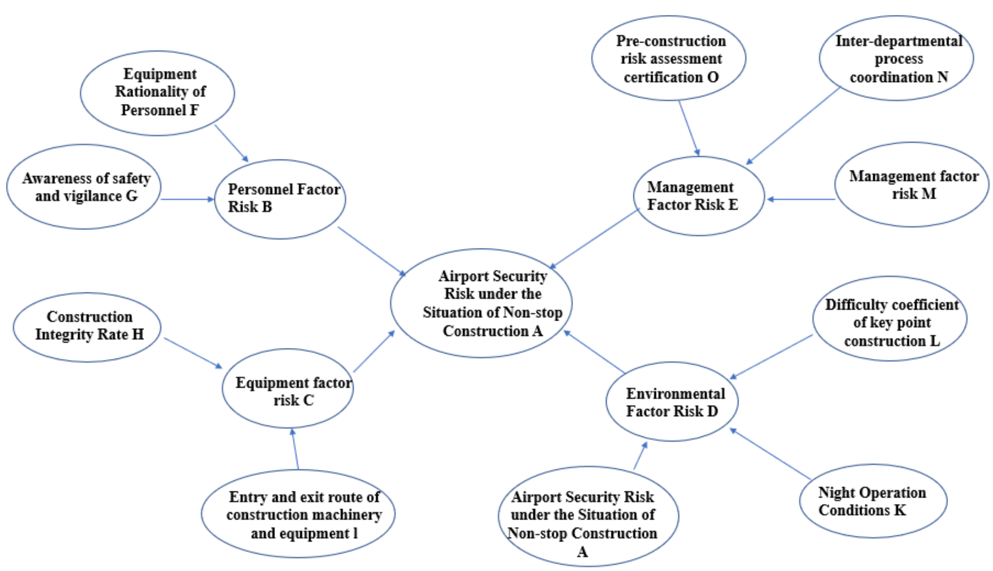

Figure 1. Topological diagram of risk evaluation on airport safety during non-stop construction.

In the topological diagram of Bayesian network, 10 node variable indicators are divided into three levels, and the variable indictors at the upper level are deduced from the variable indicators at the lower level. The total risk indicator (A) of airport safety under non-stop construction is divided into four first-level indicators, including personnel risk factors (B), equipment risk factors (C), environmental risk factors (D) and management risk factors (E). They are further subdivided into 10 secondary risk indicators, including personnel allocation rationality (F), safety awareness and vigilance awareness (G), construction sign integrity rate (H), construction machinery and equipment entrance and exit route (I), non-stop construction time crossing (J), night operation conditions (K), construction difficulty coefficient of key points (I), implementation of construction safety measures (M), and inter-departmental process coordination (N).

4.2. Determination of Marginal Probability of Each Node Variable

During risk assessment, it is challenging to express risk indicators with numerical values. To quantify risk indicators, the assignment values by experts are needed. When calculating the marginal probability of the root node of Bayesian network, experts need to assign values according to their own experience. In order to ensure that numerical value of risk indicators is as objective and scientific, it is necessary to synthesize opinions from many experts and scholars. Due to different assignment by experts, standards and conclusions are different for the same risk indictor. To effectively synthesize opinions and suggestions from different experts, the probability of risk occurrence is divided into five levels, as illustrated in Table 13.

Table 13. Risk level.

Level	Possibility of occurrence	probability value
1	Very likely	(0.8, 1]
2	likely	(0.6, 0.8]
3	Potential possibility	(0.4, 0.6]
4	Basically impossible	(0.2, 0.4]
5	impossible	(0, 0.2]

In the process of collecting opinions from experts, each evaluation index is rewritten from neutral to positive and negative expressions. For example, F means that the staffing is unreasonable and Fˆ represents that the staff is reasonable; G means that the security awareness is low and Gˆindicates that the security awareness is high. The prior marginal probability of the root node obtained from comprehensive expert opinions is shown in Table 14 [15].

Table 14. Prior marginal probability of parent node.

Probability	F	G	H	I	J	K	L	M	N	O
P	0.7	0.7	0.6	0.7	0.8	0.8	0.8	0.7	0.8	0.7
Probability	$\hat{F}$	$\hat{G}$	$\hat{H}$	$\hat{I}$	$\hat{J}$	$\hat{K}$	$\hat{L}$	$\hat{M}$	$\hat{N}$	$\hat{O}$
$\hat{P}$	0.3	0.3	0.4	0.3	0.2	0.2	0.2	0.3	0.2	0.3

4.3. Determination of Conditional Probability of Each Node Variable

Conditional probability means that risk occurs on the child node when risk occurs on the corresponding parent node variable. In addition, due to the influence of uncontrollable factors, the risk of a child node still occurs when all the parent nodes corresponding to a child node are 0. According to the Bayesian network topological diagram of risk factors for airport safety under non-stop construction, when the total index (A) of risk factors is measured by four primary indexes, namely personnel risk factor (B), equipment risk factor (C), environmental risk factor (D) and management risk factor (E). If one of these four primary indexes occurs, the total index (A) of airport safety risk is very good. The joint conditional probability between each factor and its parent node in the Bayesian network model of risk for airport safety under non-stop construction is determined by the joint evaluation of airport safety management experts and experts in the field of non-stop construction [15]. The joint conditional probabilities of personnel factors, equipment factors, environmental factors and management factors with their parent nodes are shown in Tables 15-18.

Table 15. Joint conditional probability between personnel factor and its parent node.

Parameters	B	$\hat{B}$
FG	0.90	0.10
$\hat{F}$G	0.80	0.20
F$\hat{G}$	0.70	0.30
$\hat{F}\hat{G}$	0.55	0.45

Table 16. Joint conditional probability between equipment factor and its parent node

Parameters	C	$\hat{C}$
HI	0.80	0.20
$\hat{H}$I	0.70	0.30
H$\hat{I}$	0.65	0.35
$\hat{H}\hat{I}$	0.55	0.45

Table 17. Joint conditional probability between environmental factor and its parent nodes.

Parameters	D	$\hat{D}$
JKL	0.95	0.05
$\hat{J}$KL	0.85	0.15
J$\hat{K}L$	0.70	0.30
JK$\hat{L}$	0.65	0.35
$\hat{J}\hat{K}L$	0.55	0.45
$\hat{J}$K$\hat{L}$	0.50	0.50
J$\hat{K}\hat{L}$	0.35	0.65
$\hat{J}\hat{K}\hat{L}$	0.30	0.70

Table 18 Joint conditional probability between management factor and its parent nodes.

Parameters	E	$\hat{E}$
MNO	0.90	0.10
$\hat{M}NO$	0.85	0.15
$M\hat{N}O$	0.80	0.20
$MN\hat{O}$	0.75	0.25
$\hat{M}\hat{N}O$	0.65	0.35
$\hat{M}N\hat{O}$	0.60	0.40
$M\hat{N}\hat{O}$	0.55	0.45
$\hat{M}\hat{N}\hat{O}$	0.50	0.50

According to the characteristics and formula of Bayesian network, the conditional probability of personnel factor is calculated as follows:

$$P(B)=P(F)\,P(G)\,P(B|FG) + P(\hat{F})\,P(G)\,P(B|\hat{F}G) + P(F)\,P(\hat{G})\,P(B|F\hat{G}) + P(\hat{F})\,P(\hat{G})\,P(B|\hat{F}\hat{G}) = 0.7\times0.7\times0.9+0.3\times0.7\times0.80+0.7\times0.3\times0.7+0.3\times0.3\times0.55=0.8055 \quad (11)$$

$$P(\hat{B})=1- P(B)=1-0.8055=0.1945 \quad (12)$$

The conditional probability of equipment factor is expressed as:

$$P(C)=P(H)\,P(I)\,P(C|HI) + P(\hat{H})\,P(I)\,P(C|\hat{H}I) + P(H)\,P(\hat{I})\,P(C|H\hat{I}) + P(\hat{H})\,P(\hat{I})\,P(C|\hat{H}\hat{I}) =0.7150 \quad (13)$$

$$P(\hat{C})=1- P(C)=1-0.7150=0.285 \quad (14)$$

The conditional probability of environmental factor is calculated as:

$$P(D)=P(J)\,P(K)\,P(L)\,P(D|JKL) + P(\hat{J})\,P(K)\,P(L)\,P(D|\hat{J}KL) + P(J)\,P(\hat{K})\,P(L)\,P(D|J\hat{K}L) + P(J)\,P(K)\,P(\hat{L})\,P(D|JK\hat{L}) + P(\hat{J})\,P(\hat{K})\,P(L)\,P(D|\hat{J}\hat{K}L) + P(J)\,P(\hat{K})\,P(\hat{L})\,P(D|J\hat{K}\hat{L}) + P(\hat{J})\,P(K)\,P(\hat{L})\,P(D|\hat{J}K\hat{L}) + P(\hat{J})\,P(\hat{K})\,P(\hat{L})\,P(D|\hat{J}\hat{K}\hat{L})=0.8152 \quad (15)$$

$$P(\hat{D})=1- P(D)=1-0.8152=0.1848 \quad (16)$$

The conditional probability of management factor is expressed as:

$$P(E)=P(M)\,P(N)\,P(O)\,P(E|MNO) + P(\hat{M})\,P(N)\,P(O)\,P(E|\hat{M}NO) + P(M)\,P(\hat{N})\,P(O)\,P(E|M\hat{N}O) + P(M)\,P(N)\,P(\hat{O})\,P(E|MN\hat{O}) + P(\hat{M})\,P(\hat{N}))\,P(O)\,P(E|\hat{M}\hat{N})O) + P(\hat{M})\,P(N)\,P(\hat{O})\,P(E|\hat{M}N\hat{O}) + P(M)\,P(\hat{N})\,P(\hat{O})\,P(E|M\hat{N}\hat{O}) + P(\hat{M})\,P(\hat{N})\,P(\hat{O})\,P(E|\hat{M}\hat{N}\hat{O})=0.8026 \quad (17)$$

$$P(\hat{D})=1- P(D)=1-0.8152=0.1848 \quad (18)$$

$$P(\hat{E})=1- P(E)=1-0.8026=0.1974$$

From the above calculated results, it is found that the risk of airport safety under non-stop construction is mostly affected by environmental factor, followed by personnel factor, management factor, and equipment factor. This is in agreement with previous analysis using fuzzy comprehensive evaluation method. Therefore, environmental factor needs more attention for airport safety.

5. Conclusions

In this study, risk evaluation of airport safety during non-stop construction is performed using both Fuzzy Analytical Hierarchy Process (F-AHP) and Bayesian Belief Network (BBN). Risk assessment of airport safety during non-stop construction involves four risk factors of personnel, equipment, environment, and management. F-AHP is utilized to rank impact of risk factors while BBN is implemented to assess probability of risk occurrence. The combination of F-AHP and BBN is implemented to identify the most significant risk. The results have revealed that environmental factor imposes the most significant influence on risk of airport safety during non-stop construction, followed by personnel factor, management factor, and equipment factor.

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